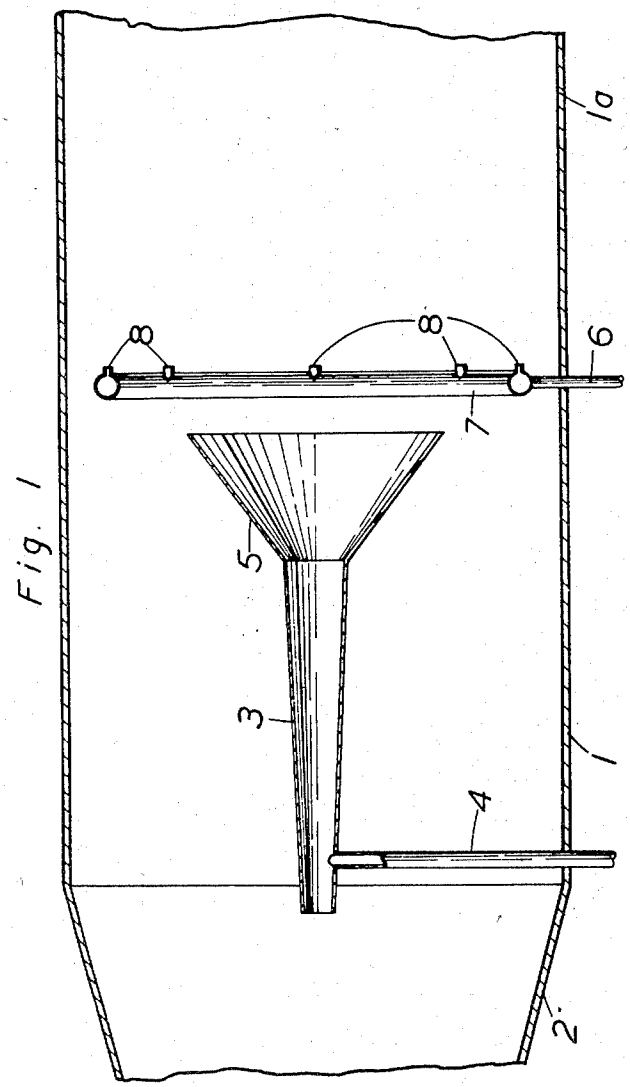
Aug. 29, 1950 A. G. EARL 2,520,388

APPARATUS FOR SUPPORTING COMBUSTION IN FAST MOVING AIR STREAMS

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Fig. 1



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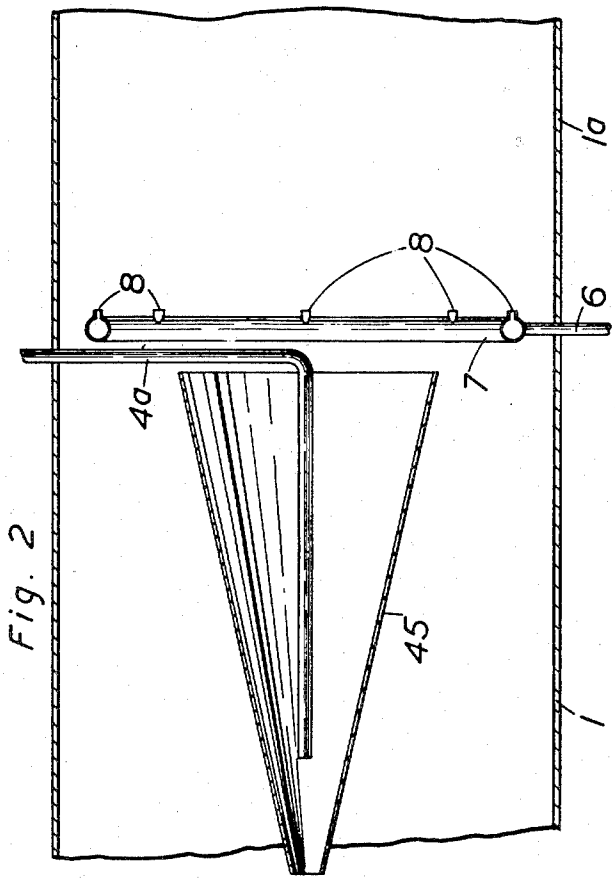


Fig. 2

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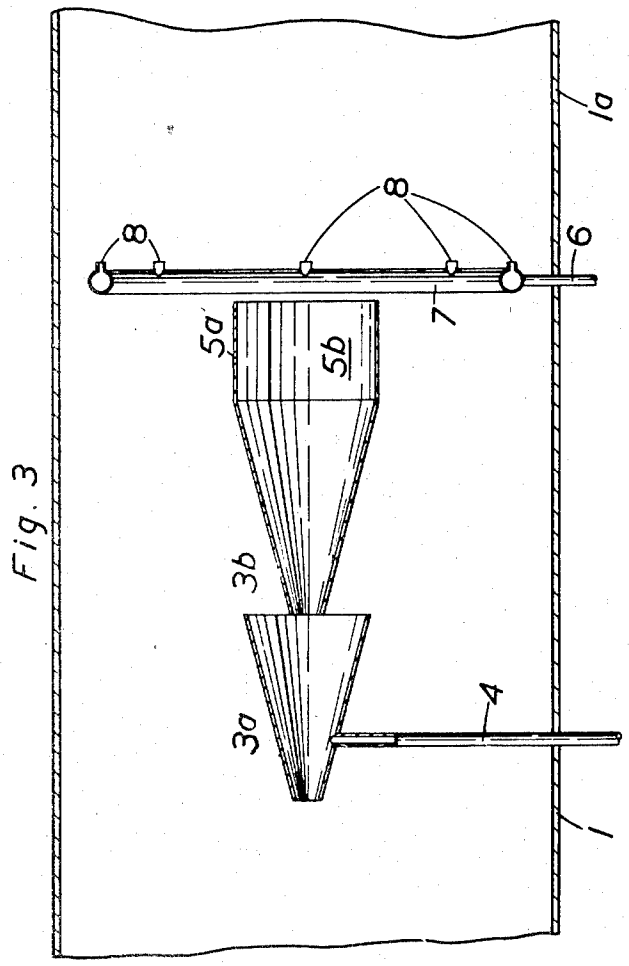


Fig. 3

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2,520,388

APPARATUS FOR SUPPORTING COMBUSTION IN FAST-MOVING AIR STREAMS

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4 Claims. (Cl. 60—44)

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This invention relates to combustion apparatus in which combustion is required to be supported by a flowing current of air or other gas (hereinafter referred to as "air") of flame-extinguishing velocity and its primary object, stated in general terms, is the provision of such an apparatus which will offer the possibility of effective and efficient combustion over a wide range of operating conditions.

Whilst, as will be seen after consideration of its details, the invention has possible application in a wider field, it is primarily concerned and is at present conceived to have its maximum utility in connection with combustion apparatus in which special problems arise due to the necessity for supporting continuous combustion by means of a fast moving air current involving a large mass flow, as for example, in gas turbine or other jet propulsion power units and in gas turbines for other purposes, the description "fast moving" being used here to indicate that the mean speed of the combustion supporting air current in its general direction of flow past a combustion zone, calculated from the ratio air volume passing in unit time/cross sectional area of flow path, is substantially higher than the speed of flame propagation in the fuel/air mixture concerned. 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 so-called "ram-jet" jet propulsion power units, as well as to other jet propulsion units and to gas turbine power units in general, in which the speed of the air current in its general direction of flow past a combustion zone, calculated on the basis indicated, might be of an order as low as 10 or as high as 500 feet per second or even more, depending on the design.

Satisfactory operation of a combustion system of the kind indicated over a wide range of air mass flow and density requires that the flame should not be extinguished under any conditions of operation and in order to prevent this the range of air/fuel ratios over which burning will take place must be as wide as possible whilst maintaining combustion efficiency at a reasonable level with weak mixture. Further, it is desirable that pressure losses should be low and that an even temperature distribution over the cross section of the flow should be achievable. Apart from the necessity for providing some means of preventing the flame from being blown out by the air flow, these requirements involve amongst

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other things the attainment of a high standard of mixing as between the combustion air and the fuel to be burnt, and of atomisation and distribution in the case of a liquid or powdered fuel. The usual practice in gas turbine and similar combustion systems is to inject liquid fuel into a region which is protected by a baffle from the full blast effect of the air flow, the fuel being ignited in this region to produce a pilot flame to which the main air flow is introduced at a downstream point, and the use of specially designed nozzles or of impact surfaces arranged in the path of the fuel jet being relied upon to achieve satisfactory atomisation of the fuel.

According to the present invention there is provided a combustion apparatus in which combustion has to be supported by a ducted air flow of flame-extinguishing velocity and in which means are provided for forming in the flow a stabilised flame adapted to act as a pilot capable of maintaining combustion against an extinguishing velocity of the flow, wherein fuel to be burnt is introduced into air flowing into ignition relationship with said stabilised flame, and at a point upstream of that at which such relation is first established, the establishment of such relation at a point downstream of its point of introduction being relied upon for ignition of said fuel and the arrangement being such that in operation an opportunity is afforded to the fuel of mixing with the air flow prior to ignition, and wherein means are provided for dividing the flow in the ducting and supplying a metered proportion thereof directly to the stabilised flame zone so that combustion therein is effected under controlled conditions of flow, the remainder of the air flow being by-passed around the stabilised flame zone and mixing at the downstream side thereof with the hot gases generated therein. The divided or isolated portion of passing air may be supplied with fuel in metered quantities and the mixture passed directly to the stabilised flame zone so that combustion therein is effected under controlled conditions of flow and fuel/air ratio.

According to a feature of the invention the means for dividing or isolating a portion of the passing air may be a diffuser duct having its mouth facing up stream in the main air flow and effecting a reduction of velocity sufficient to allow stable combustion at its downstream end under design conditions of operation. The diffuser duct may be an open ended tapering tube of small cone angle with its end of small area facing up stream and its end of larger area facing down

stream, with a wide angled open ended conical member extending from its larger end and forming the stabilised flame zone. The diffuser duct may, on the other hand comprise a plurality of open ended tapering tubes of small cone angle arranged in line one behind the other, all with their ends of smaller area facing up stream and with the small end of any one downstream of any other being arranged adjacent the larger end of the one up stream. The last tapering tube of the line may be provided with an open ended tubular member, not tapered, extending from its large end and forming the stabilised flame zone. A gauze baffle may be arranged in the diffuser duct up stream of the stabilised flame zone.

Three forms of the invention will now be described, by way of example only, with reference to the accompanying drawings in which

Figure 1 is a diagrammatic view of a combustion apparatus with a diffuser duct.

Figure 2 is a diagrammatic view of a combustion apparatus with another form of diffuser duct.

Figure 3 is a diagrammatic view of a combustion apparatus with a further form of diffuser duct.

In Figure 1 a combustion chamber duct **1** is provided with an air intake or inlet of frusto-conical form **2** to collect air and expand and decelerate its speed before it reaches a combustion chamber **1***a*. A diffuser duct or tube **3** which is a tapering tube of small cone angle is arranged within the duct **1** to collect a portion of the passing air, the end of larger diameter being adjacent the entrance of the main combustion chamber **1***a*. The diffuser tube **3** is provided with a fuel inlet pipe **4** through which fuel either in liquid, vapour or gaseous form is metered in quantities such that it forms with the air in the diffuser tube **3** a substantially constant and easily burnable air fuel mixture. The diffuser tube **3** at the point where its end of larger diameter is adjacent the entrance of the main combustion chamber **1***a* formed with a wide angled open ended conical member or secondary combustion chamber **5** forming the stabilised flame zone which is arranged to change progressively in cross sectional area within the main combustion chamber **1***a* mixture speed is decelerated to a fraction of the air speed within the main combustion chamber **1***a*. If the air fuel mixture is ignited in the pilot or secondary combustion chamber by any convenient means, such, for example, as a sparking plug, the flame front will advance up the conical member **5** until the local mean axial gas speed equals the flame speed where it will stabilise itself. Now, if the air-flow through the main air inlet **2** is altered through any circumstances, the flow through the tube **3** diffuser will also alter and the flame front in the conical member **5** will move backwards or forwards as the case may be in its combustion chamber until equilibrium of local gas speed and flame speed is reached. The flame front will not have to move backwards and forwards very far owing to the conical shaping of the conical member **5**. A stable pilot igniting flame for the main combustible mixture fed from the supply pipe **6** to a ring distributor **7** with fuel outlets **8** into the main combustion chamber **1***a* will, therefore, be maintained under all conditions of air flow, and the pilot flame is independent of the mixture strength of the mixture in the main combustion chamber **1***a*, and hence it is not seriously

affected by the main combustion chamber air mass flows and air velocities.

In Figure 2 an open ended conical diffuser duct or tube **45**, which is designed to change progressively in cross sectional area, is arranged with its small end facing upstream to divide or isolate a portion, of the passing air and decelerate it as it passes through. The tube **45** is supplied with fuel in metered quantities by a fuel pipe **4***a* such that it forms with the air a substantially constant and easily burnable mixture. The pipe **4***a* is arranged to extend radially inwards adjacent the large end of the tube **45** to pass into the stabilised flame zone and then extend axially upstream to a point near the small end of the tube **45**.

In Figure 3 two open ended tapering tubes of small cone angle **3***a* and **3***b* are arranged one behind the other in the duct **1**. The small end of the tube **3***b* is adjacent the large end of the tube **3***a*. Fuel is supplied to the tube **3***a* by a fuel pipe **4** in metered quantities to mix with the isolated portion of the air in **3***a* to form a substantially constant and easily burnable mixture. The tube **3***b* is provided with an open ended tubular member **5***a*, not tapered, to form the stabilised flame zone. A gauze baffle **5***b* is arranged at the junction of the tube **3***b* and the member **5***a* to generalise flow disturbances.

I claim:

1. Combustion apparatus comprising a duct, means to supply fuel to said duct in a plurality of circumferentially spaced points in an annular path lying substantially in a single plane normal to the axis of said duct, a tube coaxially arranged in said duct, said tube having an intake end and a discharge end located adjacent said fuel supply means, said tube having conicity of increasing cross section from its intake end to its discharge end and means to admit fuel to said tube adjacent the intake end, the diameter of the discharge end of said tube being less than the diameter of the annular path of said fuel supply means.

2. Combustion apparatus comprising a duct, means to supply fuel to said duct in a plurality of circumferentially spaced points in an annular path lying substantially in a single plane normal to the axis of said duct, a tube coaxially arranged in said duct, said tube having an intake end and a discharge end located adjacent said fuel supply means, said tube including two frusto-conical portions, the first portion beginning with its apex end as the intake end of the tube and the second portion beginning with its apex end coincident with the base end of the first portion and with its base end defining the discharge end of the tube, said first portion having a substantially smaller apex angle than said second portion, and means to admit fuel to said tube adjacent the intake end, the diameter of the discharge end of said tube being less than the diameter of the annular path of said fuel supply means.

3. Combustion apparatus comprising a duct, means to supply fuel to said duct in a plurality of circumferentially spaced points in an annular path lying substantially in a single plane normal to the axis of said duct, a tube coaxially arranged in said duct, said tube having an intake end and a discharge end located adjacent said fuel supply means, said tube being frusto-conical and increasing in cross section from its intake end to its discharge end, and means to admit fuel to said tube adjacent the intake end, the diameter of the discharge end of said tube being less than

the diameter of the annular path of said fuel supply means.

4. Combustion apparatus comprising a duct, means to supply fuel to said duct in a plurality of circumferentially spaced points in an annular path lined substantially in a single plane normal to the axis of said duct, a first frusto-conical tube coaxially arranged in said duct, said tube having an intake end and a discharge end, means to admit fuel to said tube adjacent its intake end, a second tube of increasing diameter disposed between the first-mentioned tube and the plane of said second supply means, said second tube having its end of smallest diameter adjacent the discharge end of the first-mentioned tube and its discharge end adjacent the second supply means, any diameter of said second tube being less than the diameter of the annular path of said fuel supply means.

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