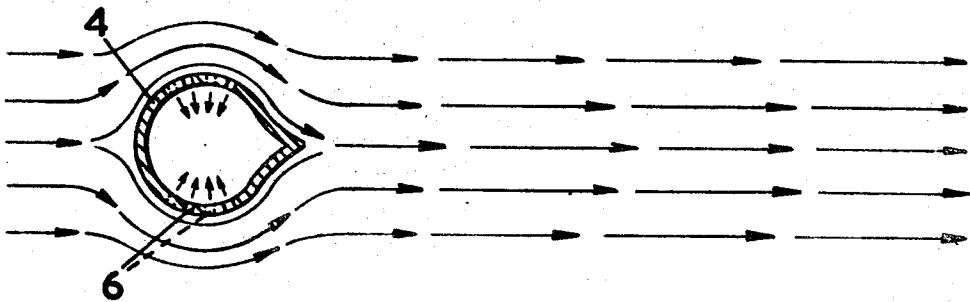


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Ireland
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[31] 27,396/68

[54] COMBUSTION DEVICES
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[52] U.S. Cl. 60/39.72
[51] Int. Cl. F02g 1/00
[50] Field of Search 431/350,
351, 353; 60/39.72, 264

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ABSTRACT: A flame stabilizer member is generally of circular cross section with its surface extended in the downstream direction as a faired flap (i.e., "teardrop" shape). The turbulence normally set up by the separation of flow over the member constitutes a flame stabilization zone. Separation can be prevented by applying suction to holes formed in the surface of the stabilizer, the turbulent zone being thereby suppressed and drag reduced. In a typical arrangement, annular stabilizing members are supported by a spider of hollow elliptical struts connected to a suction source and carrying fuel spray tubes upstream of the stabilizing members.



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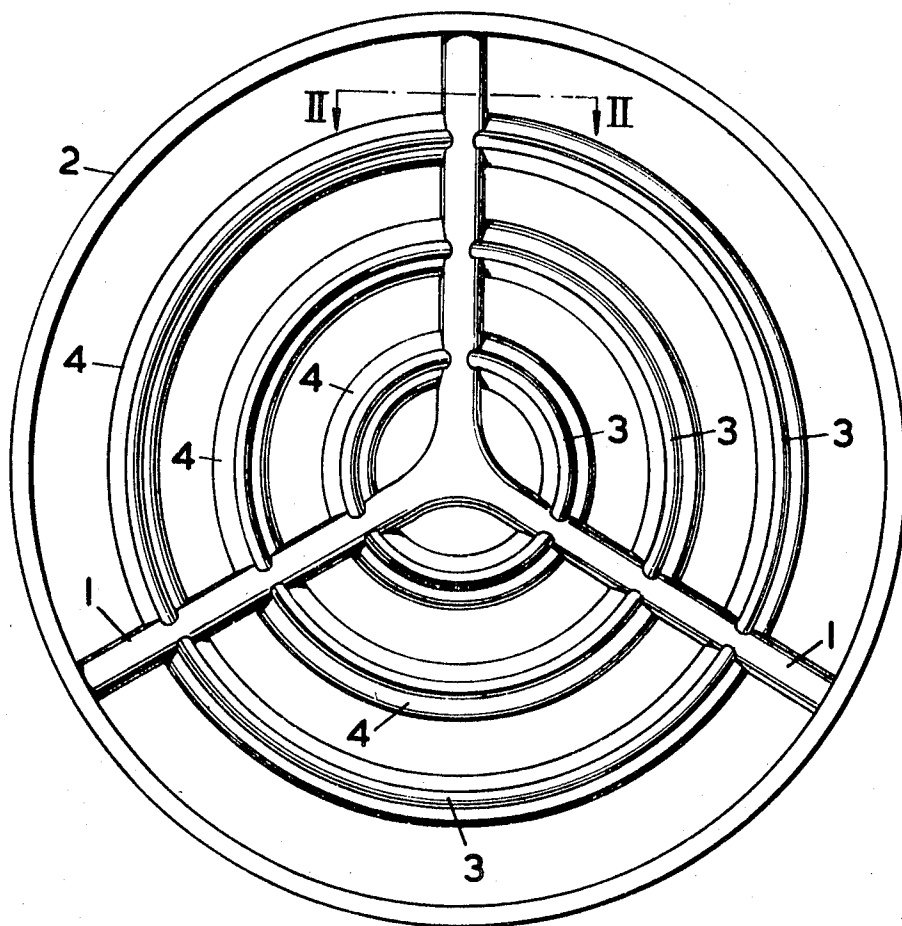


FIG. I.

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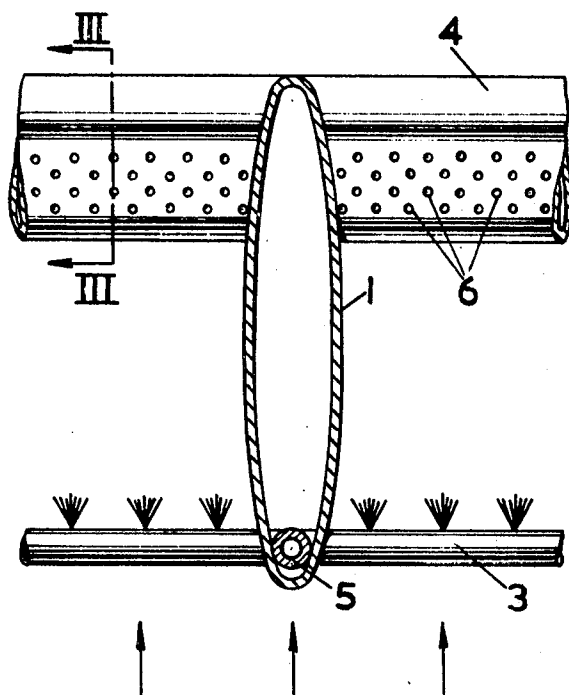


FIG. 2.

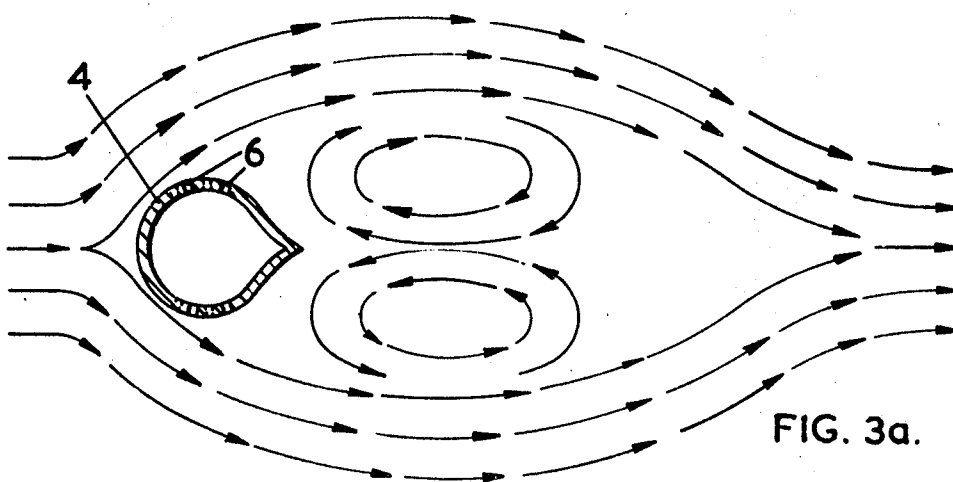


FIG. 3a.

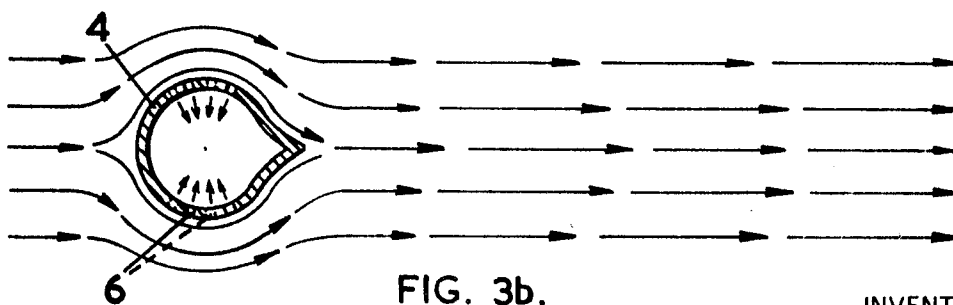


FIG. 3b.

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COMBUSTION DEVICES

The present invention relates to combustion devices wherein a flame stabilization zone is formed in a swiftly moving gas stream by the separation of flow from the surface of a body disposed within the stream.

In aircraft gas turbine jet propulsion engines, extra power can be developed by burning additional fuel in an afterburner. It has long been the practice in such installations to use fixed baffles to produce stable turbulent (or recirculation) zones in their wakes wherein flames will maintain themselves. Such baffles offer undesirable resistance to flow during such time as afterburning is not in operation. One of the more common forms of fixed baffle is a V-shaped gutter having its apex pointing upstream of the flow, the extreme simplicity of the arrangement tending to outweigh adverse considerations. By setting the arms to an included angle of the order of 45°, or slightly less according to flow velocity, a reasonable optimum between resistance and the provision of an adequate recirculation zone can be obtained.

Nevertheless, baffle resistance can be critical in determining the total amount of afterburning which can be employed, and an afterburner system having a lower pressure loss when in the nonoperating condition is desirable, provided that the penalties arising out of other considerations are not too severe. The present invention is concerned with means directed towards this end, as are prior copending U.S. Pat. application Ser. No. 780,085 filed Aug. 5, 1968 by L. D. Wigg (now U.S. Pat. No. 3,504,491) and copending U.S. Pat. application Ser. Nos. 830,259 and 830,471 filed concurrently herewith by the present Applicant.

The stability loop of a circular cylinder is very similar to that of a V-gutter of the same width so that, from the combustion point of view, they might be regarded as interchangeable. It is, however, possible to reduce the drag of the cylinder by the use of boundary layer control. If this were to be applied to a flame stabilizer for use in an afterburner system it would of course require a control flow when afterburning is not in operation but it is believed that this would be of such a low order that it would become of little importance in relation to the advantages to be gained.

A combustion device according to the invention comprises a member disposed within a fluid duct and having a substantially circular cross section with a protuberant trailing edge portion and means for influencing the boundary layer flow over the surface of the member at will so as to vary the wake formed thereby.

Preferably, suction can be applied through the surface of the member to induce the flow to adhere to the trailing edge portion.

An embodiment of the invention will now be described by way of example with reference to the accompanying diagrammatic drawings, of which:

FIG. 1 is an end view of an afterburner duct containing an arrangement of fuel injectors and flame stabilizers,

FIG. 2 is an axial section through a supporting strut taken on the line II-II in FIG. 1, and

FIG. 3a and 3b are sections through a flame stabilizer attached to the strut of FIG. 2, taken on the line III-III therein, showing the effect of different operating conditions.

In FIGS. 1 and 2, a spider has three circumferentially spaced hollow struts 1 of elliptical cross section which extend radially across an afterburner duct, defined by a cylindrical casing 2, from the axis of the duct. The spider supports three concentric annular burner arrays each comprising a fuel spray tube 3 and a flame stabilizer 4. The spray tubes in each array are in three sections which extend circumferentially between the leading edges of successive struts relative to the direction of flow through the duct as shown by the arrows in FIG. 2. Within the struts 1 are fuel supply pipes 5 which extend along the leading edges of the struts and are connected to the spray tubes 3 which have perforations in their downstream faces for

the discharge of fuel into the duct. The flame stabilizers 4 likewise are in three sections extending circumferentially between the trailing edges of the struts on the same radial alignments as the spray tubes 3. The flame stabilizers, as may be seen from FIGS. 3a and 3b, comprise tubes of substantially circular cross section flared in the downstream direction relative to flow through the duct to form protuberant trailing edge portions, the resultant profile resembling that of a teardrop laid on its side. The interiors of the flame stabilizers are connected to the interiors of the struts 1 through suitable holes (not shown), and the radially inner and outer surfaces of the flame stabilizers, relative to the axis of the duct, are pierced by numbers of small discrete holes 6.

Airflow along the duct will normally separate from the surfaces of the flame stabilizers to form stable recirculation zones in their wakes as shown in FIG. 3a. Fuel discharged from the spray tubes 3 will be entrained within the airflow before it reaches the flame stabilizers and, when ignited by conventional means, the resultant flame will maintain itself in the recirculation zone.

When afterburning is not required, the fuel supply to the spray tubes 3 is discontinued and suction applied to the interiors of the struts 1. The suction acts on the boundary layer of the flow passing around the flame stabilizers 4 by way of the holes 6 and the hollow interiors of the flame stabilizers. The separation points of the flow are thus moved rearwardly and the flow induced to adhere to the trailing edge surfaces of the flame stabilizers as shown in FIG. 3b, the resultant wake being substantially laminar with consequent reduction in drag.

It has been shown that, in the case of a circular cylinder fitted with a straight trailing edge flap having a length equal to a quarter of the cylinder diameter, the application of suction uniformly around the circumference of the cylinder required a suction coefficient of $C_q = 16/\sqrt{Re}$ to reduce the wake drag to zero at Reynolds numbers (Re) such as are to be found in reheat systems. At a Reynolds number of 10^5 , for example, the required suction coefficient would be 0.05.

In the foregoing embodiment, for practical reasons, suction is applied through rows of holes, which arrangement is slightly less efficient, but the contour of the trailing edge is such as to reduce the suction quantity required without affecting combustion performance and it is believed that a C_q of 0.04 is attainable.

Multiplying the suction coefficient by the blockage afforded by the flame stabilizers gives the fraction of the total flow bled from the duct through the surfaces of the stabilizers. A 25 percent blockage thus involves a bleed flow of about one percent. The effect of this bleed flow on engine performance depends on the thrust which can be recovered from it which in turn is dependent on pressure losses in the suction system. Suction flow can probably be exhausted rearwardly with a velocity equal to that of an aircraft, so that a bleed flow of one percent gives a one percent loss in net thrust. The corresponding rise in specific fuel consumption, dependent on type of aircraft and particular flight conditions, is estimated to be of the order of 1.3 percent compared with 3.5 to 4.25 percent due to pressure losses in a reheat system incorporating V-gutters.

Various modifications are possible to the afterburner system described above. In one, the trailing edges of the struts 1 define flame-spreading and piloting zones, suction being applied in similar fashion to the flame stabilizers for drag reduction when reheat is not in operation.

In another variation, fuel spray tubes and flame stabilizers are in the form of straight tubes arranged parallel to each other and extending transversely across a reheat duct.

Flame stabilizers as described herein are not restricted to use in afterburners, but may be used also, for example, in bypass ducts of turbofan engines where it is desired to produce extra power intermittently by burning fuel in such ducts.

I claim:

1. A combustion device comprising a fluid duct, a member disposed within the duct and having a substantially circular cross section with a protuberant trailing edge portion, and

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means for applying suction through the surface of the member whereby flow can be induced to attach to the trailing edge portion of the member to vary the wake formed by the member to produce a flame stabilization zone in a swiftly moving fluid stream.

2. A combustion device according to claim 1, wherein the surface of said member is pierced by discrete holes, the interior of said member being connected to said suction-applying means.

3. A combustion device, comprising fluid duct means; at least one member disposed within said duct means; means influencing boundary layer flow over the surface of said member to vary the wake formed thereby; and means for applying suction through the surface of said member.

4. A combustion device according to claim 1 further comprising a fuel spray tube located upstream of the member relative to flow through the duct and substantially aligned therewith.

5. A combustion device according to claim 1 comprising an annular tube mounted coaxially with the duct and of a substantially circular cross section which is flared in the downstream direction relative to flow through the duct to form a protuberant trailing edge portion, the surface of the tube being pierced by discrete holes.

6. A combustion device according to claim 5 comprising a plurality of such annular tubes of differing diameters disposed transverse of the duct.

7. A combustion device according to claim 6 in which the annular tubes are located substantially in a common transverse plane.

8. A combustion device according to claim 5 having an an-

nular fuel spray tube of corresponding mean diameter to that of the annular tube located upstream of the annular tube relative to flow through the duct and coaxial with the annular tube.

9. A combustion device according to claim 6 having a like number of annular fuel spray tubes each corresponding in mean diameter to one of the annular tubes and located upstream of the annular tubes relative to flow through the duct and coaxial with the annular tubes.

10. A combustion device according to claim 9 in which the annular spray tubes are located substantially in a common transverse plane relative to the duct.

11. A combustion device according to claim 5 in which the annular tube is supported in the duct at least in part by a hollow strut serving to connect the interior of the tube with said suction-applying means.

12. A combustion device according to claim 6 in which the annular tubes are supported in the duct by at least one hollow strut which connects the interiors of the tubes with said suction-applying means.

13. A combustion device according to claim 8 in which the annular tube is supported in the duct at least in part by a hollow strut which connects the interior of the tube with said suction-applying means and which also supports the annular fuel spray tube.

14. A combustion device according to claim 9 in which the annular tubes are supported in the duct by at least one hollow strut which connects the interiors of the tubes with a said suction-applying means and which also supports the annular fuel spray tubes.

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