

July 8, 1958

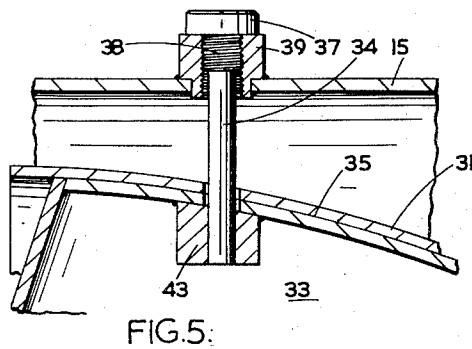
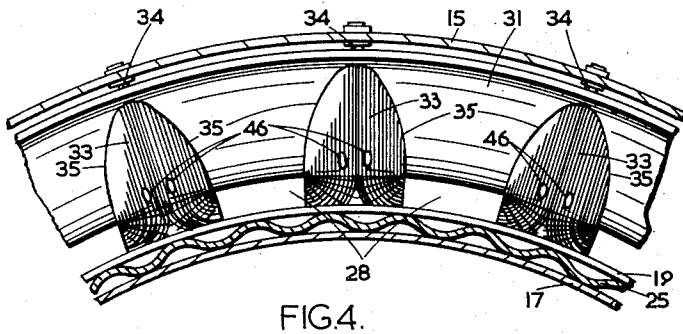
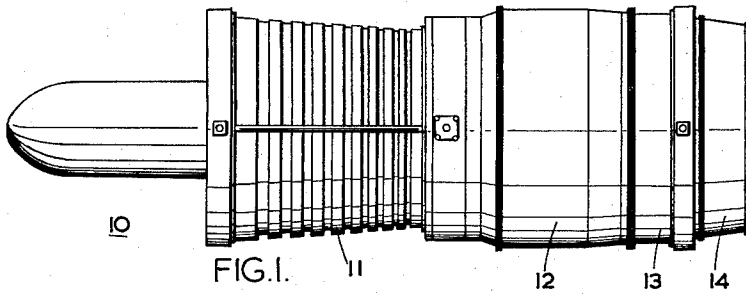
M. A. STOKES ET AL

2,841,958

COMBUSTION SYSTEM OF THE KIND COMPRISING AN OUTER AIR
CASING CONTAINING A FLAME COMPARTMENT FOR USE IN GAS
TURBINE ENGINES AND RAM JET ENGINES

Filed Dec. 13, 1956

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

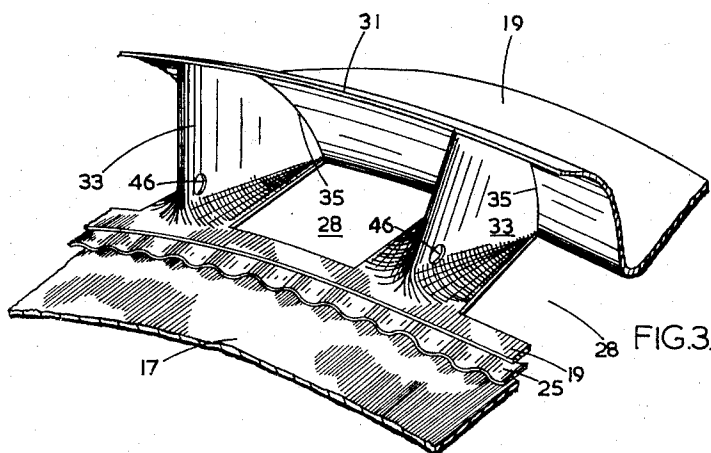


FIG. 3.

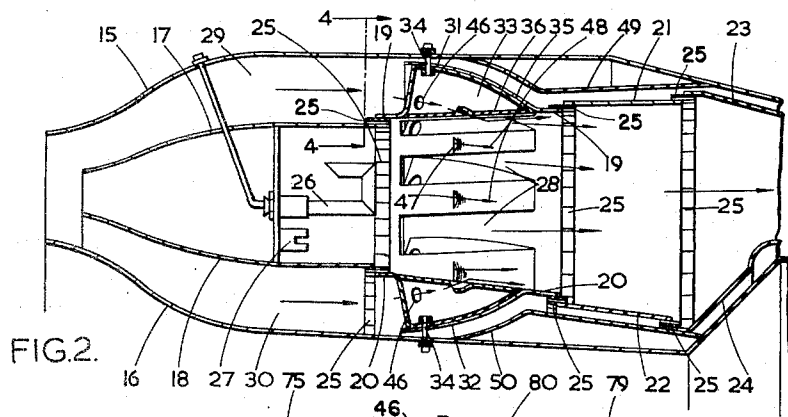


FIG. 2.

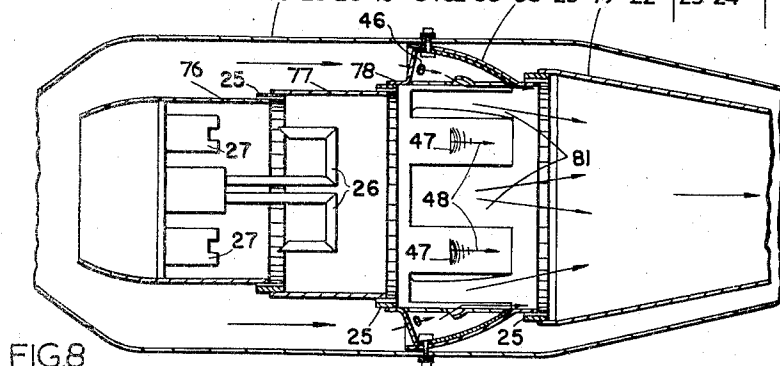


FIG. 8.

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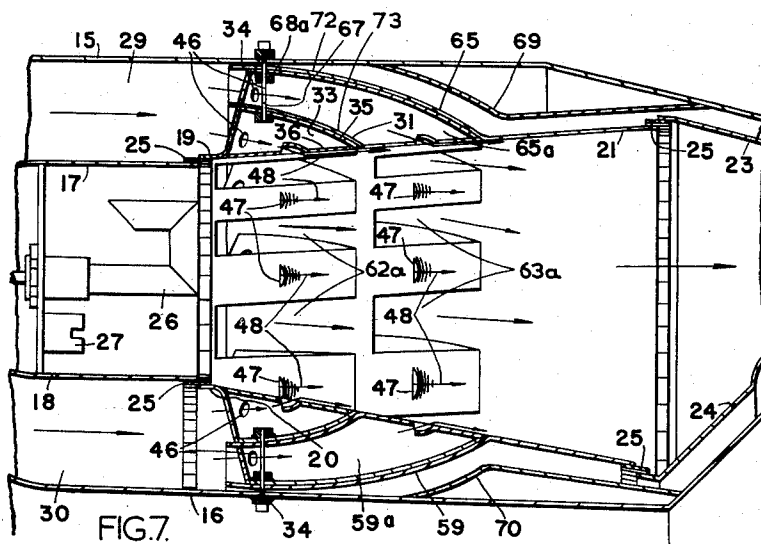
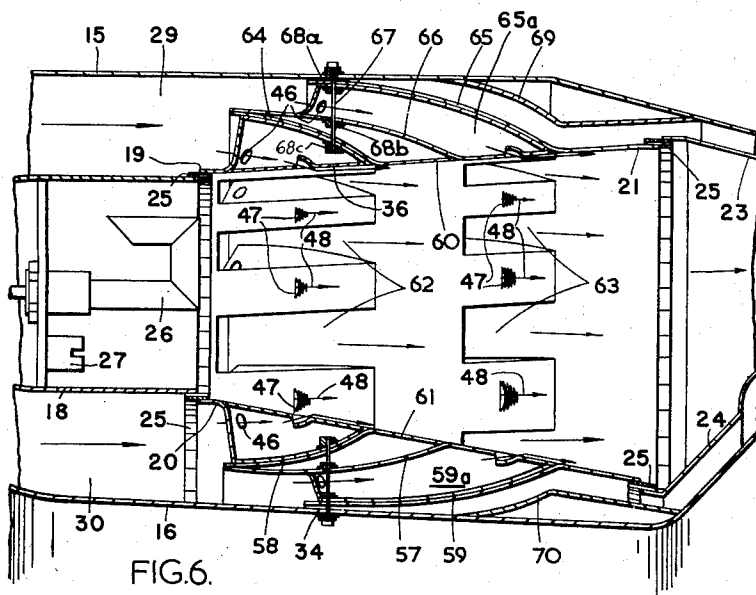
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COMBUSTION SYSTEM OF THE KIND COMPRISING AN OUTER AIR CASING CONTAINING A FLAME COMPARTMENT FOR USE IN GAS TURBINE ENGINES AND RAM JET ENGINES

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12 Claims. (Cl. 60—39.65)

The invention relates to a combustion system of an axial-flow gas turbine engine (particularly when for producing a propulsion jet), or of a ram jet engine (and the term "engine" as hereinafter used is intended to comprehend both types of engine).

It is desirable, particularly when for use in an aircraft, that the overall frontal area of such an engine be kept as low as possible, and, as the combustion system usually determines the maximum overall diameter of the engine, any reduction in frontal area will depend on whatever reduction can be made in the overall diameter of the combustion system without impairing its efficiency.

Although the invention is particularly applicable to annular combustion chamber systems it is not limited in this respect.

Combustion is normally effected within the upstream ends of flame tubes, or the upstream end of a flame chamber (depending on the construction of the engine), and diluent or mixing air, and sometimes secondary combustion air, or fuel and air are fed to the interior of each tube, or the chamber (as appropriate) from at least one external air-receiving casing, this feed usually being through plain ports formed at appropriate positions in the walls of the flame tubes or flame chamber. It is well known that the coefficient of discharge from plain ports is materially below the ideal, usually about 0.6 when the ideal is represented by unity. Slight improvement can be effected by inwardly flanging the ports and curving these flanges in a well known manner.

As the requisite area of the ports is controlled, inter alia, by the coefficient of discharge therefrom, difficulty arises in designing the flame tubes or flame chamber for the diameter of the combustion system to be kept to a minimum. This is particularly so in the case of an engine for propelling an aircraft at high supersonic speeds, having in mind that the combustion system is subject to higher pressures than would be encountered in subsonic conditions. Since it is desirable that the pressure losses through the ports should be as low as possible the designer sometimes finds that, because of the aforementioned relatively low coefficient of discharge, the ports would have to be of an area which would seriously impair the strength of the flame tubes or flame chamber, and/or prevent proper mixing of the air or fuel and air, passing through the ports, with the combustion gases within the flame tubes or flame chamber.

The main object of the invention is to improve the coefficient of discharge of the ports so as to enable smaller ones to be employed than would otherwise be needed and thus increase the strength of a flame tube or flame chamber of light construction.

According to the invention, where a ring of ports is disposed in each flame tube, or in the flame chamber as the case may be, there is arranged in the space between the flame tube or flame chamber and the air-receiving casing an annular, forwardly-facing, curved scoop which

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is interiorly divided circumferentially by a number of axially-directed, radially-extending splitter struts, the adjacent surfaces of each adjacent pair of struts, together with the portion of the scoop uniting them, defining a flow passage terminating in a port communicating with the interior of the flame tube or flame chamber, the said surfaces of the struts and the coacting surface of the scoop being so shaped aerodynamically that the flow passage diverts the air from its substantially axial path at entry to a substantially radial path where it discharges into the associated part, with a greatly reduced pressure loss.

In this manner the coefficient of discharge from a port can be increased to the maximum extent, i. e., to approach unity as nearly as possible, and the penetrative power of the air entering the flame tubes or flame chamber is improved as the air is more efficiently delivered thereto.

Preferably, it is part of the wall of each flame tube or flame chamber where the ports are to be that is appropriately curved to provide the annular scoop, and each splitter strut is preferably formed as a hollow closed-section member having a portion curved to conform to the curvature of the scoop so as to abut and be attached to it, the upstream edges nearest the flame tube or flame chamber of all the struts being integral with an upstream portion of the flame tube or flame chamber, and each port being defined at the sides by opposite lateral terminal edges of two adjacent struts, at the front by the edge of the upstream flame tube, or flame chamber, portion between said upstream edges of the struts, and at the rear by the curved portion of the scoop between the downstream ends of said terminal edges of the struts.

Consequently, a flame tube or a flame chamber, can be constructed of relatively light sheet metal and yet be of great strength which, combined with the improvement in the coefficient of discharge from the ports, enables the overall diameter of the combustion system, and therefore the frontal area of the engine, to be smaller than would otherwise be the case. Moreover, since this form of construction will enable a single row of ports to perform the function of two or more rows of ports of more usual form, a reduction in overall length of flame tubes or flame chamber, and hence of the engine itself, can be effected with a consequent saving in engine weight.

When a flame tube or flame chamber is arranged to provide film cooling (i. e., is divided into a number of longitudinal parts annularly spaced a small amount from one another by intermediate spacers in a well known manner) it is one of these parts that is adapted according to this invention, and the annular scoop may be spaced slightly from the wall of the external air-receiving casing so that some of the air may pass beyond the scoop for film cooling the succeeding flame tube or flame chamber parts and for other purposes (e. g., turbine cooling). In such a case, an appropriately shaped fairing can be arranged to reduce the free space downstream of the scoop, between the external air-receiving casing and the adjacent flame tube or flame chamber, so that the velocity of the air passing beyond the scoop for the aforesaid cooling purposes is substantially maintained.

According to a further feature of the invention, and in the case where it is desired to provide a flame tube or a flame chamber with two or more circles of ports which are to be spaced in the axial direction, it is arranged for each circle to have its own scoop and splitter strut assembly, the upstream edge of the most upstream scoop extending radially towards the external air casing to a less extent than the next downstream one and so on. In order further to improve the entry conditions of a downstream circle of ports an annular fairing could be provided to

extend from substantially the upstream edges of these ports to the outer edge of the adjacent upstream scoop.

Where two or more circles of ports are to be only slightly spaced axially and with the ports of the separate series aligned axially, the scoop associated with the most upstream ring of ports would be overlapped by the next downstream one and so on. In such a case each scoop can be provided internally with its own arrangement of splitter struts, the struts of both scoops lying in aligned radial planes for mutual support.

By virtue of the extremely strong structure afforded by the annular scoop and the associated splitter struts the flame tube or flame chamber may advantageously be supported from the external air casing, through the annular scoop, by radially-disposed pin means rigidly attached either to the scoop or air casing and connected to the other of these parts in a manner to permit relative radial movement to accommodate expansion of the parts, each of the pin means being arranged to engage the scoop at a position between the enclosing side walls of a splitter strut.

The inner surface or floor of each splitter strut, forming part of a flame tube or flame chamber proper, may be film-cooled by providing a hole/or holes in a forward part of the strut for air to enter, the said inner surface of the strut having a louvred slit or slits through which the air is directed as a film along this inner surface.

In the accompanying drawings:

Figure 1 is a diagrammatic elevation of a gas turbine engine embodying the invention;

Figure 2 is a longitudinal section through part of an annular type combustion system, of a gas turbine engine embodying the invention having a single circle of ports;

Figure 3 is a perspective view of a portion of a curved scoop and two splitter struts and is an enlargement of the corresponding parts of Figure 2;

Figure 4 is an arcuate portion of an enlarged section on line 4—4 of Figure 2;

Figure 5 is an enlarged section of a detail of Figure 2;

Figure 6 is a longitudinal section through part of an annular type combustion system, embodying the invention, including two spaced circles of ports;

Figure 7 is a longitudinal section through part of another annular type combustion system, embodying the invention, with different axial spacing of the ports; and

Figure 8 is a longitudinal section through a can-type combustion chamber embodying the invention.

In Figure 1 the gas turbine engine 10 comprises a compressor 11, a combustion system 12, a turbine 13 and an exhaust cone assembly 14.

The combustion system shown, in part, in Figure 2 comprises an annular casing consisting of two parts 15 and 16 and a flame chamber which consists of a number of pairs of spaced ring-like parts 17, 18; 19, 20; 21, 22; and 23, 24.

Between adjacent parts 17 and 19 is a corrugated ring-like spacer 25 and there are similar corrugated ring-like spacers between each adjacent pair of parts such as 18, 20; 22, 24.

The corrugated spacers 25 provide, in known manner, for film cooling of the internal surfaces of the flame chamber. The flame chamber includes conventional combustion apparatus such as J-tubes 26 and secondary air inlets 27.

In the section of the flame chamber bounded by the ring-like parts 19 and 20 are circles of rectangular ports 28, only the ports in the ring-like part 19 being seen in Figure 2, although there are corresponding ports in the ring-like part 20.

Between the casing part 15 and the ring-like parts 17, 19, 21 and 23 is an annular air-receiving space 29; and between the casing part 16 and the ring-like parts 18, 20, 22 and 24 is an annular air-receiving space 30. In the portion of the annular space 29 which is adjacent the ports 28 is an annular, curved, scoop 31 and there is a

corresponding annular scoop 32 in the corresponding part of the annular space 30.

The scoop 31 is formed as an upstream continuation of the downstream portion of ring-like part 19. Circumferentially spaced splitter struts 33 are welded to the upstream portion of ring-like part 19 and have surfaces 35 abutting the interior surface of the scoop 31. Each strut 33 is provided with an internal floor 36 (Figure 2) welded to the underside thereof and is flush with the upstream and downstream portions of ring-like part 19. In effect, the floors 36 cooperate with the upstream and downstream portions of ring-like part 19 to form the section of the flame chamber containing the ports 28.

The scoop 31 and splitter struts 33 are supported relatively to the casing part 15 by a plurality of radially-disposed pins 34 (Figure 5). Each pin 34 has a head 37 and a threaded portion 38 by which it is attached to a nut 39 welded to the casing part 15. The inner end of each pin 34 is slidable in a boss 43 welded to the inner surface of a strut 33.

The pins 34 thus permit relative radial movement caused, for example, by relative thermal expansion between the casing part 15 and scoop 31 and associated strut 33.

Each strut 33 has a pair of holes 46 (Figures 2, 3 and 4) adjacent its forward edge to provide for a flow of air to the interior of the strut 33; and each floor portion 36 has one or more louvred openings 47 (Figure 2) for flow of air in the direction indicated by arrows 48 to provide for film cooling of the inner surface of the floor portion 36.

The arrangement of scoop 32 and associated splitter struts in relation to ring-like part 20 is similar to the arrangement of scoop 31 and splitter struts 33 and will not be described in detail.

As can be seen, scoops 31 and 32 are spaced slightly from the adjacent casing parts 15 and 16, respectively, to allow for a flow of coolant air beyond the scoops.

Between the scoop 31 and the casing part 15 is welded a fairing 49 to reduce the free space between the casing part 15 and the flame chamber and there is, of course, a corresponding fairing 50 between the casing part 16 and the flame chamber.

In Figure 6 the combustion system is again of the annular kind and is similar in all respects to Figure 2 except that the ring-like parts 60 and 61 are each provided with two axially-spaced rings of ports 62 and 63, only the ports associated with the ring-like part 60 being seen in the drawing. There are two air scoops 64 and 65 associated with ring-like part 60, and two air scoops 58, 59 associated with ring-like part 61. The scoops are similar in construction to the scoops described with reference to Figure 2. The air scoop 65 partially overlaps scoop 64, and a fairing 66 extends from the upstream edge of the ports 63 to the upstream edge of the scoop 64 and forms a floor to the scoop 65. There is a similar fairing 57 associated with the scoop 59. In other respects the scoops 59 and 65 have splitter struts 59a, 65a, respectively similarly arranged to those described with reference to the scoops 31 and 32 in Figure 2.

In Figure 6 the pin mounting is similar to that described with reference to Figure 2 except that each pin 67 is accommodated in three bosses, 68a, 68b and 68c, so as to allow relative movement between the scoops and the various parts associated with them.

Fairings 69 and 70 are included in a similar manner and for a similar purpose to the fairings described with reference to Figure 2.

In Figure 6, the special construction of the scoop 65 is dictated by the axial spacing of the rings of ports 62 and 63. The rings of ports 62a, 63a are axially closer in Figure 7 and the scoops 72 and 73 completely overlap so that the fairing 66 (shown in Figure 6) is not required. The splitter struts associated with each scoop

lie in aligned radial planes to provide mutual support. The remaining details are as described with reference to the previous figures.

Figure 8 shows one can type of combustion chamber embodying the invention, the outer casing part 75 being tubular in this instance and the inner flame tube comprising tubular parts 76, 77, 78 and 79. The part 78 is provided with ports 81, and the remaining details of the embodiment, including a single scoop 80 are similar, in essential respects, to the arrangement described with reference to Figure 2.

In all of the arrangements described each adjacent pair of splitter struts together with the portion of the scoop uniting the struts defines a flow passage terminating in the corresponding port; and the size of each port is made substantially equal to the area at the entry to the scoop. The scoop and struts are shaped, aerodynamically, so that the flow passage diverts the air entering the scoop from its substantially axial path at entry to a substantially radial path at discharge, through the ports, into the flame tube or chamber with low pressure loss.

What we claim as our invention and desire to secure by Letters Patent of the United States is:

1. An engine combustion system comprising an outer air-receiving casing, a flame compartment supported in said casing and annularly spaced from said casing, said flame compartment having a ring of ports, and, supported in the annular space between the flame compartment and the air-receiving casing, an annular, forwardly-facing curved scoop, said system also comprising splitter struts dividing the interior of the curved scoop circumferentially, said splitter struts being axially-directed but radially-extending, said splitter struts having outer surfaces, the adjacent outer surfaces of each adjacent pair of struts, together with a portion of the scoop uniting the struts, defining a flow passage terminating in one of said ring of ports, said ring of ports communicating with the interior of the flame compartment, said surfaces of said struts and a portion of the scoop uniting the struts being so shaped aerodynamically that said flow passage diverts the air from its substantially axial path at entry to a substantially radial path where the air discharges through the port into the compartment, with a greatly reduced pressure loss.

2. A system according to claim 1, and in which a part of a wall of said compartment adjacent said ports, is curved to provide said scoop.

3. A system according to claim 1 and in which each of said splitter struts is formed as a hollow closed-section member having a portion curved to conform to the curvature of the scoop and to abut the scoop, said struts having upstream edges, the upstream edges of the struts nearest the flame compartment being integral with the flame compartment, each of said ports being defined at its sides by opposite lateral terminal edges of two adjacent struts and being defined at its front by the edge of the upstream flame compartment portion, and at the rear by the curved portion of the scoop between the downstream ends of said terminal edges of said struts.

4. A system according to claim 1 and in which said flame compartment is formed as a plurality of sections, one section of the tube being adapted to provide the scoop, and adjacent sections of the flame compartment overlapping to provide film cooling.

5. An engine combustion system comprising an outer air-receiving casing, a flame compartment supported in said casing, and annularly spaced from said casing, said flame compartment having a ring of ports, and, supported in the annular space between the flame compartment and the air-receiving casing, an annular, forwardly-facing curved scoop, said system also comprising splitter struts dividing the interior of the curved scoop circumferentially, said splitter struts being axially-directed but radially-extending, said splitter struts having outer surfaces, the

adjacent outer surfaces of each adjacent pair of struts, together with a portion of the scoop uniting the struts defining a flow passage terminating in one of said ring of ports, said ring of ports communicating with the interior of the flame compartment, said surfaces of said struts and a portion of the scoop uniting the struts being so shaped aerodynamically that said flow passage diverts the air from its substantially axial path at entry to a substantially radial path where the air discharges through the port into the compartment, with a greatly reduced pressure loss, the flame compartment having two or more circles of ports which are spaced axially, each circle of ports having its own scoop and splitter strut arrangement.

6. A system according to claim 5 and in which the upstream edge of the main upstream scoop extends radially toward the external air casing to a lesser extent than the next downstream scoop.

7. A system according to claim 6, and in which an annular fairing extends from substantially the upstream edges of the downstream circle of ports to the outer edge of the adjacent upstream scoop.

8. An engine combustion system comprising an outer air-receiving casing, a flame compartment supported in said casing, and annularly spaced from said casing, said flame compartment having a ring of ports, and, supported in the annular space between the flame compartment and the air-receiving casing, an annular, forwardly-facing curved scoop, said system also comprising splitter struts dividing the interior of the curved scoop circumferentially, said splitter struts being axially-directed but radially-extending, said splitter struts having outer surfaces, the adjacent outer surfaces of each adjacent pair of struts, together with a portion of the scoop uniting the struts defining a flow passage terminating in one of said ring of ports, said ring of ports communicating with the interior of the flame compartment, said surfaces of said struts and a portion of the scoop uniting the struts being so shaped aerodynamically that said flow passage diverts the air from its substantially axial path at entry to a substantially radial path where the air discharges through the port into the compartment, with a greatly reduced pressure loss, and in which the flame compartment is provided with two or more of the spaced circles of ports, the circles of ports being only slightly spaced axially and with the ports of the separate circles aligned axially, the scoop associated with the most upstream ring of ports being overlapped by the next scoop.

9. A system according to claim 8, and in which each scoop is provided internally with its own arrangement of splitter struts, the struts of each scoop lying in aligned radial planes for mutual support.

10. An engine combustion system comprising an outer air-receiving casing, a flame compartment supported in said casing, and annularly spaced from said casing, said flame compartment having a ring of ports, and, supported in the annular space between the flame compartment and the air-receiving casing, an annular, forwardly-facing curved scoop, the system also comprising splitter struts dividing the interior of the curved scoop circumferentially, said splitter struts being axially-directed but radially-extending, said splitter struts having outer surfaces, the adjacent outer surfaces of each adjacent pair of struts, together with a portion of the scoop uniting the struts defining a flow passage terminating in one of said ring of ports, said ring of ports communicating with the interior of the flame compartment, said surfaces of said struts and a portion of the scoop uniting the struts being so shaped aerodynamically that said flow passage diverts the air from its substantially axial path at entry to a substantially radial path where the air discharges through the port into the compartment, with a greatly reduced pressure loss, and each splitter strut having a forward part and a floor, each forward part being provided with a hole and each floor being provided with a louvred slit whereby air en-

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tering the hole can pass through the louvered slit to provide film cooling of the floor.

11. An engine combustion system including a flame tube and an outer air-receiving casing annularly spaced from the tube, a ring of ports disposed in each flame tube, and, in the space between the flame tube and the air-receiving casing, an annular, forwardly-facing, curved scoop which is interiorly divided circumferentially by a number of axially-directed, radially-extending, splitter struts; the adjacent surfaces of each adjacent pair of struts, together with the portion of the scoop uniting them, defining a flow passage terminating in a port communicating with the interior of the flame tube, said surfaces of the struts and the co-acting surfaces of the scoop being so shaped aerodynamically that the flow passage diverts the air from its substantially axial path at entry to a substantially radial path where it discharges into the associated part, with a greatly reduced pressure loss.

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12. An engine combustion system including an annular flame chamber, and an outer air-receiving casing annularly spaced from the chamber, a ring of ports disposed in each chamber, and, in the space between the flame chamber and the air-receiving casing, an annular, forwardly-facing, curved scoop which is interiorly divided by a number of axially-directed, radially-extending, splitter struts; the adjacent surfaces of each adjacent pair of struts, together with a portion of the scoop uniting them, defining a flow passage terminating in a port communicating with the interior of the flame chamber, said surfaces of the struts and the co-acting surface of the scoop being so shaped aerodynamically that the flow passage diverts the air from its substantially axial path at entry to a substantially radial path where it discharges into the associated part, with a greatly reduced pressure loss.

No references cited.