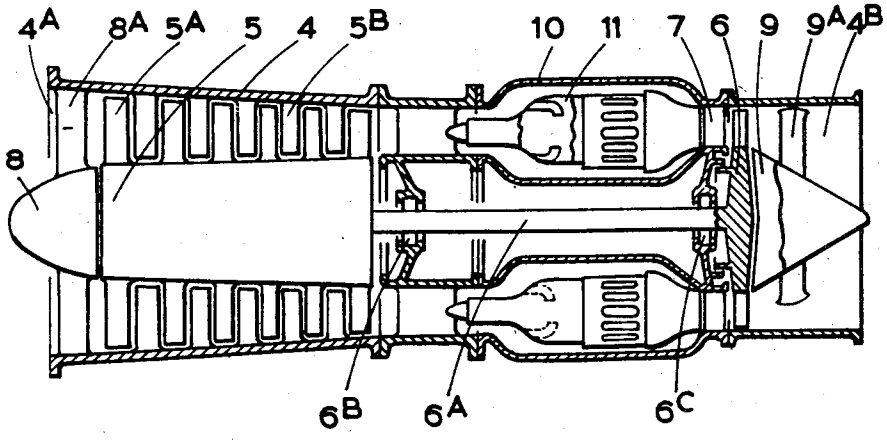
April 15, 1958 F. M. JOHNSON ET AL 2,830,439

COMBUSTION EQUIPMENT FOR GAS TURBINES WITH HOT GAS EXTRACTION AND MIXING MEANS

Filed Jan. 20, 1955 4 Sheets-Sheet 1

FIG. 1.



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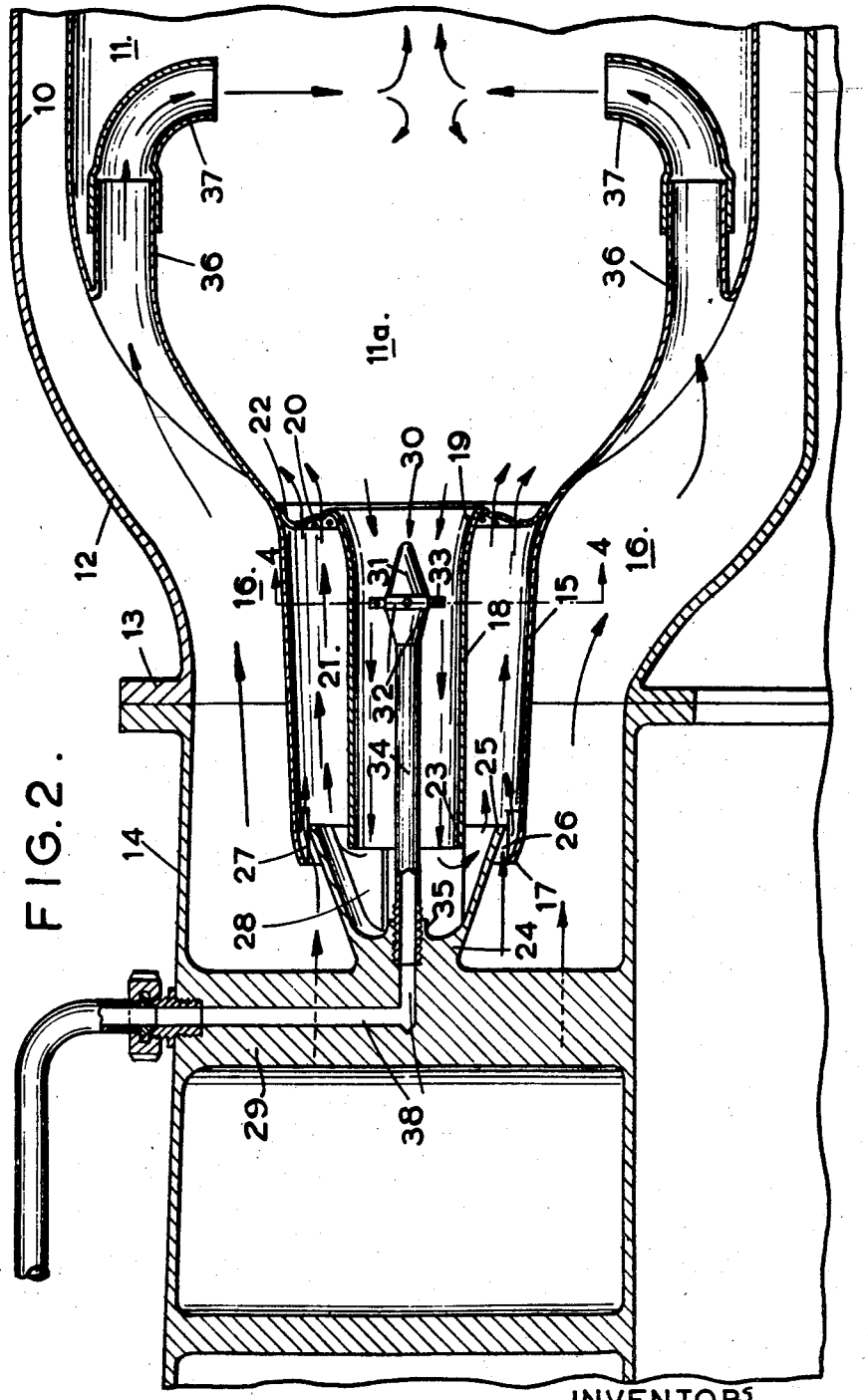


FIG. 2.

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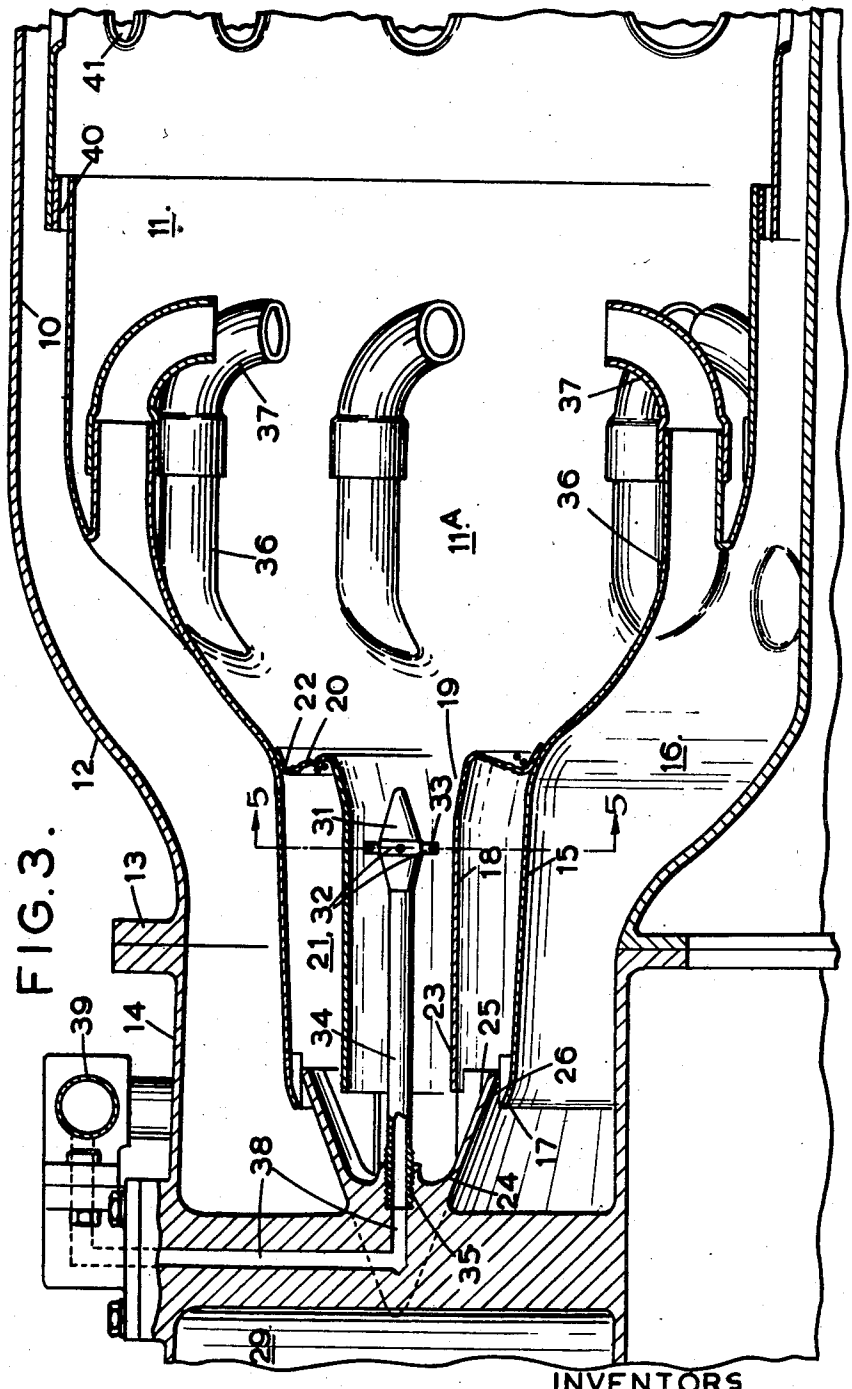


FIG. 3.

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COMBUSTION EQUIPMENT FOR GAS TURBINES WITH HOT GAS EXTRACTION AND MIXING MEANS

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FIG. 4.

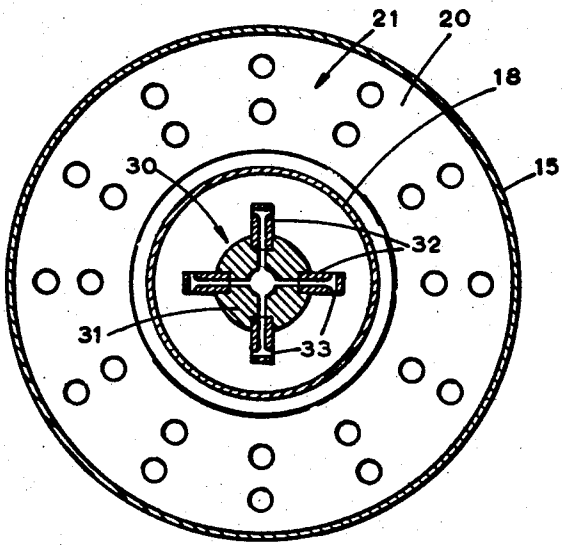
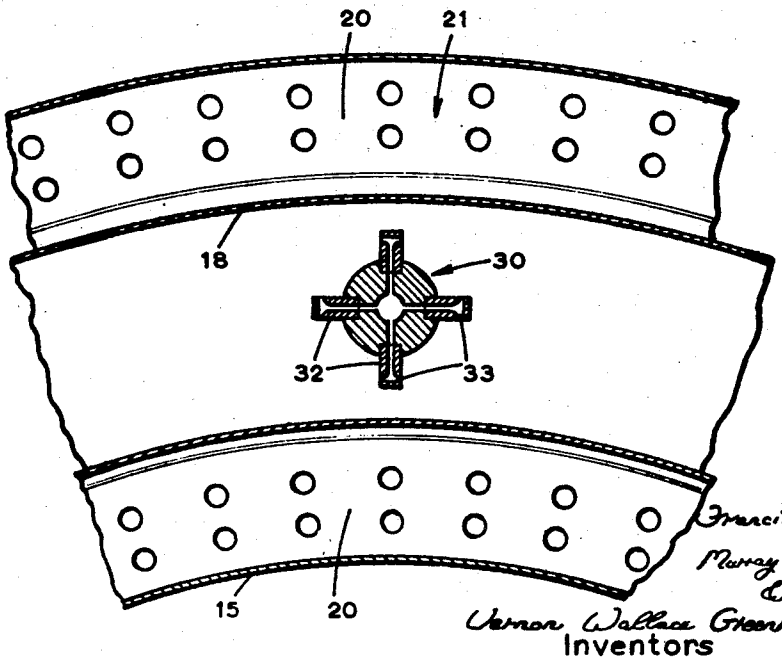


FIG. 5.



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2,830,439

COMBUSTION EQUIPMENT FOR GAS TURBINES WITH HOT GAS EXTRACTION AND MIXING MEANS

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Application January 20, 1955, Serial No. 483,082

Claims priority, application Great Britain February 24, 1954

9 Claims. (Cl. 60—39.74)

This invention relates to combustion equipment and is particularly applicable to combustion equipment for gas turbine engines.

Such combustion equipment normally comprises an air casing into which air is delivered, and a flame tube within the air casing within which combustion takes place. The combustion process is conveniently divided into a primary zone in which initial combustion of the fuel and air takes place, and a secondary zone in which further air is added to complete the combustion process, and in certain cases also further air is added to dilute the combustion products so as to reduce the temperature of the gases at the exit from the combustion chamber.

According to this invention the combustion equipment comprises a conduit which is led off from and returned to the primary combustion zone of the flame tube, means including an ejector operated by a flow of air supplied to the combustion equipment for creating a sufficient pressure difference at the ends of said conduit to cause in operation a flow of gas therethrough, and means to supply fuel to said conduit.

In using the word "conduit" there is implied a pathway for a stream of gas which may in its course be divided into different streams flowing in different passage-ways.

According to a feature of this invention the combustion equipment comprises an outlet pipe connected to receive gases from the primary combustion zone of the flame tube, ejector means positioned at the outlet end of said pipe and supplied with a flow of air so as to cause a region of low pressure adjacent the outlet end of the pipe, a further pipe connected to said region of low pressure to receive said flow of air and the gases emerging from the outlet pipe and to convey them to within the primary zone of the flame tube, and means to supply fuel to said outlet pipe upstream of its outlet end to mix with the gases in the pipe.

According to a feature of the invention the means to supply fuel may be a fuel atomiser.

According to one arrangement of the invention the flame tube is provided at its inlet end with an elongated tubular portion which opens at its upstream end to the incoming air stream, and there is provided a second tube coaxially within the first tube and having its upstream end downstream of the upstream end of the outer tube, a bell-shaped baffle positioned coaxially within the upstream end of the outer tube so as to provide between its outer surface and the inner surface of the outer tube a convergent passage, thereby to produce a low pressure region downstream of the lip of the baffle and adjacent the upstream end of the inner tube, and fuel injector means positioned within the inner tube so arranged that heated combustion products from the primary combustion zone enter the inner tube, have fuel injected to mix with them in flowing through that tube whereby the gases are cooled, and are caused to reverse in direction at the upstream end of the inner tube to flow through the annular space

between the two tubes back into the primary combustion zone, together with the air entering the outer tubular portion at its upstream end.

Preferably the air entering the flame tube in this manner forms only part of the primary air, and the remainder may be introduced into the primary zone in any known or convenient manner, for example as described in U. S. patent application Serial No. 329,568.

The baffle and the fuel injector may conveniently be supported from structure upstreams of the flame tube and tubular members, for example from a strut extending across the entry duct to the air casing. At the downstream end of the inner tube there may be provided a perforated baffle extending across the annular space between the tube members and this baffle may form the support for the inner tube. The baffle may be formed integrally with the inner tube, and the outer tubular portion may be formed as an integral part of the upstream end of the flame tube.

Examples of this invention are illustrated in the accompanying drawings in which

Figure 1 is a diagram of a gas turbine showing the combustion equipment.

Figure 2 is a section through the upstream end of a tubular combination chamber.

Figure 3 is a similar section through part of an annular combustion chamber.

Figure 4 is a cross-sectional view on a larger scale of the fuel injector and surrounding tubes taken on line 4—4 of Figure 2 looking in the direction of the arrows;

Figure 5 is a view similar to Figure 4 but taken on line 5—5 of Figure 3.

The gas turbine engine illustrated in Figure 1 consists of a casing 4 with an inlet 4A for air and an outlet 4B for the products of combustion. Air entering the inlet 4A enters the compressor comprising a rotor 5 having a number of rotating blades 5A rotating between blades 5B fixed to the casing. The compressor is driven by a turbine 6 through a shaft 6A mounted in bearings 6B and 6C.

Air from the compressor enters the air casing 10 of the combustion equipment and thence flows into the flame tubes 11 in the manner hereinafter described from whence it passes out through a series of fixed turbine nozzle guide vanes 7 to drive the turbine.

The air entering the engine is guided over a cone 8 supported in a casing on members 8A and on leaving the turbine the gases pass over a cone 9 supported from the casing by members 9A.

The combustion equipment is more particularly illustrated in Figure 2 and comprises tubular air casings 10 and tubular flame tubes 11 within the air casings. The upstream portion 12 of each air casing is of increasing cross-section area and at its upstream end the air casing is formed with a flange 13 by which it is connected to a delivery duct 14 of a compressor of the engine.

The flame tube 11 at its upstream end 11A is also of increasing cross-section area in the direction of flow and it is formed with an integral tubular upstream extension 15 which may project into the compressor delivery duct. The extension is substantially cylindrical in form, and thus there is formed an annular passage 16 of substantially constant cross-section area between the upstream end 11*a* of the flame tube and its extension 15 and the wall of the delivery duct 14 and the upstream part 12 of the air casing. The length of the extension 15 is about twice its diameter, and the extension is formed at its upstream end with a lip 17 which is inclined slightly inward.

Coaxially within the extension of the flame tube there is mounted an inner tubular member 18 which is sub-

stantially cylindrical in form, being flared slightly in the outward direction at its end 19 remote from the upstream end of the flame tube extension 15, and also being formed at this end with a radially-extending perforated web 20 which extends across the annular passage 21 between the inner tubular member 18 and the flame tube extension 15. The radially-extending web 20 is formed at its outer periphery with a flange 22 to lie within the flame tube 11 adjacent the point where the cylindrical extension 15 joins the increasing area part 11*a* of the flame tube, and the web is secured to the flame tube as by welding or bolting to support the inner tubular member 18 within it.

The inner tubular member 18 is open at its other end 23, i. e., its upstream end relative to the general direction of airflow, and coaxial with this end 23 is provided a bell-shaped member 24, the lip 25 of which is of somewhat larger diameter than the tubular member 18, the bell-shaped member 24 opening towards the open end of the tubular member 18. The bell-shaped member 24 may axially overlap the tubular member 18 so that the lip 25 surrounds the end 23 of the tubular member 18, as illustrated or the bell-shaped member 24 may terminate in the same plane as the tubular member 18, or the members may be axially spaced apart by a small amount.

The lip 25 lies within the upstream end of the tubular extension 15 of the flame tube, and forms with the lip 17 a short annular passage 26 which is preferably convergent.

Webs 27 may be formed internally of the upstream end of the extension 15 to position it concentrically over the lip 25 of the bell-shaped member 24, and the latter may be formed internally with webs 28 to position the tubular member 18 within it.

The bell-shaped members 24 are conveniently formed as part of the radially-extending struts 29 which are normally provided between the inner and outer walls of the compressor delivery duct 14, but may for example be formed as separate units and secured say to the outer wall of the compressor delivery duct.

Within the inner tubular member 18 there is provided a fuel injector 30, which is preferably towards the end 19 of the inner member. The fuel injector 30 may comprise a central body 31 and a number of short closed-ended pipes 32 extending radially of the body, the pipes being formed with transverse drilled holes 33. The fuel injector is preferably supported by a tubular member 34 extending through the open end 23 of the tubular member 18, and the tubular member 34 may be secured as shown to a boss 35 concentrically within the bell-shaped member 24. Where the latter is formed as part of a strut 29, fuel passages 38 will be formed in the strut leading from the fuel supply system of the engine to the inlet end of the tubular member 34, which serves as the fuel supply pipe to the fuel injector 30, and thence through passages in the injector body 31 and through pipes 32 to the holes 33. These are preferably of small diameter to atomize the fuel.

The inlet portion of the flame tube is also formed with further apertures for the admission of primary air which may be of any convenient form. For example, as shown, the inlet portion 11*a* of the flame tube is formed with a pair of cylindrical tubular parts 36 at opposite sides of a diameter, and having their axes at their inlet ends parallel to the axis of the flame tube. The tubular parts 36 are of small diameter relative to the flame tube, and are turned through approximately a right angle so that their outlet ends 37 are directed towards the centre-line of the flame tube and towards one another.

In operation, when air is delivered to the combustion equipment, the main part of the air flows through the annular passage 16, and a small part flows through the annular passage 26 between the lip 17 of the tubular extension 15 and the lip 25 of the bell-shaped member 24, which thus acts as an ejector. The flow through passage 26 causes a depression within the lip 25, thus promoting a flow of hot gas from within the primary combustion area of the inlet end 11*a* of the flame tube and through the inner tubular member 18 towards the bell-shaped member 24. Fuel is injected into this gas through holes 33, which tends to cool the gas and thus to vaporize the fuel, and the mixture then reverses in direction to flow towards the inlet end 11*a* of the flame tube through the annular passage or pipe 21 where intermingling of the fuel and gas with the air entering through passage 26 takes place.

Fuel, air and gas flow through the apertures in the web 22, the divergent shape of the inlet end of the flame tube and the flared end 19 of the member 18 causing the mixture to flow first away from the centre-line of the flame tube.

Part of the air flowing in passage 16 enters the flame tube through inlets 36, 37 and is burned with the fuel entering through passage 21, the primary combustion taking place substantially within the inlet end 11*a* of the flame tube; further air enters the downstream part of the flame tube, as is conventional, to provide for the completion of combustion and the dilution air.

In Figure 3 is a similar view to Figure 2 but shows the invention applied to an engine in which instead of a number of flame tubes annularly arranged, the flame tube 11 is itself an annulus and has an annular outlet pipe 18 leading off from the primary combustion zone of the flame tube, an annular ejector member 24 and an annular extension 15 forming a pair of return passages or pipes 21. A number of fuel injectors 30 are spaced circumferentially within the outlet pipe 18.

Like parts have like numbering to those shown in Figure 2. In addition there is shown in Figure 3 a manifold 39 supplying fuel to the fuel intake bores 38 and a secondary air inlets to the flame tube at 40 and 41.

We claim:

1. Combustion equipment for a gas-turbine engine having an air casing into which air is delivered and a flame tube within said air casing and within which combustion takes place, the flame tube being divided into a primary zone into which air is delivered and in which initial combustion of the fuel takes place and a further zone into which further air is delivered comprising an elongated conduit having its inlet end open and connected to the primary combustion zone of the flame tube and its outlet end led back to said primary combustion zone, ejector means operated by the flow of air delivered into the flame tube and acting intermediate the length of said conduit to create a sufficient pressure difference between the ends of said conduit to cause in operation a flow of gas therethrough over the whole cross section thereof, and means to supply fuel for combustion to said conduit for movement by said flow to said primary zone for initial combustion.

2. Combustion equipment as claimed in claim 1 wherein said means to supply fuel comprises a fuel atomizer constructed to direct fuel jets transversely to the direction of gas flow in said conduit.

3. Combustion equipment as claimed in claim 1 wherein said conduit comprises an outlet pipe connected to receive gases from the primary combustion zone of the flame tube and a return pipe to lead said gases back to the primary zone, ejector means positioned at the outlet end of the outlet pipe and operated by said flow of air to cause a region of low pressure adjacent the outlet end of said outlet pipe, said flow of air passing into said return pipe together with gases from the outlet pipe, and means to supply fuel into said outlet pipe upstream of its outlet end to mix with the gases in the pipe.

4. Combustion equipment as claimed in claim 3 wherein said means to supply fuel comprises a fuel atomizer.

5. Combustion equipment for a gas-turbine engine hav-

ing an air casing into which air is delivered and a flame tube within said air casing and within which combustion takes place, the flame tube being divided into a primary zone into which air is delivered and in which initial combustion of the fuel takes place and a further zone into which further air is delivered, wherein the flame tube has at its inlet end an elongated tubular portion which opens at its upstream end to the flow of air being delivered into the air casing, and comprising an inner tubular member co-axially within the elongated tubular portion and having its inlet end opening to within the flame tube and having its outlet end on the side of the upstream end of the elongated portion toward said primary zone, a bell-shaped baffle positioned co-axially within the upstream end of the elongated tubular portion and having a lip adjacent the outlet end of the inner tubular member, thereby to define between its outer surface and the inner surface of the elongated tubular portion a convergent passage and to produce a low-pressure region downstream of its lip, and fuel injector means positioned within the inner tubular member upstream of its outlet end.

6. Combustion equipment as claimed in claim 5, comprising also means to introduce further air into the primary combustion zone in addition to that entering through said elongated tubular portion of the flame tube.

7. Combustion equipment as claimed in claim 5 wherein there are provided radially-extending struts immediately upstream of the flame tube, and wherein said bell-shaped baffle and said fuel injector means are supported from said struts.

8. Combustion equipment for a gas-turbine engine having a casing into which air is delivered and a flame tube within said casing, the flame tube having a primary

zone into which air is delivered and initial combustion of fuel occurs and a down stream zone into which further air is delivered, wherein the flame tube has at its inlet end an elongated, tubular portion of reduced area open at its upstream end to the air flowing in said casing, an inner tubular member within the tubular portion and having its inlet end open adjacent the primary zone of the flame tube and having its outlet end open near the upstream end of the elongated tubular portion, a turning baffle positioned to divert the gas flow from the outlet end of the inner tubular member into the inlet end of the elongated tubular portion, said baffle being spaced from the walls of the last mentioned portion to define a convergent passage for the air from the casing to produce a low pressure region adjacent the outlet end of the inner tubular member, and fuel injector means positioned within the inner tubular member upstream of its outlet end.

9. The combustion equipment as defined in claim 8 in which flame tube has a rapidly enlarging section adjacent the elongated tubular portion, and means extending through said section adapted to direct air from the casing radially inwardly toward the center of the said primary zone of the flame tube.

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