

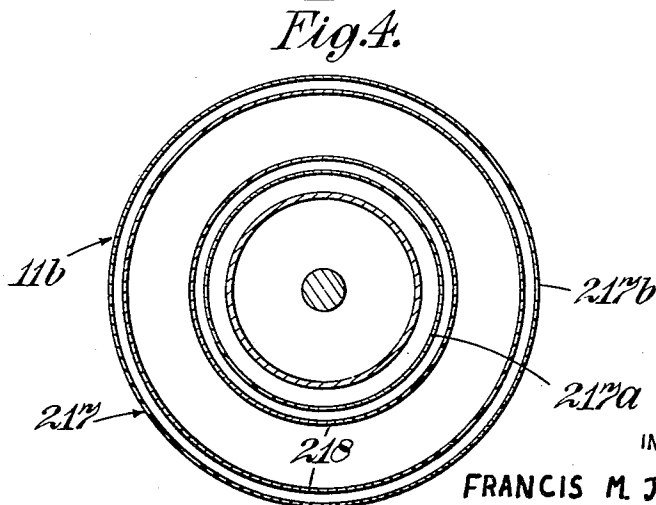
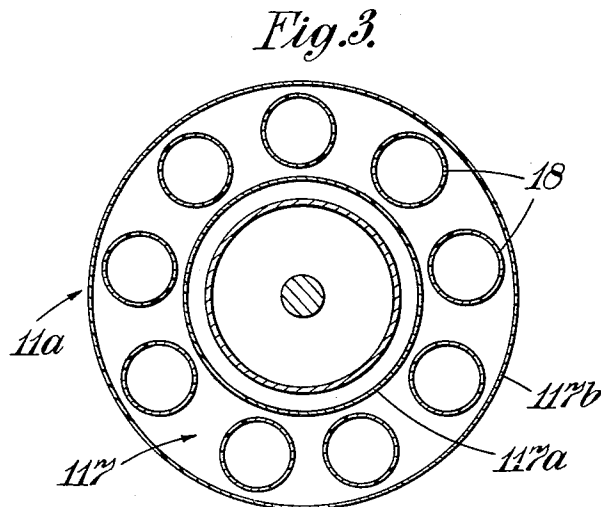
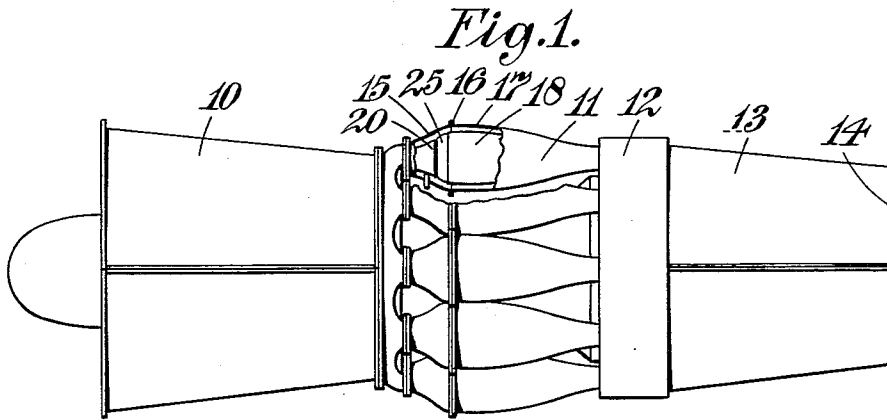
April 10, 1956

F. M. JOHNSON
COMBUSTION EQUIPMENT FOR GAS-TURBINE ENGINES
WITH ANTICARBON WALL PORTION

2,741,090

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3 Sheets-Sheet 1

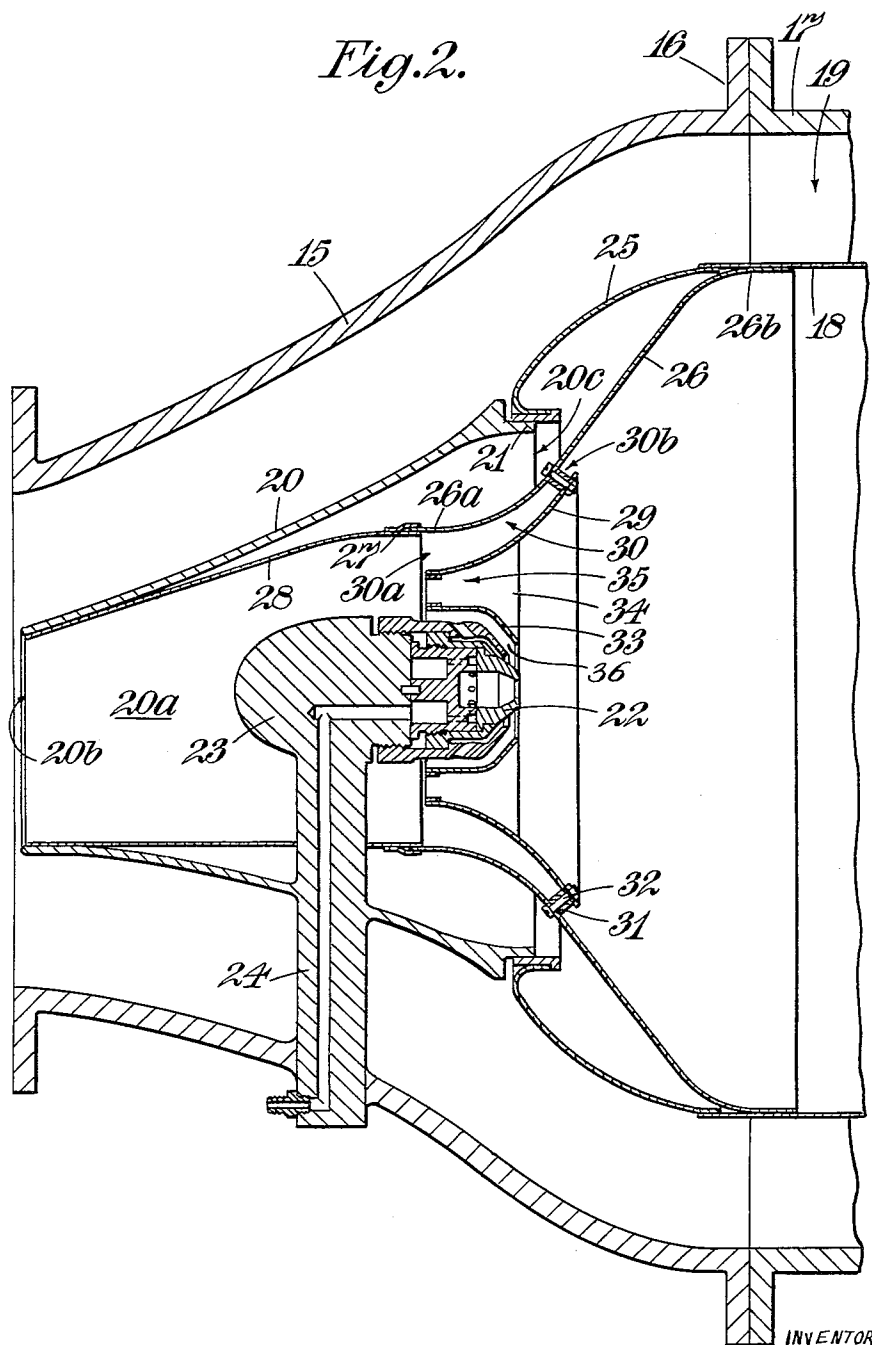


INVENTOR
FRANCIS M. JOHNSON
By *Wilkinson + MacKenzie*
ATTORNEYS

6 F. M. JOHNSON
COMBUSTION EQUIPMENT FOR GAS-TURBINE ENGINES
WITH ANTICARBON WALL PORTION

3 Sheets-Sheet 2

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BY *Wilkinson & Mauchinsky*
ATTORNEYS

6 F. M. JOHNSON
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3 Sheets-Sheet 3

WITH ANTICARBON WALL PORTION

By Wilkinson & Mawhinney
ATTYS

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2,741,090

COMBUSTION EQUIPMENT FOR GAS-TURBINE ENGINES WITH ANTICARBON WALL PORTION

Francis Murray Johnson, Streatham, London, England, assignor to Rolls-Royce Limited, Derby, England, a British company

Application April 10, 1950, Serial No. 154,965

Claims priority, application Great Britain June 30, 1949

8 Claims. (Cl. 60—39.65)

This invention relates to combustion equipment for gas-turbine engines. It is concerned with combustion equipment of the kind comprising a flame tube accommodated within an air casing, so as to provide a passage between the outer wall of the flame tube and the air casing through which air passes before being introduced into the flame tube through suitable apertures or entry ducts, and wherein primary air is introduced at the inlet end of the flame tube. In combustion equipment of this kind there are at least two distinct supplies of air into the interior of the flame tube, referred to as "primary air," with which combustion of the fuel is initiated, and "mixing air," which is introduced mainly to dilute the combustion gases and to cool them. The mixing air may also assist the completion of combustion.

It has hitherto been the practice in combustion equipment of the kind specified, to provide fuel injection means at the inlet end of the flame tube to introduce a spray of atomized liquid fuel into the flame tube and to introduce primary air into the flame tube through a perforated baffle, or swirling device which surrounds the fuel injection means. Certain such arrangements have included a wall portion of the flame tube at its inlet end which is divergent in the direction of the flow of air therethrough.

It has been found in practice that with such known arrangements there is a tendency for the formation of a carbon deposit on the perforated baffle or swirl device through which the primary air is introduced and/or on the divergent wall portion, which deposit adversely affects the metering of the primary air into the combustion chamber. As a result, deterioration of combustion efficiency has occurred, adversely affecting the operation of the engine.

The primary object of the present invention is to reduce or obviate the tendency for carbon to be deposited on the flame tube parts in the region of introduction of primary air, whereby such undesirable deterioration of combustion efficiency is avoided.

According to the present invention, in combustion equipment of the kind specified for gas-turbine engines, the flame tube has, at its inlet end, a wall portion which is divergent in the direction of the flow of air through the flame tube, which wall portion constitutes part of the boundary surface of the space within the flame tube, and has supported adjacent to the wall portion an annular part of divergent substantially frusto-conical form located so as to constitute with the wall portion an annular channel through which a major part of the flow of primary air is introduced into the flame tube, the primary air emerging from the channel along the inner surface of the wall portion.

Adoption of the invention provides that the main flow of primary air into the flame tube takes place along the surface of the divergent wall portion, to sweep this surface and, in some cases, also that of the main wall portion of the flame tube to which the divergent wall portion is attached; the tendency for carbon formation on these surfaces is thereby reduced.

Preferably the cross-sectional area of the channel in the

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direction of air flow therethrough is convergent to produce an acceleration of flow and thus to increase the scouring action of the primary air flow along the surface of the divergent wall portion.

The invention is applicable to one type of combustion equipment of the kind specified in which there are a plurality of flame tubes of tubular form accommodated each within a separate tubular air casing, so that the gap between the wall of the flame tube and the air casing is of annular section.

The invention is also applicable to another type of combustion equipment of the kind specified in which the flame tubes are of tubular form and are accommodated within an air casing of annular construction, so that a plurality of flame tubes are accommodated in a single annular air casing.

A third type of combustion equipment of the kind specified to which the invention is applicable is that in which the flame tube is itself of annular form, accommodated within an annular air casing.

In applying the present invention to combustion equipment of the first and second types mentioned, one preferred construction provides a divergent wall portion and annular part which are both of divergent tubular form, the divergent wall portion being connected to the inlet end of the main wall portion of the flame tube, and the annular part being supported internally of the divergent wall portion to provide an annular channel for the passage of primary air into the flame tube. In such an arrangement fuel injection means may be provided concentrically within the annular part to introduce atomized or vaporized fuel into the flame tube at its inlet end.

In applying the invention to the third type of combustion equipment mentioned one preferred construction provides a first divergent wall portion which is attached to the inlet end of the main portion of an outer defining wall of the annular flame tube, while a second wall portion is attached to the inlet end of the main portion of the inner defining wall of the annular flame tube, the two wall portions together defining a space between the inner and outer walls of the flame tube which is divergent in the direction of the flow of air through the flame tube; likewise an annular part is associated with each of the wall portions mentioned, so that inner and outer annular channels are constituted for the passage of primary air into the interior of the flame tube. With such an arrangement a series of fuel injection means are conveniently located circumferentially in the annulus between the two annular parts to introduce fuel in atomized or vaporized form to the combustion chamber.

According to a feature of this invention a subsidiary flow of primary air may be introduced into the flame tube in the region of the transverse plane through the flame tube approximately containing the downstream end of the annular ring part or parts. Thus in the case of the first and second types of combustion equipment mentioned such subsidiary flow may be introduced through an annular area between the fuel injection means and the downstream end of the annular part, while in the case of the third type of combustion equipment mentioned the subsidiary flow may be introduced through an annular area between the two annular parts. Preferably such subsidiary air is supplied to the interior of the flame tube with a degree of swirl given it by swirl vanes which, due to the tangential velocity component of the subsidiary flow of primary air, are efficiently scoured to reduce the tendency for carbon to deposit thereon.

A further feature of the invention provides for a further subsidiary flow of primary air between the fuel injection means and the flame tube at its inlet end.

In arrangements of combustion equipment according

to the present invention the supply of primary air to the inlet end of the frame tube is preferably effected from the engine compressor through a divergent entry duct, which may be formed integrally with the flame tube or which may be assembled in conjunction therewith. Thus the divergent entry duct may extend into the delivery duct from the air compressor of the engine to divide the flow of air in the delivery duct so that some of it passes into the divergent duct while the remainder passes externally thereof and thence into the space between the flame tube and air casing, whence it passes into the interior of the flame tube as mixing air. The divergent entry duct may include an internal duct-defining liner connecting at its downstream end with the inlet end of the divergent wall portion of the flame tube.

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

Fig. 1 illustrates diagrammatically a gas turbine engine,

Fig. 2 is a view of part of a combustion chamber of the engine in longitudinal cross-section, on an enlarged scale,

Fig. 3 shows a modified form of gas turbine engine to which the invention is applicable,

Fig. 4 shows a further modified form of gas turbine engine in accordance with the invention, and

Figure 5 is a perspective view from within the combustion space looking on the fuel injection device.

The gas turbine engine of Fig. 1 comprises a compressor 10, delivering compressed air to combustion equipment 11, from which the products of combustion pass through a turbine 12 which drives the compressor 10, and thence through a jet pipe 13 having a propelling nozzle 14, to atmosphere. The engine is suitable for aircraft jet propulsion.

The combustion equipment 11 comprises a plurality of substantially tubular flame tubes within substantially tubular air casings. One such air casing and flame tube is shown in section in Fig. 2, the arrangement comprising an entry expansion chamber portion 15 which is connected with the delivery of the engine compressor 10 and is of divergent substantially circular cross-section. The expansion chamber 15 is connected by a bolted flange joint 16 with a tubular main air casing part 17 which in turn is connected at its outlet end with a nozzle entry assembly of the turbine 12. Internally of the air casing 17 there is accommodated a generally tubular flame tube 18. The flame tube 18 is spaced from the wall of the air casing 17 to form an annular duct 19 which extends into the expansion chamber 15 and provides a passage for the flow of mixing air into the flame tube.

Within the expansion chamber 15 is mounted a duct part 20, defining a divergent entry duct 20a, the smaller end 20b of which duct is directed towards the inlet end of the expansion chamber 15, and this entry duct part 20 divides the air entering the air casing 17 from the compressor system into a mixing air flow which passes into the annular duct 19 between the flame tube 18 and air casing 17 and into a primary air flow which passes through the divergent entry duct 20a into the interior of the flame tube 18 at its entry end. The divergent entry duct part 20 is also formed at its downstream end 20c with a spigot flange 21 which serves to support the flame tube 18, so that the entry duct 20 is in effect an extension of the flame tube 18 into the expansion chamber 15.

Fuel injection means 22 is supported on the axis of the flame tube in the plane of the exit end of the divergent entry duct part 20, being conveniently carried on a boss 23 by a number of legs 24 (one only of which is shown in the drawing) cast integrally with the entry duct part 20. The fuel injection means 22 may be of any known or convenient kind, and is preferably of the kind injecting liquid fuel as an atomized spray through an atomizing orifice. The fuel injection means 22 in this embodiment

is of generally cylindrical form, the axis of which lies on the axis of the flame tube. The fuel injection means may be as described in U. S. Patent No. 2,700,416 which issued on January 25, 1955, where provision is made to prevent or reduce the tendency to carbon formation on the orifice part or parts of the fuel injector.

The inlet end of the flame tube is of double skin formation, the outer skin 25 of which provides the socket for the spigot 21 on the divergent entry duct part 20, and the inner skin 26 of which is spaced inwardly of the divergent entry duct part 20, to constitute a divergent annular wall portion of the flame tube. This portion spigots at its inlet end 26a in an annular socket 27 on a sheet-metal liner 28 within the divergent entry duct 20a. At its outer end 26b the divergent wall portion 26 connects with a substantially cylindrical main portion of the flame tube 18. Within the divergent wall portion 26 an annular ring 29 of divergent, substantially frusto-conical form is provided, which ring is of less axial length and less maximum diameter than the divergent wall portion 26 of the flame tube. The ring 29 is located so as to provide, with the divergent wall portion 26, an annular channel 30 which converges from its inlet end 30a, which end lies substantially in the plane of the exit end 26c of the divergent entry duct 20a to receive air therefrom, to its outlet end 30b which lies adjacent the divergent face of the inner wall 26. The ring 29 is spaced from the inner skin 26 by means of tubular spacer members 31, and is supported by bolts 32 which conveniently pass through the spacer members 31.

In this manner the main flow of primary air entering the divergent entry duct 20a passes into this annular channel 30 and enters the flame tube 18, substantially without swirl, in a direction parallel to the surface of the divergent wall portion 26 so as to scour this surface.

A sleeve 33 surrounding the fuel injector 22 is supported within the ring 29 by a number of swirl vanes 34. The latter (see Figure 5) are so shaped and disposed relative to one another as to provide passages 35 for a subsidiary flow of primary air which at entry are substantially axial i. e. the entry areas face upstream into the divergent entry duct, while at exit the passages 35 direct the air flow with a considerable tangential component of velocity into the flame tube 18. Further the passages 35 between the vanes 34 are convergent so that relatively high exit velocity is obtained preventing or reducing the tendency for carbon to be deposited on the exit surfaces of the vanes 34. A further annular gap 36 is formed between the sleeve 33 and the fuel injection means 22 through which a subsidiary flow of primary air passes from the divergent entry duct 20a into the interior of the flame tube, thus to cool the fuel injection means 22.

The design is such that the main flow of primary air takes place through the annular channel 30 defined between the divergent wall portion 26 of the flame tube and the ring 29 associated therewith, while comparatively minor subsidiary flows of primary air take place through the swirl vane passages 35 and through the annular passage 36 surrounding the fuel injector 22. These flows of primary air will reduce or obviate the tendency for carbon to be deposited on the flame tube parts in the region of introduction of primary air.

A modified form of gas turbine engine to which the invention is applicable is shown in transverse cross section in Fig. 3. In this arrangement the combustion equipment 11a comprises a plurality of flame tubes 18 accommodated in a single annular air casing 117, which is co-axial with the compressor 10 and the turbine 12 of the engine. It will be appreciated that the construction according to the invention may be readily applied to such an arrangement. Each flame tube 18 will be identical with those of the embodiment already described, as will be the divergent entry duct part 20 correspond-

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ing with each flame tube. The annular air casing 117 comprising an inner member 117a and an outer member 117b is bolted to an annular expansion chamber of divergent cross sectional area in the direction of the flow of air.

A further modified form of gas turbine engine to which the invention is applicable is shown in transverse cross section in Fig. 4. In this arrangement, combustion equipment 11b comprises a single annular flame tube 218 accommodated in a single bar casing 217, both of which are co-axial with the compressor 10 and the turbine 12 of the engine. The construction according to the invention may also be readily applied to this arrangement, as will be appreciated. Each flame tube 218, while being identical with that of the first embodiment above described in longitudinal cross section, will extend circumferentially to form a continuous annular duct. The inner member 217a and the outer member 217b of the annular air casing 217 will be bolted to an annular expansion chamber of divergent cross-sectional area in the direction of the flow of air. The divergent entry duct part 20 will support the inlet end of the annular flame tube 218.

I claim:

1. Combustion equipment for a gas-turbine engine comprising an air casing and a flame tube accommodated in said air casing and defining a combustion space within said flame tube, said flame tube having an imperforate inlet wall portion curved away from said combustion space and bounding a duct through which air flows into said flame tube, a first part of said inlet wall portion being convex toward said combustion space, and a second part of said inlet wall portion immediately downstream of said first part being frusto-conical and bounding the combustion space and being divergent with respect to said flow of air whereby carbon formation is liable to occur on said second part, and a further wall portion which is adjacent said inlet wall portion, is curved away from said combustion space and is located on the side of said inlet wall portion adjacent said combustion space, said further wall portion being at least in part convex toward said combustion space, said further wall portion and said inlet wall portion affording between the inlet wall portion and the whole length of the further wall portion an annular channel curved away from said combustion space, and said second part of the inlet wall portion being substantially wholly beyond the downstream end of said further wall portion, whereby air entering the combustion space through said channel passes along the surface of said second part of the inlet wall portion, whereby carbon formation on said second part is substantially reduced.

2. Combustion equipment for a gas-turbine engine comprising an air casing and a flame tube accommodated in said air casing and defining a combustion space within said flame tube, said flame tube having an imperforate inlet wall portion curved away from said combustion space and bounding a duct through which air flows into said flame tube, a first part of said inlet wall portion being convex toward said combustion space, and a second part of said inlet wall portion immediately downstream of said first part being frusto-conical and bounding the combustion space and being divergent with respect to said flow of air whereby carbon formation is liable to occur on said second part, and a further wall portion which is adjacent said inlet wall portion is curved away from said combustion space and is located on the side of said inlet wall portion adjacent said combustion space, said further wall portion being at least in part convex toward said combustion space, and said further wall portion lying nearer to said inlet wall portion at its downstream end than at its upstream end thereby to define between the inlet wall portion and the whole length of the further wall portion an annular channel which is curved away from said com-

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bustion space and which converges from its inlet end to its outlet end, and said second part of the inlet wall portion being substantially wholly beyond the downstream end of said further wall portion, whereby air entering the combustion space through said channel passes along the surface of said second part of the inlet wall portion, whereby carbon formation on said second part is substantially reduced.

3. Combustion equipment for a gas-turbine engine comprising a tubular air casing and a tubular flame tube accommodated in said air casing and defining a combustion space within the flame tube, said flame tube having an imperforate inlet wall portion curved away from said combustion space towards the air casing and formed substantially as a body of revolution bounding a duct through which air flows into said flame tube, a first part of said inlet wall portion being convex toward said combustion space, and a second part of said inlet wall portion immediately downstream of said first part being frusto-conical and bounding the combustion space and being divergent with respect to said flow of air whereby carbon formation is liable to occur on said second part, and a further wall portion which is adjacent said inlet wall portion, is curved away from said combustion space, and is located on the side of said inlet wall portion adjacent said combustion space, said further wall portion being at least in part convex toward said combustion space, said further wall portion and said inlet wall portion affording between the inlet wall portion and the whole length of the further wall portion an annular channel curved away from said combustion space and said second part of the inlet wall portion being substantially wholly beyond the downstream end of said further wall portion whereby air entering the combustion space through said channel passes along the surface of said second part of the inlet wall portion, whereby carbon formation on said second part is substantially reduced.

4. Combustion equipment for a gas-turbine engine comprising a tubular air casing and a tubular flame tube accommodated in said air casing and defining a combustion space within said flame tube, said flame tube having an imperforate inlet wall portion curved away from said combustion space toward the air casing and formed substantially as a body of revolution bounding a duct through which air flows into said flame tube, a first part of said wall portion being convex toward said combustion space, and a second part of said wall portion immediately downstream of said first part being frusto-conical and bounding the combustion space and being divergent with respect to said flow of air whereby carbon formation is liable to occur on said second part, and a further wall portion which is adjacent said inlet wall portion, is curved away from said combustion space and is located on the side of said inlet wall portion adjacent said combustion space, said further wall portion being at least in part convex toward said combustion space, and said further wall portion lying nearer to said inlet wall portion at its downstream end than at its upstream end thereby to define between the inlet wall portion and the whole length of the further wall portion an annular channel which is curved away from said combustion space and which converges from its inlet end to its outlet end, and said second part of the inlet wall portion being substantially wholly beyond the downstream end of said further wall portion, whereby air entering the combustion space through said channel passes along the surface of said second part of the inlet wall portion, whereby carbon formation on said second part is substantially reduced.

5. Combustion equipment for a gas-turbine engine comprising an annular air casing having an inner annular wall and an outer annular wall, and a plurality of tubular flame tubes accommodated in said air casing and defining a combustion space within each of said flame tubes, each of said flame tubes having an imperforate inlet wall portion curved away from said combustion space and formed

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substantially as a body of revolution bounding a duct through which air flows into said flame tube, a first part of said inlet wall portion being convex toward said combustion space, and a second part of said inlet wall portion immediately downstream of said first part being frusto-conical and bounding the combustion space and being divergent with respect to said flow of air whereby carbon formation is liable to occur on said second part, and a further wall portion which is adjacent said inlet wall portion is curved away from said combustion space and is located on the side of said inlet wall portion adjacent said combustion space, said further wall portion being at least in part convex toward said combustion space, said further wall portion and said inlet wall portion affording between the inlet wall portion and the whole length of the further wall portion an annular channel curved away from said combustion space, and said second part of the inlet wall portion being substantially wholly beyond the downstream end of said further wall portion, whereby air entering the combustion space through said channel passes along the surface of said second downstream part of the inlet wall portion, whereby carbon formation on said second part is substantially reduced.

6. Combustion equipment for a gas-turbine engine comprising an annular air casing having an inner annular wall and an outer annular wall, and a plurality of tubular flame tubes accommodated in said air casing and defining a combustion space within each of said flame tubes, each of said flame tubes having an imperforate inlet wall portion curved away from said combustion space and formed substantially as a body of revolution bounding a duct through which air flows into said flame tube, a first part of said inlet wall portion being convex toward said combustion space, and a second part of said inlet wall portion immediately downstream of said first part being frusto-conical and bounding the combustion space and being divergent with respect to said flow of air whereby carbon formation is liable to occur on said second part, and a further wall portion which is adjacent said inlet wall portion, is curved away from said combustion space and is located on the side of said inlet wall portion adjacent said combustion space, said further wall portion being at least in part convex toward said combustion space, and said further wall portion lying nearer to said inlet wall portion at its downstream end than at its upstream end thereby to define between the inlet wall portion and the whole length of the further wall portion an annular channel which is curved away from said combustion space and which converges from its inlet end to its outlet end, and said second part of the inlet wall portion being substantially wholly beyond the downstream end of said further wall portion, whereby air entering the combustion space through said channel passes along the surface of said second part of the inlet wall portion, whereby carbon formation on said second part is substantially reduced.

7. Combustion equipment for a gas-turbine engine comprising an annular air casing having an inner annular wall and an outer annular wall, and an annular flame tube accommodated in said air casing and having an inner annular flame tube wall and an outer annular flame tube wall spaced from the respective air casing walls and defining a combustion space between the flame tube walls, said flame tube having an imperforate inner inlet wall portion and an imperforate outer inlet wall portion, each of said inlet wall portions being curved away from said combustion space towards the adjacent annular wall of the air casing and being formed substantially as a body of revolution, said inlet wall portions together bounding an air inlet duct through which air flows towards said combustion space, a first part of said inner inlet wall portion being convex toward said combustion space, and a second part of said inner inlet wall portion immediately downstream of said first part being frusto-conical and bounding

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the combustion space and extending inwardly from the first part towards the inner air casing wall whereby carbon formation is liable to occur on said second part, and a further inner wall portion which is adjacent said inner inlet wall portion, is curved away from said combustion space and is located on the side of said inner inlet wall portion adjacent said combustion space, said further inner wall portion being at least in part convex toward said combustion space, said further inner wall portion and said inner inlet wall portion affording between the inner inlet wall portion and the whole length of the further inner wall portion a first annular channel curved away from said combustion space, and said second part of the inner inlet wall portion being substantially wholly beyond the downstream end of said further inner wall portion, whereby air entering the combustion space through said first annular channel passes along the surface of said second part of the inner inlet wall portion and carbon formation on said second part is substantially reduced, said imperforate outer inlet wall portion having a first part which is convex towards the combustion space and a second part which is immediately downstream of said first part of the outer inlet wall portion and is frusto-conical and extends outwardly from the first part towards the outer air casing wall whereby carbon formation is liable to occur thereon, a further outer wall portion which is adjacent said outer inlet wall portion, is curved away from said combustion space and is located on the side of said outer inlet wall portion adjacent said combustion space, said further outer wall portion being at least in part convex toward said combustion space, said further outer wall portion and said outer inlet wall portion affording between the outer inlet wall portion and the whole length of the further outer wall portion a second annular channel curved away from said combustion space, and said second part of the outer inlet wall portion being substantially wholly beyond the downstream end of said further outer wall portion, whereby air entering the combustion space through said second annular channel passes along the surface of said second part of the outer inlet wall portion and carbon formation on said second part is substantially reduced.

8. Combustion equipment for a gas-turbine engine comprising an annular air casing having an inner annular wall and an outer annular wall, and an annular flame tube accommodated in said air casing and having an inner annular flame tube wall and an outer annular flame tube wall spaced from the respective air casing walls and defining a combustion space between the flame tube walls, said flame tube having an imperforate inner inlet wall portion and an imperforate outer inlet wall portion, each of said inlet wall portions being curved away from said combustion space towards the adjacent annular wall of the air casing and being formed substantially as a body of revolution, said inlet wall portions together bounding an air inlet duct through which air flows toward said combustion space, a first part of said inner inlet wall portion being convex toward said combustion space, and a second part of said inner inlet wall portion immediately downstream of said first part being frusto-conical and bounding the combustion space and extending inwardly from the first part towards the inner air casing wall whereby carbon formation is liable to occur on said second part, and a further inner wall portion which is adjacent said inner inlet wall portion, is curved away from said combustion space and is located on the side of said inner inlet wall portion adjacent said combustion space, said further inner wall portion being at least in part convex toward said combustion space, said further inner wall portion lying nearer to said inner inlet wall portion at its downstream end than at its upstream end thereby to define between the inner inlet wall portion and the whole length of the further inner wall portion a first annular channel curved away from said combustion space, and said second part of the inner inlet wall portion being sub-

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stantially wholly beyond the downstream end of said further inner wall portion, whereby air entering the combustion space through said first annular channel passes along the surface of said second part of the inner inlet wall portion and carbon formation on said second part is substantially reduced, said imperforate outer inlet wall portion having a first part which is convex towards the combustion space and a second part which is immediately downstream of said first part of the outer inlet wall portion and is frusto-conical and extends outwardly from the first part towards the outer air casing wall whereby carbon formation is liable to occur thereon, a further outer wall portion which is adjacent said outer inlet wall portion, is curved away from said combustion space and is located on the side of said outer inlet wall portion adjacent said combustion space, said further outer wall portion being at least in part convex toward said combustion space, said further outer wall portion lying nearer to said outer inlet wall portion at its downstream end than at its upstream end thereby to define between the outer inlet wall portion and the whole length of the further outer wall portion a second annular channel curved away from said combustion space, and said second part of the outer

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inlet wall portion being substantially wholly beyond the downstream end of said further outer wall portion, whereby air entering the combustion space through said second annular channel passes along the surface of said second part of the outer inlet wall portion and carbon formation on said second part is substantially reduced.

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