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COMBUSTION CHAMBER WITH SWIRLER

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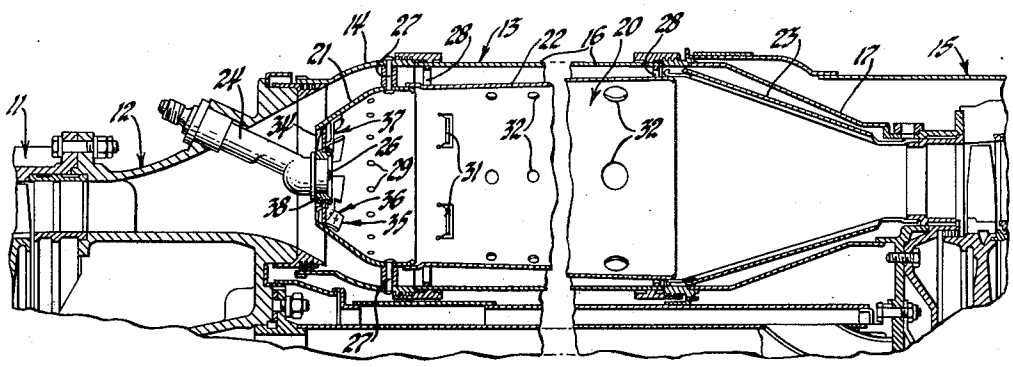

Fig. 1

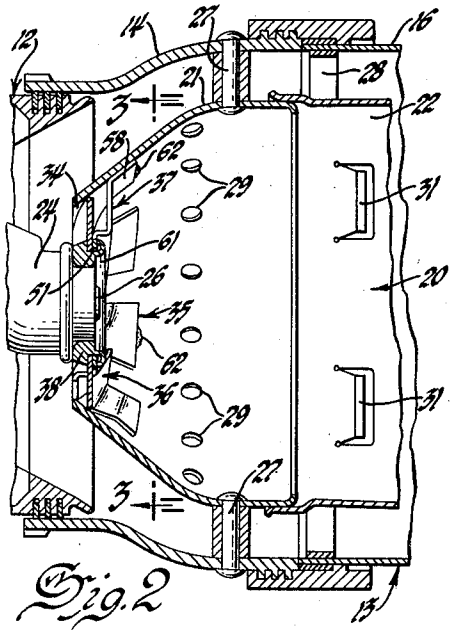

Fig. 2

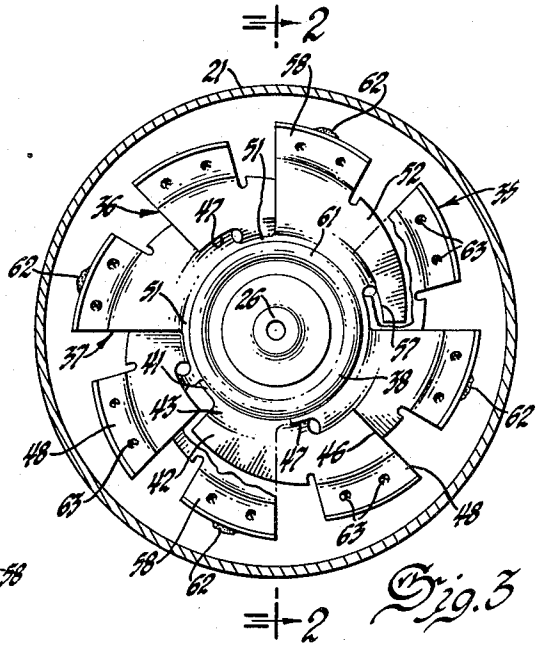

Fig. 3

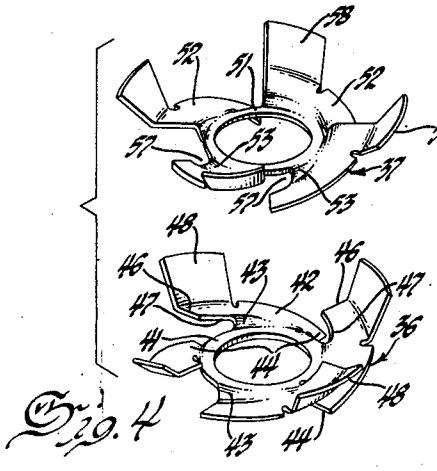

Fig. 4

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COMBUSTION CHAMBER WITH SWIRLER

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11 Claims. (Cl. 60—39.65)

This application is a continuation-in-part of my (abandoned) application entitled "Combustion Chamber with Swirler," Serial No. 174,043, filed July 15, 1950.

My invention relates to combustion chambers, particularly such as are used in gas turbine engines. The type of combustion chamber to which the invention is directed is, in general, an elongated generally cylindrical body formed with numerous apertures through which air is admitted and an outlet through which the products of combustion are discharged into a turbine. This combustion chamber or flame tube is installed within a passage to which air is supplied by a compressor. The passage may either be generally cylindrical in form and contain one flame tube, or it may be annular and contain a number of flame tubes. Fuel sprayed into the flame tube is burned and mixed with an excess of air passing through the apertures in the flame tube.

Such combustion apparatus has presented many difficult problems because of the high temperatures involved, the necessity for light weight and compactness, and the importance of minimizing resistance to air flow from the compressor to the turbine. The conditions of combustion are generally rather critical, particularly in view of the high rate of air flow as compared with the velocity of flame propagation. In general, it has been found necessary for satisfactory results to spray the fuel into the forward end of the flame tube, to introduce a relatively small part of the air at the forward end of the tube to initiate combustion, and to admit the remaining air progresively through numerous apertures disposed along the wall of the flame tube.

My invention is particularly directed to improvements in the forward end of the combustion chamber relating to the admission of the initial or primary combustion air. It has been found that the characteristics of the combustion apparatus are improved by imparting a substantial component of circumferential velocity of swirl to the primary air. Various structural arrangements for admitting the primary air and imparting swirl to it have been proposed. This invention provides an improved structure which has been found to increase the reliability of combustion, provide more thorough mixing of the air and fuel, and give a more satisfactory temperature pattern than structures previously known.

A further important feature and advantage of the invention lies in the fact that flame tubes in accordance with the principles of the invention are remarkably free from deposition of carbon from the fuel in the forward portion of the flame tube. This feature is particularly important in view of the trend toward the use of less volatile fuels, or fuels containing relatively heavy petroleum fractions, in gas turbine engines.

The adaptation of gas turbine engines to heavier fuels has been thought to require the adoption of combustion apparatus which creates a considerably increased pressure drop in the air flowing through the chamber in comparison to combustion apparatus suitable for volatile fuels, such as gasoline and kerosene. The greater pressure drop results in a decrease in engine efficiency.

By virtue of this invention, heavier fuels may be burned satisfactorily in a combustion chamber of high air-flow efficiency, and the same combustion apparatus may be used for both light and heavy fuels.

Although theoretical analysis of combustion apparatus has not progressed very far, and it may be impossible to state with certainty the reasons for good or bad performance of combustion chambers for gas turbine engines, I believe that the major reason for the superior performance of combustion chambers incorporating my invention is as follows:

The entrance portion or forward end cap of the combustion chamber flame tube is generally in the form of a dome, and the entrance for primary combustion air is located centrally of the dome with a swirler structure mounted in the diverging wall of the dome adapted to impart circumferential velocity to the entering air and cause it to scour the surface of the dome.

The invention, as illustrated herein, is incorporated in a combustion chamber structure which, apart from the entry section of the flame tube, is fully disclosed in U. S. Patent 2,699,040, Gaubatz, issued January 11, 1955.

The principal objects of the invention are to improve the characteristics of gas turbine combustion chambers and to provide an inlet portion for such combustion chambers incorporating improved structure for the admission of primary combustion air.

The preferred manner in which the objects and advantages of the invention are realized will be apparent to those skilled in the art from the appended description and the accompanying drawings, in which Figure 1 is a longitudinal sectional view of a combustion chamber for a gas turbine engine, including portions of adjacent structure of the engine; Figure 2 is a longitudinal section of the forward portion of the flame tube on a larger scale, taken on the plane indicated by the section line 2—2 in Figure 3; Figure 3 is a cross-sectional view taken on the plane indicated by the section line 3—3 in Figure 2; and Figure 4 is an exploded axonometric view of the air-directing member or swirler.

The gas turbine engine, illustrated fragmentarily in Figure 1, includes an axial-flow compressor **11**, an annular diffuser **12**, an air duct or outer combustion chamber **13** which is one of a number of such chambers supplied by the compressor, and a turbine **15** driven by the combustion gases from the combustion chambers. Since the general nature of such engines is fully understood by those skilled in the art, further description will be omitted in the interest of conciseness. The duct **13** comprises a diverging entrance section **14** slidably mounted on a circular discharge passage of the diffuser, a cylindrical intermediate section **16**, and an outlet section **17**, the after end of which is mounted on the turbine, and in which the cross section of the duct is modified from circular to a sector of an annulus.

The inner chamber or flame tube, indicated generally as **20**, likewise comprises three sections conforming generally in shape to the air duct in which they are located: a diverging entrance section **21**, also referred to as a dome or cap; a generally cylindrical section **22**; and a discharge section **23**. The sections of both inner and outer tubes are constructed to accommodate thermal expansion and to facilitate disassembly and assembly for inspection and replacement of parts. Fuel is injected by a nozzle assembly **24** mounted in the diffuser **12** and terminating in a spray nozzle **26** at the forward end of the flame tube. The cap **21** is supported in the duct section **14** by struts **27** and the intermediate portion **22** is centered by fingers **28**. Air is admitted to the combustion chamber through a ring

of holes 29 in the dome and through apertures 31 and 32 in the intermediate portion of the flame tube.

The above general description of the combustion chamber structure is sufficient for an understanding of this invention by those skilled in the art. A more complete description of the structure may be found in the above-mentioned patent of Arthur W. Gaubatz.

The forward portion of the dome 21 is in the form of a frustum of a cone with a forward opening 34. The swirler assembly 35 is mounted in the opening 34 so as partially to close the opening and to direct the air admitted from the swirler circumferentially of the flame tube. The swirler comprises two formed sheet metal plates 36 and 37 and a bushing 38. The swirler portion 36 is a unitary sheet metal stamping comprising an inner ring 41 and four skewed or helical plates or vanes 42, each of which extends nearly 90 degrees around the axis of the swirler and is joined to the ring by a foot portion 43 of distorted form, as will be apparent from the drawings. The face of the member 36 which is uppermost in Figure 4 is directed rearwardly when it is in place. The leading edge of the vane is indicated at 44 and the trailing edge at 46. A notch 47 is formed between the trailing portion of the vane and the ring 41. A mounting lug 48 extends outwardly from the trailing portion of each vane and is bent rearwardly from the plane of the vane and formed to a conical surface so as to lie against the conical portion of the dome 21.

The swirler portion 37 is very similar in structure to the portion 36, comprising a ring 51, vanes 52, and mounting lugs 58. The feet 53 are located adjacent the trailing edge of the vane, leaving notches 57 adjacent the leading edge. The two parts of the swirler are assembled by rotation relatively to each other so that the notches 47 and 57 are interengaged and the lugs 48 and 58 alternate at an angular spacing of 45 degrees. As will be seen, the air-guiding vanes 42 and 52 overlap approximately 35 to 40 degrees. When the parts 36 and 37 are thus assembled, the bushing 38 is inserted, the flange of the bushing bearing against the ring portion 41 of the member 36. The thin wall portion 61 of the bushing extending through the rings is spun outwardly to provide a flange bearing against the ring 51 of the member 37, thus holding these parts assembled. The swirler assembly 35 is then fixed in the dome 21 by tack-welding the tabs 58 of the member 37 as indicated at 62, and then spot-welding all eight tabs to the dome as indicated at 63. The outer edges of the guide vanes 42 and 52 taper inwardly toward the leading edges so that they fit closely within the conical cap 21 around the entire peripheral portion.

The air from the compressor flows axially through the combustion chamber. Approximately twelve per cent of the air required for complete combustion of the fuel (primary air) enters through the opening 34 in the dome. The remainder of the combustion air (secondary air) and a large amount of air supplied to dilute and cool the combustion products enter through the openings 29, 31, and 32.

The primary air enters axially of the opening 34 with considerable velocity. This axial velocity is largely converted to circumferential velocity or swirl in the swirler 35. Because of centrifugal force, the primary air presses against the inner surface of the end cap 21 and the forward part of the flame tube 22, scouring the surface and preventing coking of fuel on these surfaces.

This structure thus has important advantages over those in which the swirler is mounted in a cylindrical sleeve ahead of the diverging part of the flame tube so that the air must turn sharply outward to scour the combustion chamber, which it will not do. In my apparatus, the air develops a radial velocity in the swirler, the outer boundary of which is continuous with the wall of the dome downstream of the swirler.

The size of the swirler entrance 34 and the pitch angle of the blades 42 and 52 may be varied in design to vary the amount of primary air entering the flame tube or the amount of swirl, or both. Air thus entering will, of course, enter substantially in a circumferential direction with a relatively slight component of motion axially of the combustion chamber.

Previously known swirler arrangements have failed to direct the air so as to scour the combustion chamber or have failed to impart sufficient swirl and reduce axial movement of the air to a satisfactory degree, and have, in most cases, been unduly complicated or structurally unsound. It will be apparent that the structure of the invention is highly satisfactory in all such respects. It may also be pointed out that the structure is of considerable strength and provides adequate support for the discharge end of the nozzle structure 24 which fits within the bushing 38.

Many modifications of the invention within the scope thereof will occur to those skilled in the art. The invention is not to be regarded as limited by the detailed description of the preferred embodiment thereof.

I claim:

1. A combustion apparatus comprising, in combination, an air duct, a flame tube within the duct comprising an entrance portion open at the upstream end relative to air flow through the tube and a second portion downstream thereof continuing to an outlet for combustion products, means for introducing fuel into the flame tube, and a fixed swirler structure mounted in the said entrance portion adapted to limit the quantity of air entering and direct the air in a circumferential direction, the swirler comprising two plates, each plate being formed with a plurality of skewed fan-like blades and the plates being interengaged with the blades of the plates overlapping to define helical passages between the blades for admission of primary combustion air.

2. A combustion apparatus comprising, in combination, an air duct, a flame tube within the duct comprising a diverging entrance portion open at the upstream end relative to air flow through the tube and a second portion downstream thereof continuing to an outlet for combustion products, means for introducing fuel into the flame tube including a nozzle, and a fixed swirler structure mounted in the said upstream end adapted to limit the quantity of air entering and direct the air in a circumferential direction, the swirler comprising two plates, each plate being formed with a plurality of skewed fan-like blades adapted to abut the entrance portion at their peripheral edges, the leading edge of the blades of one plate and the trailing edge of the blades of the other plate being notched and the plates being interengaged with the blades of the plates overlapping.

3. A combustion apparatus comprising, in combination, an air duct, a flame tube within the duct comprising a diverging entrance portion open at the upstream end relative to air flow through the tube and a second portion downstream thereof continuing to an outlet for combustion products, and a swirler structure mounted in the said upstream end adapted to limit the quantity of air entering and direct the air in a circumferential direction, the swirler comprising two plates, each plate being formed with a plurality of skewed fan-like blades adapted to abut the entrance portion at their peripheral edges and one plate being formed with mounting tabs extending from the blades formed to lie against the surface of the entrance portion, the plates being interengaged with the blades of the plates overlapping, the said tabs being fixed to the entrance portion, and means clamping the central portions of the plates together.

4. A combustion apparatus comprising, in combination, an air duct, a flame tube within the duct open at the upstream end relative to air flow through the tube and continuing to an outlet for combustion products,

means for introducing fuel adjacent the upstream end of the flame tube including a nozzle, and a swirler structure mounted in the said upstream end adapted to limit the quantity of air entering and direct the air in a circumferential direction, the swirler comprising two plates, each plate being formed with a plurality of skewed fan-like blades adapted to abut the flame tube at their peripheral edges and mounting tabs extending from the blades formed to lie against the surface of the flame tube, the leading edge of the blades of one plate and the trailing edge of the blades of the other plate being notched and the plates being interengaged with the blades of the plates overlapping, the tabs of both plates being fixed to the flame tube.

5. A combustion apparatus comprising, in combination, an air duct, a flame tube within the duct open at the upstream end relative to air flow through the tube and continuing to an outlet for combustion products, means for introducing fuel adjacent the upstream end of the flame tube including a nozzle entering through the open end of the entrance portion, and a swirler structure mounted in the said open end around the nozzle adapted to limit the quantity of air entering and direct the air in a circumferential direction, the swirler comprisng two plates, each plate being formed with a central opening for the nozzle and a plurality of skewed fan-like blades adapted to abut the flame tube at their peripheral edges and mounting tabs extending from the blades formed to lie against the surface of the flame tube, the plates being interengaged with the blades of the plates overlapping, the tabs of both plates being fixed to the flame tube.

6. A combustion apparatus comprising, in combination, an air duct, a flame tube within the duct comprising a diverging entrance portion open at the upstream end relative to air flow through the tube and a second portion downstream thereof continuing to an outlet for combustion products, means for introducing fuel adjacent the upstream end of the flame tube including a nozzle entering through the open end of the entrance portion, and a swirler structure mounted in the said open end around the nozzle adapted to limit the quantity of air entering and direct the air in a circumferential direction, the swirler comprising two plates, each plate being formed with a central opening for the nozzle and a plurality of skewed fan-like blades adapted to abut the entrance portion at their peripheral edges and mounting tabs extending from the blades formed to lie against the surface of the entrance portion, the leading edge of the blades of one plate and the trailing edge of the blades of the other plate being notched and the plates being interengaged with the blades of the plates overlapping, the tabs of both plates being fixed to the entrance portion, and a bushing for the nozzle fixed in the central openings of the plates and clamping the plates together.

7. A combustion apparatus comprising, in combination, an air duct, a flame tube within the duct open at the upstream end relative to air flow through the tube and continuing to an outlet for combustion products, the upstream end portion of the flame tube being defined by a generally conical dome-like wall diverging downstream with a central opening therein, and means mounted within and bounded by the said diverging wall adapted to convert a substantial part of the axial velocity of the air entering the said open upstream end to circumferential and radial velocity to cause the air to scour the said wall.

8. A combustion apparatus comprising, in combination, an air duct, a flame tube within the duct open at the upstream end relative to air flow through the tube and continuing to an outlet for combustion products, the upstream end portion of the flame tube being defined by a generally conical dome-like wall diverging downstream with a central opening therein, and means mounted within and bounded by the said diverging wall adjacent the opening adapted to impart circumferential and radial velocity to air entering the said open upstream end to cause it to scour the said wall.

9. A combustion apparatus comprising, in combination, an air duct, a flame tube within the duct open at the upstream end relative to air flow through the tube and continuing to an outlet for combustion products, the upstream end portion of the flame tube being defined by a truncated generally ogival wall diverging downstream with a central opening at the truncated apex thereof and curving smoothly into the wall of the flame tube downstream therefrom, and a swirler mounted within the said ogival wall at the said opening and bounded peripherally by the said ogival wall adapted to impart circumferential and radial velocity to air entering the said open upstream end to cause it to scour the said wall.

10. A combustion apparatus comprising, in combination, an air duct, a flame tube within the duct open at the upstream end relative to air flow through the tube and continuing to an outlet for combustion products, the upstream end portion of the flame tube being defined by a generally conical dome-like wall diverging downstream with a central opening therein, and a swirler mounted within and bounded by the said diverging wall adapted to impart circumferential and radial velocity to air entering the opening to cause it to scour the said wall.

11. A combustion apparatus comprising, in combination, an air duct, a flame tube within the duct open at the upstream end relative to air flow through the tube and continuing to an outlet for combustion products, the upstream end portion of the flame tube being defined by a generally conical dome-like wall diverging downstream with a central opening therein, and a swirler mounted within the said opening comprising blades extending to the said diverging wall adapted to impart circumferential velocity to air entering the opening to cause it to scour the said wall.

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