Jan. 26, 1954

P. F. ASHWOOD

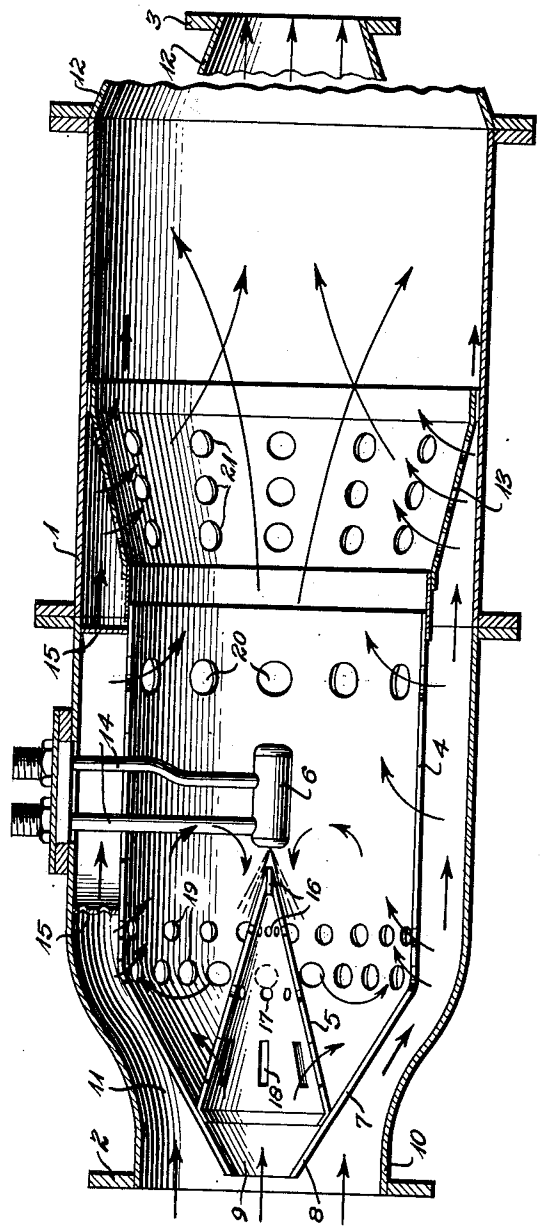
2,667,033

COMBUSTION APPARATUS FOR OPERATION IN FAST-MOVING AIR STREAMS

Filed Dec. 23, 1947

3 Sheets-Sheet 1

Fig. 1.



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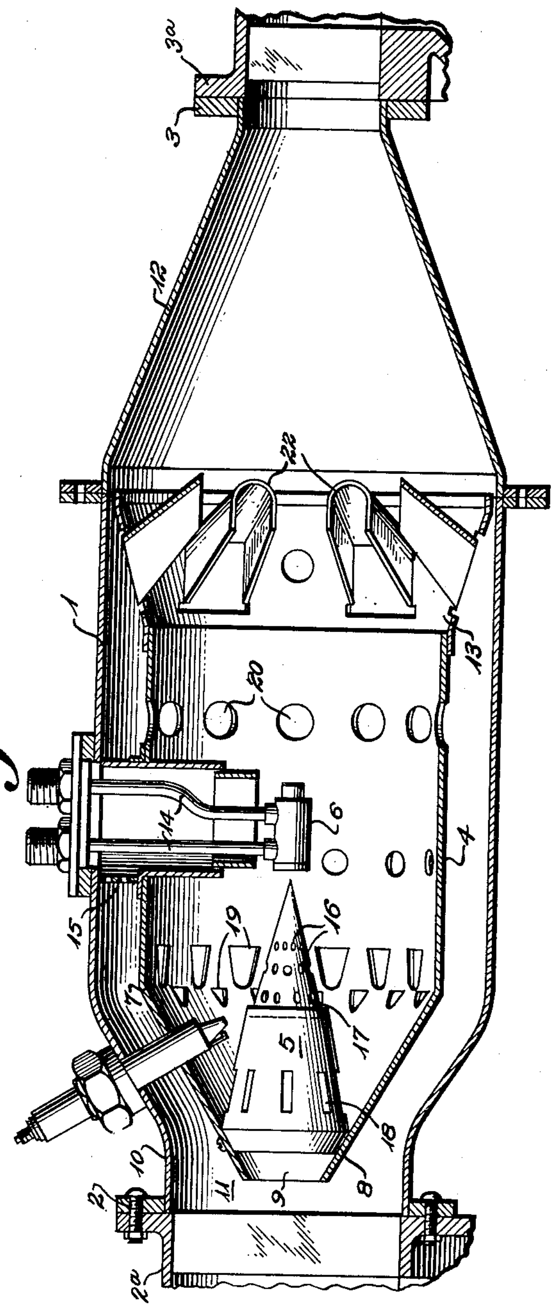
3 Sheets-Sheet 2

Fig. 2.



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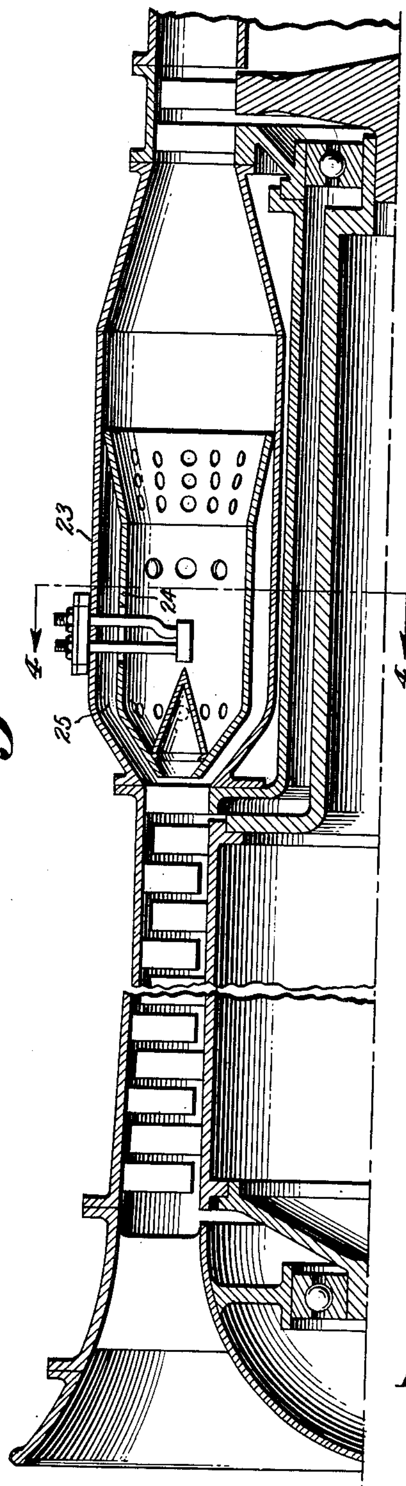

Fig. 3.

Fig. 4.

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COMBUSTION APPARATUS FOR OPERATION IN FAST-MOVING AIR STREAMS

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Application December 23, 1947, Serial No. 793,375

Claims priority, application Great Britain January 9, 1947

4 Claims. (Cl. 60—39.37)

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This invention relates to combustion apparatus for gaseous or liquid fuels and has for its object to provide a combustion apparatus suitable for use in circumstances in which combustion has to be supported by a fast moving ducted gas flow of flame-extinguishing velocity. Whilst, as will be seen after consideration of its details, the invention has possible applications in a wider field, it is primarily concerned and is at present conceived to have its maximum utility in connection with combustion apparatus in which special problems arise due to the necessity for supporting continuous combustion by means of a fast moving gaseous current involving a large mass flow, as for example, in gas turbines or other jet propulsion power units and in gas turbines for other purposes. The description "fast moving" as applied to a combustion-supporting gas flow is used herein to indicate that the mean speed of the gas in its general direction of flow past a combustion zone, calculated from the ratio air volume passing in unit time/cross sectional area of flow path, is substantially higher than the speed of flame propagation in the fuel/gas mixture concerned. For hydrocarbons fuels burning in air the speed of flame propagation is considered as being of the order of 1 foot per second at atmospheric temperature; the invention, on the other hand, is especially applicable to combustion apparatus for gas turbines or/and jet propulsion power units in which the speed of the air current in its general direction of flow past a combustion zone, calculated on the basis indicated, might be of an order as low as 10 or as high as 300 feet per second or even more, depending on the design.

The object of the invention stated in general terms is to enable stable combustion to be supported not only by a fast moving gas flow but also with high air/fuel ratios and with high rates of fuel injection and low pressure loss, all of which are requirements further arising in connection with gas turbines and jet propulsion units; the invention in fact owes its origin to the needs of such units and it is primarily to these that its application is contemplated, although of course it may be applied in other cases where comparable problems arise.

In combustion systems employing velocities of the order indicated, the gas flow must de diffused or reduced in velocity before combustion can be effectively maintained. It has accordingly been the practice to employ a diffuser section of substantial length in series with the inlet to the apparatus and the combustion zone, which has necessarily involved undue length and weight of

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the apparatus. This difficulty is a serious one in power plants, especially those for aircraft, of the combustion gas turbine type in which a compressor supplies air by way of a combustion system to a turbine, in which case it is usual to effect further diffusion of the air emerging from the compressor before allowing it to enter the combustion zone. Since in such a case the combustion apparatus is usually arranged annularly about the common axis of the compressor and turbine, the increase of weight for a small increase of length is quite disproportionate. It is accordingly a further object of the invention to reduce the overall length required for the diffusion and combustion processes as compared with known combustion systems. Equally however, the invention may be applied to the reduction of length of a combustion system even where there is no compressor.

The invention may conveniently be considered as having two principal aspects which, whilst being closely inter-related, have also some degree of independence. It will be assumed for the purpose of further consideration that a combustion apparatus according to the invention basically requires a duct suitable for carrying the air or other gas flow in which combustion is to be supported, and a combustion chamber within that duct which defines a zone of at least initial combustion.

Considered in its first aspect the invention proposes to employ upstream injection of fuel into the upstream limiting region of the combustion zone, in association with division of the gas flow in the ducting upstream of the said limiting region of the combustion one, a proportion of the gas flow being decelerated and by-passing the upstream limit of and being allowed to enter the combustion zone only at a point downstream of that limit, whilst the remainder of the flow is allowed to enter the upstream limiting region of the combustion zone, preferably also after diffusion.

In its second aspect the invention may be considered from the point of view that it provides for the combustion zone to be in overlapping relationship in the general direction of the gas flow with a diffusion or gas deceleration system embodied in the ducting through which passes at least a part of the combustion-supporting gas flow, the diffusion system being such as to effect under the conditions of operation controlled diffusion of the gas flow passing therethrough and delivering said gas flow into a continuation of the ducting downstream of the upstream limit of the combustion zone.

In the preferred embodiment of the invention the features of both these aspects of the invention are used in combination, but it will be evident to those skilled in the art that they are capable of some degree of independent application. Preferably also the foregoing features of the invention are used by constructing the combustion chamber at its upstream end to direct a part only of a gas flow in the duct at one or more points into a radially inner part of a fuel jet or spray directed upstream into the upstream limiting region of the combustion zone.

Preferably also, in regard to the second aspect of the invention, the diffusion or flow velocity reducing system through which air is by-passed around the upstream end of the combustion zone is afforded between the combustion chamber and the ducting, preferably by mutually relating the internal form of the ducting and the external form of the chamber defining the combustion zone so as to form a diffusion passage between said ducting and chamber having its entry at the upstream limit of said chamber and its outlet at a downstream region of the combustion zone therein.

According to a further feature of the invention the division of the gas flow is such that only a minor proportion of the gas flow is supplied to the upstream limiting region of the combustion zone, the major proportion of the flow being by-passed and having its first entry to the chamber as a major inflow in a zone of the combustion chamber downstream of its upstream limiting region but yet still in a region of upstream fuel injection thereto. The intention here is to provide a primary combustion zone at the upstream end of the combustion chamber in which a major part of the combustion takes place. The combustion chamber, however, preferably extends downstream for a sufficiently substantial distance to allow combustion to be substantially completed within it, the wall of the combustion chamber being ported at successive zones spaced in the direction of flow in order to admit secondary combustion gas inflows and diluent and mixing inflows.

A particular constructional form which may be regarded as representing a more limited aspect of the invention is that arising from the application of a combustion apparatus according to the invention to a gas turbine unit of the kind comprising a coaxial compressor and turbine and having its combustion apparatus embodied therein as an annular series of combustion chambers contained in ducting annularly disposed coaxially with the compressor and turbine and conducting the output of the former to the latter. In such a case the upstream ends of the combustion chambers, by making use of the feature of the invention which provides for an overlap between the diffusion system of the combustion apparatus and its combustion zone, may be made to lie close up to the compressor outlet so that virtually no additional length is required for diffusion of the compressor output after leaving the compressor proper. It will be appreciated, of course, that in such a case either the gas ducting may be an annular air casing containing all the combustion chambers, or there may be a separate air casing for each combustion chamber.

Examples of construction in accordance with the invention are illustrated in the drawings of which:

Figure 1 is a longitudinal sectional view of a complete and self-contained combustion apparatus, the downstream end of the ducting being broken away for convenience of illustration;

Figure 2 is a similar view of a somewhat modified self-contained combustion apparatus containing one combustion chamber and showing fragments of the upstream compressor and downstream turbine;

Figure 3 is a longitudinal sectional view of one radius of the combustion apparatus in which the ducting which receives a plurality of flame tubes is annular; and,

Figure 4 is a view in section taken along the line 4—4 of Figure 3.

Referring to the drawings, the combustion apparatus comprises an air duct 1 having at its upstream end a flange 2 by which it is intended that it should be secured direct to the outlet from a compressor in a gas turbine of conventional type. A fragment of a compressor of conventional type is shown in Figure 2 and is indicated by the reference character 2*a*. The opposite or downstream end of the air duct has a flange 3 by which it is intended to be secured to the nozzle housing of a turbine. A fragment of a conventional turbine nozzle housing is indicated at 3*a* in Figure 2. A general arrangement of this character is of course well know and so is not considered to require further description. Within the air duct is a combustion chamber in the form of a flame tube 4 having its upstream end formed by a conical baffle 5 with its apex pointing downstream. Inside the flame tube a fuel nozzle 6 is arranged in alignment with the apex of the conical baffle 5 to inject fuel in an upstream direction into the upstream limiting region of the flame tube 4, that is at the apex of the cone 5, as indicated in Figure 1. The conical baffle is mounted on a frustoconical part 7 of the flame tube 4 which forms in effect an outward and downstream extension from the base of the cone, but also forms a lip 8 extending some distance upstream beyond the base of the cone to form an aperture 9 dimensioned to admit a desired proportion of the total air flow to the interior of the cone, the proportion in the preferred cases illustrated being a minor proportion which is in the nature of a pilot flow. The flame tube is so arranged that the plane of its entry 9 is close up to that of the flange 2. The air duct, except for a short cylindrical part immediately downstream of the compressor at 10, also increases in diameter in the downstream direction so as to form with the frusto-conical nose 7 of the flame tube an annular space 11 of increasing cross sectional area in the downstream direction designed as a diffusion passage suitable for the velocity conditions involved. It will be appreciated that although the walls of the annulus 11 in the drawings do not diverge appreciably, the progressive increase in the downstream direction of its mean radius is sufficient to afford an increasing cross-section. From the downstream end of the annular diffusion passage 11 so formed both the flame tube and the air duct are of cylindrical form for some distance, the air duct terminating at its downstream end in a tapering section 12 leading to the turbine inlet. Upstream of this region the flame tube has an outwardly flared frusto-conical portion 13 which increases in diameter nearly to that of the air casing, the downstream end of this part being radially located by spaced peripheral projections engaging the wall of the air duct. A small amount of air leakage is thus allowed between the flared portion 13 and the air duct as indicated by the arrows in Figure 1, to prevent overheating effects.

It will be noted that the fuel injection nozzle supply pipes 14 are arranged to enter the chamber laterally, being screened from the air flow by an enclosing fairing 15, so that the nose of the chamber is completely free from unnecessary structure, thus assisting in allowing the combustion chamber to be brought up close to the entry to the air duct and giving the maximum freedom in designing the upstream end of the chamber. It is contemplated that the fuel injection nozzle should be of the spill-controlled type, since this type of injection nozzle has excellent characteristics from the point of view of good atomisation over a wide range of fuel flows and is also capable of fine regulation.

The conical baffle 5 forms a diffuser for air entering at 9 and has at least one port or set of ports 16 at or near its apex in order to introduce to a radially inner region at the base of the fuel jet or spray a pilot supply of combustion air insufficient to cause reversal thereof whilst further ports 17, 18, respectively are provided at intervals towards the base of the cone to provide a pilot supply of air to a radially inner intermediate region of the jet or spray and also to the radially outer part of the fuel jet spray at a region where, as indicated by the arrows in Figure 1, flow reversal thereof will take place in use due to the air flow.

The major primary supply of combustion air enters through a set of ports 19 at or near the outlet from the annular diffusion passage 11 (that is at about the shoulder of the flame tube); this supply of air, it will be noted, is so arranged in the region of the fuel jet or spray as to introduce air enveloping the latter somewhat downstream of its region of flow reversal. Further sets of ports 20, 21 for the inlet of secondary combustion air and of cooling or diluent air respectively are provided at spaced downstream zones of the combustion chambers.

The constructions illustrated in the Figures 1 and 2 respectively differ mainly in the arrangement of the ports 16, 17, 18, in the conical baffle 5, and in the arrangement of the ports 19, 20, 21, in the flame tube, which are self-evident from the drawing. It will be noted also that the diluent air is introduced in the case of Figure 2 through scoop-type elements 22. These have the advantage of introducing the mixing air with less pressure loss than the simple ports of Figure 1 but naturally involve somewhat greater manufacturing complication.

The nature of the flow path of air and fuel in the two cases is similar and is indicated by the arrows in Figure 1; summarising, it will be noted that first the flow is divided immediately on entry to the duct 1, a major proportion being by-passed through the diffuser channel 11 around the upstream limiting region of the primary combustion zone, and there being a major inflow of primary air for combustion at 19, with secondary inflows at 20, 21, which complete the combustion and effect dilution and mixing of the combustion gases with cooler air to reduce the temperature to a level and degree of uniformity acceptable for operation of a turbine. A minor or pilot flow of air is diffused while entering the cone 5 through the inlet 9 to be fed to the interior and reversal region of the fuel jet or spray. The latter, due to the air flow, reverses in the upstream limiting region of the combustion chamber, whilst due to the baffling effect of the chamber construction there is a recirculation of hot gases to the root of the fuel jet.

The constructions illustrated are intended to be used in a gas turbine power plant in which several identical combustion units are disposed annularly about the common axis of a compressor and turbine, but it will be evident that the duct could be of annular form with a plurality of flame tubes disposed around its annulus, the parts again being mutually formed to provide a diffusion channel corresponding to the passage 11. An example of this type of construction is shown in Figures 3 and 4 wherein an annular duct 23 is provided with a plurality of flame tubes 24 disposed in circumferentially spaced relation within the duct. The spatial relationships between the flame tubes 24 and the annular duct 23 are such that a diffusion channel 25 is provided which is similar in function to the diffusion channel 11. The remaining parts in Figures 3 and 4 correspond to the disclosure of Figure 1 except that the turbine and compressor are more fully illustrated.

Throughout the specification the term "diffusion" is used to express a zone in which kinetic energy is converted to pressure energy and in which the gas is decelerated without energy loss.

I claim:

1. Combustion apparatus comprising means for supplying a combustion supporting gas flow including a compressor, a duct directly connected to the output of said compressor for receiving the output of said supply means and conveying it in a common general direction, means for injecting fuel in an upstream direction within said duct, the flow of injected fuel being reversed by the gas flow, and structure defining within the duct at least one passage for by-passing gas past the region of fuel reversal, each such passage increasing in cross-sectional area in the downstream direction to provide for diffusion of all the gas by-passing said region.

2. Combustion apparatus comprising means for supplying a combustion supporting gas flow including a compressor, a duct directly connected to the output of said compressor for receiving the output of said supply means and conveying it in a common general direction, a combustion chamber within said duct, means for injecting fuel in an upstream direction in said chamber adjacent its upstream end, inlet means in said chamber upstream of said fuel injection means for admitting gas to reverse the flow of injected fuel, at least one passage defined within the duct but without the chamber for by-passing gas past the region of fuel reversal, each such passage increasing in cross-sectional area in the downstream direction to provide for diffusion of all the gas by-passing said region and further inlet means in said chamber for admitting by-passed gas therethrough.

3. In a combination gas turbine power plant having a compressor, a turbine coaxial with said compressor, ducting annularly disposed coaxially of said compressor and turbine and conducting the output from the former to the latter in a common general direction, a plurality of combustion chambers arranged in annular series within said ducting and each defining a zone of at least initial combustion, and means injecting fuel in an upstream direction with respect to the general direction of flow of the compressor output through the ducting in each chamber, each chamber having inlet means upstream of said fuel injecting

means admitting part of the compressor output to reverse the flow of injected fuel, the improvement that comprises the provision of a diffuser system between said ducting and chambers incorporating at least one gas flow passage bypassing the region of reversal of fuel flow in each chamber having inlet means at its upstream end for admitting at least part of the compressor output, and outlet means at its downstream end for delivery of same into a continuation if the ducting downstream of said region of fuel reversal, each such passage increasing in cross-sectional area in the downstream direction so as to effect under conditions of operation controlled diffusion of all the gas by-passing said region of fuel reversal in each chamber.

4. A combustion apparatus comprising means for supplying a combustion supporting gas flow including a compressor, a duct directly connected to the output of said compressor for receiving the output of said supply means and conveying it in a common general direction, a combustion chamber within said duct, means for injecting fuel in an upstream direction in said chamber adjacent its upstream end, inlet means in said chamber upstream of said fuel injection means for admitting gas to reverse the flow of injected fuel, said combustion chamber and duct together defining at least one passage for by-passing gas past the region of fuel reversal, each such passage increasing in cross-sectional area in the downstream direction to provide for diffusion of all the gas by-passing said region.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
972,504	Brown	Oct. 11, 1910
1,542,294	Fogler	June 16, 1925
2,164,225	Walker	June 27, 1939
2,404,335	Whittle	July 16, 1946
2,503,006	Stalker	Apr. 4, 1950
2,526,122	Darlington	Oct. 17, 1950
2,529,506	Lloyd et al.	Nov. 14, 1950
2,556,161	Bailey et al.	June 12, 1951

FOREIGN PATENTS

Number	Country	Date
588,572	Great Britain	May 28, 1947