May 12, 1959 P. LLOYD 2,885,858

COMBUSTION SYSTEM WITH MIXING CHAMBER

Original Filed Nov. 22, 1948 2 Sheets-Sheet 1

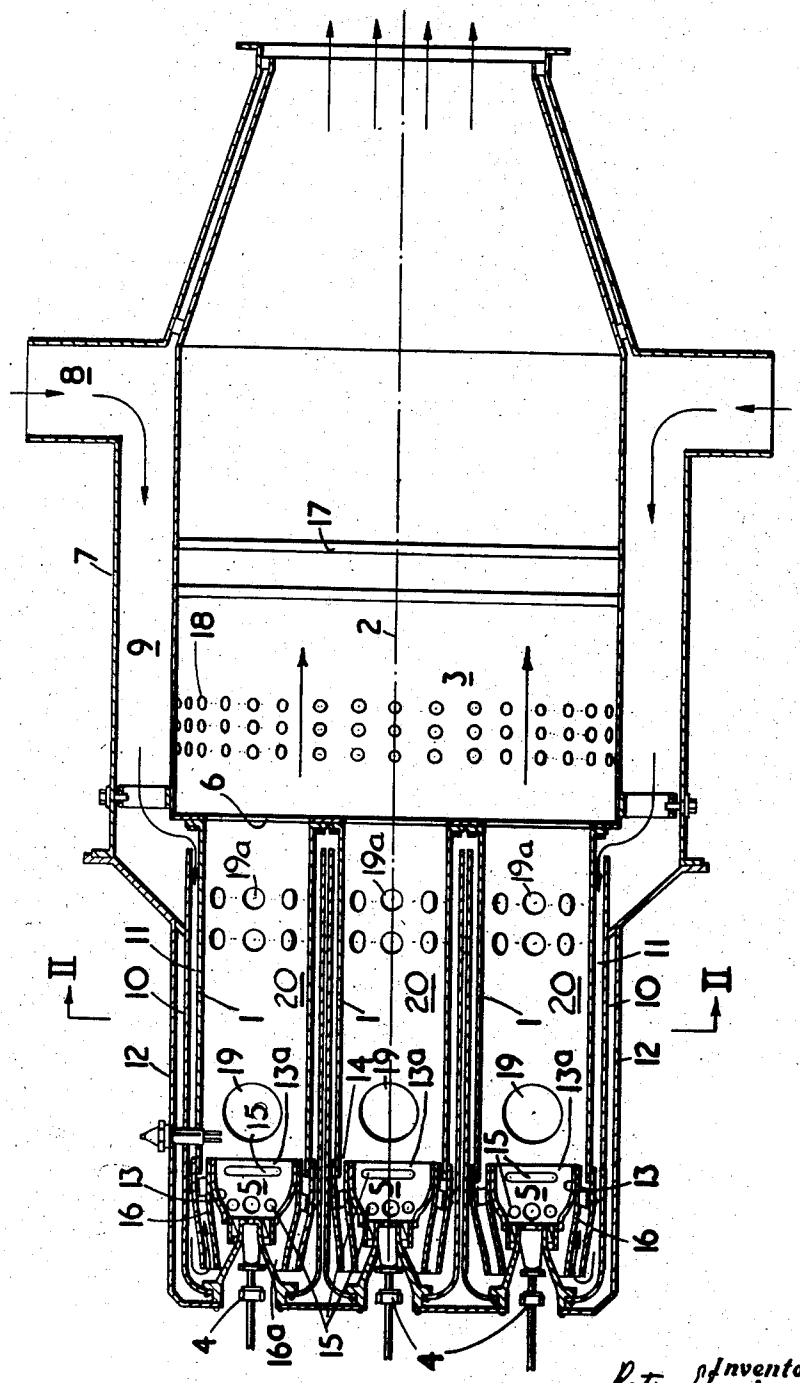

FIG. 1

Peter Lloyd Inventor
By
Stevens, Davis, Miller & Mosher
Attorneys

May 12, 1959 P. LLOYD 2,885,858

COMBUSTION SYSTEM WITH MIXING CHAMBER

Original Filed Nov. 22, 1948 2 Sheets-Sheet 2

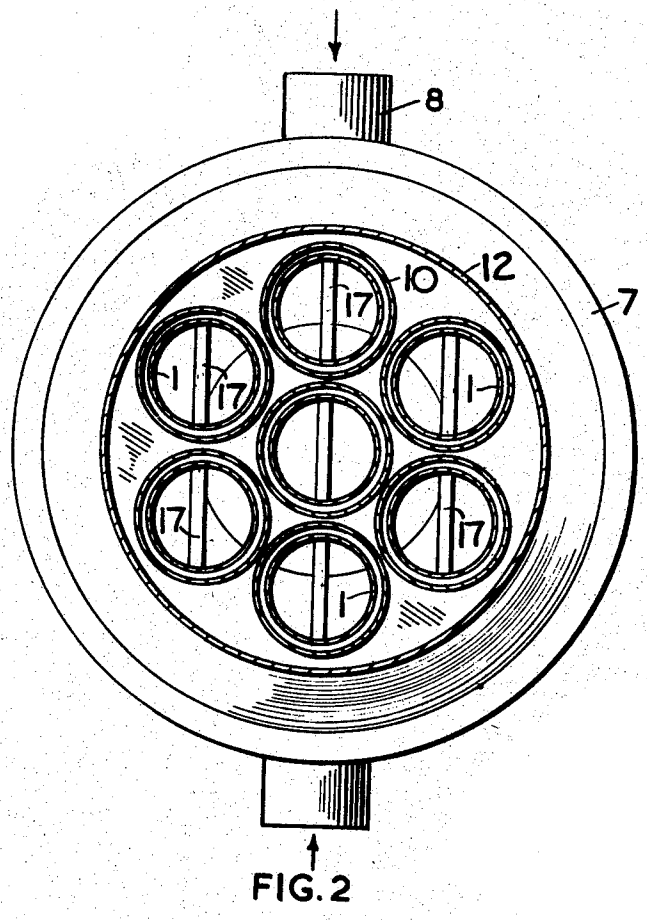

FIG. 2

Peter Lloyd Inventor
By
Stevens, Davis, Miller & Mosher
Its Attorneys

United States Patent Office 2,885,858 Patented May 12, 1959

2,885,858

COMBUSTION SYSTEM WITH MIXING CHAMBER

Peter Lloyd, Farnham, England, assignor to Power Jets (Research and Development) Limited, London, England, a British company

Continuation of abandoned application Serial No. 61,323, November 22, 1948. This application January 19, 1953, Serial No. 331,946

Claims priority, application Great Britain December 2, 1947

1 Claim. (Cl. 60—39.65)

This invention relates to combustion system and is concerned with making provision for obtaining effective mixing of the gases produced by the combustion reactions in such systems. The present application is a continuation of application Serial No. 61,323, filed November 22, 1948 and now abandoned.

More particularly, but not exclusively, the invention relates to combustion systems in which combustion has to be supported by an airstream of such velocity and mass flow that the combustion supporting air must be introduced into the combustion zone in stages in order to avoid extinguishing the flame; that is to say the flame must be screened from the direct blast of the airflow and the air introduced at successive stages so that there is in effect a primary and one or more further combustion zones.

In this connection, moreover, it may be remarked that the invention is considered to have particular application to cases in which special problems arise due to the necessity for supporting combustion by means of a fast moving air current involving a large mass flow, as for example in gas turbine and jet propulsion units, the description "fast moving" being used here to indicate that the mean speed of the air current past the combustion zone, calculated from the ratio volume passing in unit time/cross sectional area of the flow path, is substantially higher than the speed of flame propagation in the fuel/air mixture concerned. For hydrocarbon fuels burning in air the speed of flame propagation is considered as being of the order of one foot per second at atmospheric temperature; the invention, on the other hand, is especially applicable to combustion apparatus for gas turbine 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 particular object of this invention, is to provide such mixing as will result in a uniform distribution of temperature of the outlet of the combustion system.

For this purpose, according to the present invention, a combustion system comprises a plurality of flame tubes, each defining a region which is a substantially self-contained combustion zone in the sense that substantially the whole of the air required for combustion therein is led into it, and each leading into a common tubular mixing chamber.

The intention is that no combustion air should be delivered into the mixing chamber and in the case where some air is allowed to enter, that this should be done under controlled conditions mainly for cooling purposes, and that this air should take little or no part in the main combustion reactions.

In the preferred form the flame tubes are all of similar construction and are arranged in a circular series about a common axis, the mixing chamber being tubular and co-axial with the series of flame tubes.

The combustion system according to the invention may conveniently be cooled by one of the methods described in United States Patent No. 2,664,702 issued January 5, 1954, in the name of Lloyd, et al. wherein air intended to be introduced into a combustion chamber at one particular axial region is brought into contact with the outside of the chamber downstream of this region and is then caused to flow in an upstream direction in contact with the chamber wall before being allowed to enter the chamber at the required region.

The combustion system of the invention may alternatively or in addition be cooled by another of the methods described in said patent wherein it is proposed to restrict the temperature rise of a flame tube wall by maintaining between the hot gas flow and the internal surface of the wall over a substantial distance in the direction of the flow therethrough, a layer of cooler air which is stable in the sense that it is not substantially turbulent and that its mixing with the hot gases is wholly or mainly due to diffusion or to a difference in velocities rather than to the creation of turbulence or to the penetrating action of airstreams. According to this method cooling air is introduced into the flame tube through which the hot combustion gases are flowing as a stream enveloping the flow of hot gases and moving in the same direction as and at a velocity which is the same as or comparable to that in the outermost zone of the hot gas flow, the arrangement being such than an envelope of freshly introduced air will be maintained between the hot gases and the flame tube wall for a substantial distance downstream (relative to the direction of flow within the duct) from the locality at which the air enters the duct.

By way of example one form of embodiment of the invention is described hereinunder with reference to the accompanying drawing in which:

Figure 1 is an axial section of said embodiment.

Figure 2 is a section on the line II—II in Figure 1.

In the said drawings a combustion system suitable for application in a gas turbine plant comprises a plurality of flame tubes **1** arranged symmetrically in a circular series about a common axis **2**, and a tubular mixing chamber **3** co-axial with the system into which chamber all the flame tubes **1** deliver their gases of combustion. Each flame tube **1** is supplied with fuel injecting means **4** and with all the air necessary for complete combustion in a primary zone **5** and further combustion zones **20** within the flame tube, the mixing chamber **3** receiving gases only from the outlets **6** of the flame tubes **1**. In the application of the systems to a gas turbine engine, the mixing chamber **3** is arranged to deliver in turn to a volute (not shown) which leads to the turbine inlet. The diameter of the mixing chamber **3** is conveniently approximately equal to the diameter of the circular series of flame tubes **1** and its length would normally be of the order of that of the flame tubes **1**.

In order to apply the cooling method of the above-mentioned patent, surrounding the mixing chamber **3** and co-axial therewith is an outer casing **7**, and an air entry **8** is provided towards the downstream end of the casing **7** (relative to the direction of flow through the chamber **3**) through which air is admitted and as shown by the arrows flows upstream (relative to the same direction of flow) through the annular space **9** between the chamber **3** and casing **7**. Each flame tube **1** is provided with an annular shield or casing **10** and air is led through the annular space **11** between the shield **10** and the tube **1** towards the upstream end of the tube in which region the air flow is reversed through 180° as shown by the arrows and flows in a downstream direction (relative to the direction of flow in the mixing chamber **3** and flame tube **1**) into the upstream end of each flame tube. Some of the air flowing through the annular space **11** enters

the further combustion zones **20** within the flame tube through apertures **19**, **19***a* in the flame tube peripheral wall. All the casings **10** are surrounded by a further casing **12** forming a closed and insulating air sheath around the casings **10**.

Each flame tube **1** has a nose **13** enclosing the primary combustion zone **5**, into which fuel is injected from the burner **4** and combustion is initiated, the flame tube **1** being of larger diameter than the nose **13** to form around the latter an annular air entry **14**, the dimensioning of the parts being such that as stated in said patent in operation at the design point, the velocity of the cooling air through said entry **14** and of the hot gases emerging from the primary combustion zone **5** will be sufficiently closely matched to enable them to flow as distinct streams for some substantial distance downstream through the flame tube **1** in order to provide over such distance an envelope of relatively cool aair around the flame tube wall. The nose **13** constitutes the usual stabilizing baffle used in such cases, and is provided with suitable air inlets **15** for the admission of air for supporting the primary combustion. The condition of matching the flow as between the hot gases and the cooling air is readily obtainable for a given condition of operation by correct proportioning of the nose **13** and the downstream part of the flame tube **1**. The matching of the air flows will not however hold good over a wide range of operating conditions and will accordingly be based upon the conditions obtaining at the maximum temperature of operation, since a breakdown of the cooling air layer at lower temperatures can in most cases be accepted.

As shown, and as described in said patent, the nose **13** has its open side **13***a* facing downstream and has a tubular upstream extension or scoop **16**, normally of frusto-conical or similarly tapered form having such a shape in relation to the flange tube **1** and an upstream orifice **16***a* of such dimensions as to give the requisite relation between the flows through and around the scoop **16**.

The mixing chamber **3** is tubular and is provided with any suitable baffles **17** for mechanically inducing turbulence; in some cases, however, the internal turbulence resulting from the expansion of the gas streams from the flame tube **1** into the mixing chamber **3** will be itself sufficient to induce the required mixing.

It is to be understood that the use of major air streams for mixing purposes is to be avoided since these would destroy the desired uniformity of gas outlet temperature which is envisaged by the use of the mixing chamber **3**. However, this does not exclude the possibility of admitting some air to the chamber **3** in a controlled manner for cooling the wall or other parts of this chamber. For example some of the air which flows upstream through the annular space **9** may be allowed to enter the chamber **3** directly through lateral apertures **18** in the chamber wall to form a relatively cool peripheral air lining therein.

I claim:

A combustion system comprising a plurality of similar flame tubes disposed around a common axis and having outlets at their ends facing generally in the same axial direction, a common tubular mixing chamber lying along said common axis, and having a pheripheral wall and end walls, the end wall nearest the flame tubes being formed with holes with which said flame tube outlets register and the other end wall being formed with a single central outlet on the chamber axis, a casing enclosing said flame tubes and said mixing chamber, the casing defining with the peripheral wall of the chamber an annular space and being formed in its side wall with an air inlet opening into said annular space and with an outlet opening in its end corresponding to said outlet from the mixing chamber, tubular jackets each enclosing one of said flame tubes with radial clearance and defining therewith an annular passage open at the end to said annular space, fuel injectors at the ends of said flame tubes remote from said outlet, said flame tubes being formed with primary air inlets at said remote ends and further inlets intermediate their ends, said inlets leading from said annular passages into the interior of the flame tubes, the inlets, the annular passages and the annular space being of such a size as to permit the flow therethrough of sufficient air to effect substantially complete combustion of the fuel in the flame tubes.

References Cited in the file of this patent

UNITED STATES PATENTS

1,163,333	Galbraith et al.	Dec. 7, 1915
1,345,361	Good	July 6, 1920
2,074,602	Wilstam	Mar. 23, 1937
2,447,482	Arnold	Aug. 24, 1948
2,458,497	Bailey	Jan. 11, 1949
2,503,006	Stalker	Apr. 4, 1950
2,541,170	Mayers et al.	Feb. 13, 1951
2,565,843	Dennison	Aug. 28, 1951
2,588,728	Hundstad	Mar. 11, 1952
2,595,999	Way et al.	May 6, 1952
2,609,664	Staley	Sept. 9, 1952

FOREIGN PATENTS

341,871	Great Britain	Jan. 21, 1931
588,572	Great Britain	May 28, 1957