APPARATUS FOR PRODUCING A FLAME JET BY COMBUSTING COUNTER FLOW REACTANTS

Filed Dec. 7, 1965 2 Sheets-Sheet 1

Fig.1.

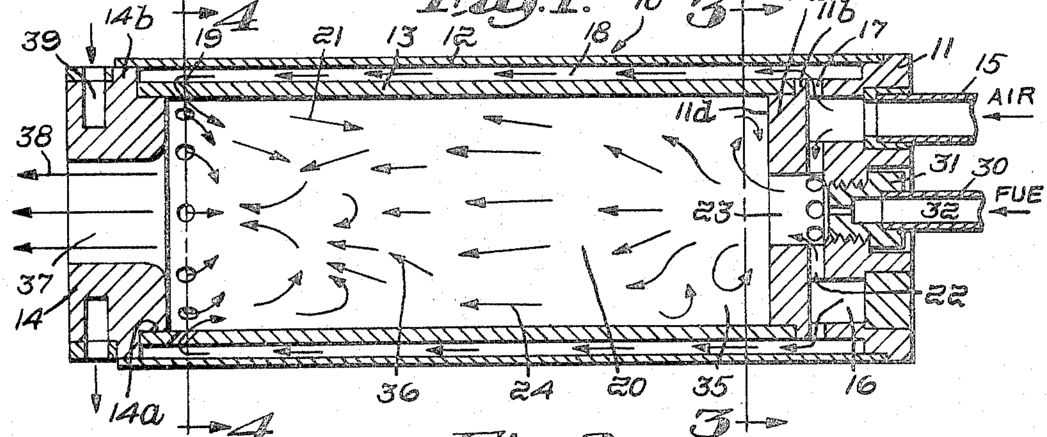

Fig.2.

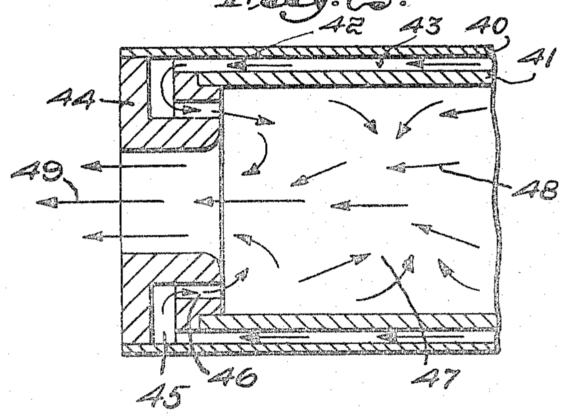

Fig.4.

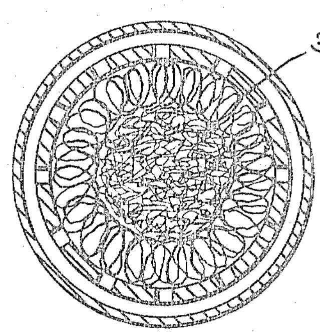

Fig.3.

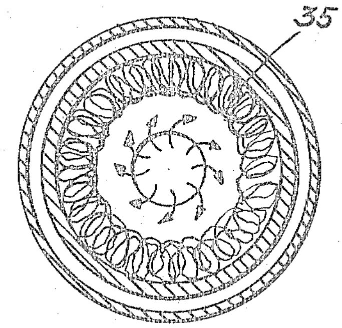

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Fig. 5.

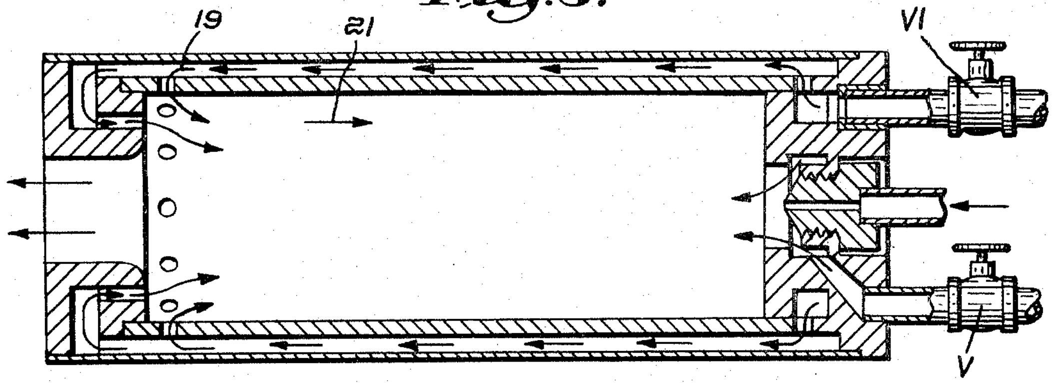


Fig. 6.

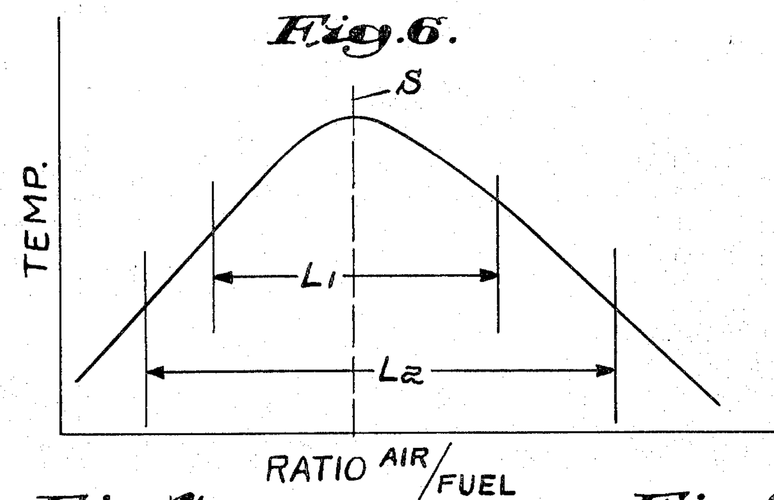


Fig. 7.

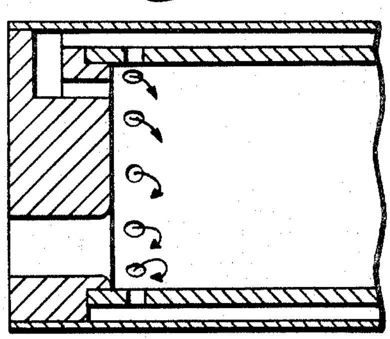
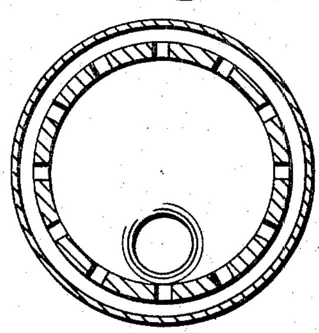


Fig. 8.



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3,363,661

APPARATUS FOR PRODUCING A FLAME JET BY COMBUSTING COUNTER FLOW REACTANTS

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2 Claims. (Cl. 158—27.4)

ABSTRACT OF THE DISCLOSURE

A combustor comprising spaced concentric tubular bodies and having a space for premixing fuel, oxygen and a quantity of nitrogen at one end thereof and a central flame discharge nozzle at the other end thereof. A flame stabilizing wall separates the premixing space from the combustion chamber. Oxygen and nitrogen pass through the space between the tubular bodies and is led in a reversely turned path in the area of the discharge nozzle to provide a secondary flame initiating region.

This invention relates to methods and apparatus for burning quantities of fuel and oxidant at superatmospheric pressures in a confined space to provide a flame jet and, more particularly, the invention is concerned with a novel technique for bringing together desired quantities of fuel and air in a combustion chamber in a controlled manner so that a greatly extended range of fuel-to-air ratios may be burned stably within the combustion chamber at high through-put velocity.

It is a chief object of the invention therefore to improve methods of producing flame jets and to devise a method of combusting by which increased amounts of reactants can be combusted within a given chamber volume.

Another object of the invention is to provide a method of controlling the manner in which an oxidant is mixed with fuel so as to accomplish cooling of the flame within an extended range of stable burning. Another object of the invention is to devise improved burner structures for receiving and burning reactants.

In realizing the foregoing objectives, it is important to evaluate prior art techniques for producing flame jets. It is now customary in the art to employ a tubular burner structure into an inner end of which fuel and an oxidant such as air are introduced under pressure with the resulting mixture being instantly combusted. This produces a stream of products of combustion which is emitted from an outer end of the burner structure at very high velocity.

It has been found by those skilled in the art that for any given volume of burner chamber in which combustion thus takes place there is a definite limit as to the fuel-to-air ratio which may be used, as well as the quantities of fuel and air which may be introduced into the burner and combusted while maintaining stable burning. Experience has shown that undesirable limitations are thereby imposed on the performance capabilities and the operating temperature ranges of such flame jets and this becomes especially important in connection with operations where the flame jet is employed to produce spalling of mineral bodies of various types.

With these shortcomings of conventional flame jets in mind, I have conceived of a novel method of burning fuel and oxidant in a manner such that a relatively larger quantity of fuel and oxidant may be combusted for any given chamber volume without appreciable loss of flame stability and with a desirable lowering of flame temperatures.

My improved method of burning is based on the novel concept of providing a primary flow of air which is mixed

with fuel and burned initially in a combustion chamber and further providing a secondary flow of air which is injected into an end of the burner chamber opposite to that in which combustion is initiated to thereby set up a counter flow of air. This counter flow of air is caused to move in opposed relation to the flow of products of combustion to thereby set up a region of extreme turbulence at the exit end of the burner chamber. As a result of this turbulence a highly desirable secondary mixing of fuel with air is produced in very close proximity to the outlet nozzle through which the flame nozzle is emitted.

I find that by thus introducing a counter flow of air into the exit end of the burner an extended range of usable fuel-to-air ratios of a determinable nature may be realized and as a result significantly larger quantities of fuel may be utilized in a given burner volume. I also find that the flame so produced has the ability to run with excess air and this excess air provides for substantial cooling of the flame.

The nature of the invention and its other objects and novel features are more fully described below in connection with the description of the accompanying drawings in which:

FIGURE 1 is a cross sectional view of a preferred form of burner construction of the invention in which a counter flow of oxidant may be employed;

FIGURE 2 is a fragmentary cross sectional view of a burner generally similar to the burner of FIG. 1 but illustrating a modified form of inlet means for producing a counter flow of oxidant;

FIGURE 3 is a cross section taken on the line 3—3 of FIGURE 1;

FIGURE 4 is a cross section taken on the line 4—4 of FIGURE 1;

FIGURE 5 is another cross-sectional view generally corresponding to FIGURE 1 but further illustrating another modified arrangement for regulating flows of fuel and oxidant independently;

FIGURE 6 is a graph showing an air to fuel ratio plotted against temperature changes;

FIGURE 7 is a cross sectional view of a modified form of burner for secondary flow; and

FIGURE 8 is a cross section taken on the line 8—8 of FIGURE 7.

In carrying out the method of the invention in one preferred form, I produce a flame jet by combusting air and fuel in the same general manner disclosed in Patent No. 3,103,251. In Patent No. 3,103,251 issued to the assignee of the applicant in the present invention, there has been disclosed a method of flame working a mineral body in which cooling of a flame jet may be realized by employing air as an oxidant, and allowing inert gas in the air to reduce temperature of the flame. The range of fuel-to-air ratios used is limited by the need for remaining within a region of stable burning to avoid faulty flame operation or flame extinction.

There has further been disclosed in application Ser. No. 306,887 filed Sept. 5, 1963, entitled, "Method and Apparatus for Producing Flame Jet and Controlling Temperature and Flame Stability of Same," now issued under date of June 14, 1966 as Patent No. 3,255,802, also owned by the assignee of the present applicant, a method and means for inducing products of combustion to recirculate against a flame stabilizing surface and thereby produce a region of flame initiating which permits combustion reaction to take place over a somewhat extended range of fuel-to-air ratios without flame extinction.

In producing a jet flame in accordance with the present invention, I preferably employ a burner construction having a flame stabilizing surface of the class disclosed in application Ser. No. 306,887, and I also make use of the cooling action of quantities of inert gas as referred to in Patent No. 3,103,251.

However, in addition I provide for controlling flow of oxidant in a specific manner to create in a burner chamber a region of high turbulence at a point appreciably removed from the flame stabilizing surface and in this way there is created and maintained a secondary flame initiating region.

Considering in more detail the preferred form of burner structure for carrying out the method of the invention as illustrated in FIGURE 1, arrow **10** in general refers to a tubular body which is made up of an outer tubular section **12** and an inner tubular portion **13** occurring in spaced relation to the tubular portion **12**. Fitted into adjacent ends of the tubular bodies **12** and **13** is a nozzle piece **14** which is shouldered at **14***a* to receive an end of the tubular member **13** as shown with an extended end of the tubular body **12** being located around a shouldered part **14***b* of the nozzle piece **14**.

At the opposite end of the tubular burner structure described, there is provided an injector head **11** against which the tubular section **12** is fitted as shown, and this injector head is formed with an inner annular part **11***a* having a shouldered section **11***b* against which is received the tubular member **13**. Mounted through the injector head **11** is an air conduit **15** which communicates with an annular manifold volume **16** occurring between the part **11** and the part **11***a*. Numeral **30** denotes a fuel conduit which extends centrally through the member **11** and communicates with an aperture or well **23** in turn leading into the interior of the tubular member **13**. Air is supplied under pressure and led through the tubular member **15** into the manifold space **16**. Fuel is supplied under pressure through the conduit **30** and passes through the surrounding injector part **31** into the well **23**. The nozzle **14** may, if desired, be cooled by a flow of water indicated by arrows, conducted through the annular passage **39** shown at the left hand side of FIGURE 1.

In accordance with the invention the air supplied through the conduit **15** is separated into two independent flows. These flows of air may be referred to conveniently as a "primary flow" and a "secondary flow." The primary flow of air as it enters the annular manifold space **16** passes through a series of openings **22** which communicate with the well **23** and thus allow the air to be discharged through the well into the burner chamber.

The secondary flow of air is caused to exit through a plurality of openings **17** from the manifold volume **16** and passes through an annular passageway **18** occurring between tubes **12** and **13** to exert a desirable cooling action with respect to combustor tube **13**. This secondary flow of air continues into the end of the burner structure and is there diverted abruptly through a plurality of inlet openings **19** which are arranged around the tubular member **13** and which preferably are formed with an angle as shown in FIGURE 1 so that the air is caused to be substantially reversed in its path of flow and is caused to move in a direction from left to right as viewed in FIGURE 1.

In accordance with the invention the fuel and air leaving the well **23** by some suitable means is ignited and continuously burns to produce a stream of products of combustion, which stream moves at high velocity from right to left as viewed in FIGURE 1. The flow of products of combustion containing portions of unburned fuel meets abruptly with the plurality of flows of secondary oxidant or air injected inwardly through the openings **19**. As a result there is formed an exceedingly highly turbulent region which is generally indicated by arrows at the point noted by numeral **36**. Since the secondary air is being injected around the entire circumference of the burner tube **13**, there is created an outer toroidal flow of oxidant which tends to become intimately mixed with the central flow of products of combustion carrying unburned fuel therein.

As a result of the meeting of the secondary flow of air with the stream of products of combustion, there is realized a gradation of the fuel-to-air ratio from rich to lean at some point or region of which the ratio is stoichiometric. The effect of the turbulent region is to create a flame initiating region which tends to maintain more stable burning than would otherwise be the case. In effect this flame initiating region created by the turbulence of the secondary air in-put may be conveniently thought of as a secondary flame initiating region since there is a first or primary flame emitting region at the area closely adjacent to the well **23**. The annular member **11***a* is formed with a special flame stabilizing surface **11***d* which tends to promote the formation of a toroidal path of flow of burning material **35** so that this burning material is thrown back upon itself to come into contact with fresh quantities of fuel and oxidant emitted through the well **23** as set forth in application Ser. No. 306,887.

Thus there are created two flame initiating regions separated from one another and cooperating to promote stable burning at both ends of the burner structure.

I have found that the provision of a counter flow of air at the region **36** allows large quantities of fuel and air to be combusted. For example in prior art burners having a chamber diameter and length shown, for example, by volume **20** in the drawings where these dimensions were 2 inches and 16 inches respectively, a maximum of 400 s.c.f.m. of air could be burned stably. The present burner of the invention, having the identical combustor dimensions, is capable of burning over 500 s.c.f.m. of air with fuel. In addition, the improved burner of the invention is found to provide much easier igniting and, more importantly, is stable over an appreciably wider range of fuel-to-air ratios. This latter feature is illustrated diagrammatically in FIGURE 6 in which S denotes the stoichiometric ratio and **L1** represents the limits of stable burning of a conventional burner of the class described. In comparison **L2** represents the limits of stable burning of the same burner provided with means for employing counter flow oxidant.

Where the fuel to air ratio provides for an appreciable excess of air being utilized, there is realized a highly significant cooling which extends the cooling effects obtainable by the technique of Patent No. 3,103,251. This cooling action is capable of rendering the flame jet which is released from the burner structure capable of producing thermal spalling action with a considerably larger number of minerals, and particularly minerals such as slate and other substances where relatively lower temperatures must be employed.

In thus employing a counter flow of oxidant such as air, I may also realize a desirable cooling effect for the nozzle portion of the burner. An arrangement of this type has been disclosed in FIGURE 2 for example. As shown therein the secondary air flow **42** passes through an annular passage **43** contained between tubes **40** and **41**. Nozzle piece **44** contains the annular space **45** through which the secondary air flows before becoming discharged through reversely directed annular openings **46**. It will be apparent that the secondary air in passing over the relatively large surface area presented by opening **45** and holes **46**, provides a very substantial cooling effect to the nozzle piece **44**. It will also be observed that in the arrangement of FIGURE 2 the reversely directed openings **46** afford a modified and desirable means of injecting a counter flow along paths which are in axially opposed relationship to a flow of stream of products of combustion as indicated by the arrow **49** and thus there may be created an even more turbulent region as represented by the reference character **47**.

Summarizing therefore the novel steps of the invention are, in essence, the operations of directing opposed flows of oxidant from two extremities of an enclosed combustion chamber volume. One flow which may be thought of as the primary flow contains fuel. The secondary air flow is provided to assist in burning the fuel which is carried in the stream of products of combustion and to maintain high combustion stability. All of the air so supplied can be consumed in the combustion reaction.

Furthermore, this secondary flow of air is heated, having acted as a coolant for the combustor tube **13** as it traveled through the passage **18**. This contained heat adds further to the flame stabilizing effect of the turbulent region created by this in-put of secondary air.

I may desire to modify the structure described in various ways as, for example, in FIGURE 5 I have shown a burner construction similar in all respects to that shown in FIGURE 1 with the exception that the flow of air which is to constitute the primary air may be independently supplied through a valve member V, while the secondary flow of air to constitute the counter flow of the invention may be independently supplied through a valve **V1**. There may be thus realized desirable controls in the flame stability realized for any given quantity of fuel and air to be combusted and likewise there may be realized a variable control of the temperature of the jet emerging from the burner structure in line with the description above with reference to FIGURE 2.

Various other changes and modifications may be resorted to within the scope of the appended claims.

I claim:

1. A burner apparatus for burning liquid fuel, oxygen and a quantity of nitrogen at superatmospheric pressure and producing a nitrogen cooled flame jet, said apparatus including an enclosure body having a discharge nozzle formed with a central flame exit aperture, the opposite end of said enclosure body having an annular mixing space for premixing oxygen, nitrogen and liquid fuel droplets, said enclosure body further having a relatively larger combustion chamber communicating with the premixing space, a cylindrical sleeve located around the annular mixing space and the combustion chamber in spaced relation to form an annular passageway which at its intermediate portion is isolated from the interior of the combustion chamber, a flame stabilizing wall constructed and arranged to separate the premixing space and the combustion chamber, said flame stabilizing wall being formed with a fuel injecting passageway for conducting a fuel mixture from the premixing space into the combustion chamber, said flame stabilizing wall further presenting a flat annular flame stabilizing surface which is located around and which extends abruptly away from said fuel injection passageway, said combustion chamber having a predetermined size which defines a volume limited by the quantity of nitrogen relative to the quantity of oxygen and fuel droplets combusted therein whereby a range of stable burning above and below stoichiometric range is realized and recirculation of flame portions may be induced against the said flame stabilizing surface in a toroidal path of flow to provide a primary flame initiating region and said enclosure body occurring around the annular mixing space having further formed at outer portions thereof passageways for conducting nitrogen and oxygen independently of liquid fuel into and along the said annular passageway between the combustion chamber and the said cylindrical sleeve, said discharge nozzle being formed with a tubular section received in the end of the said combustion chamber and having axially disposed openings located therethrough, the outer end of said nozzle including an enlarged annular flange portion mounted within the end of the cylindrical sleeve and defining a space through which nitrogen and oxygen passing from the annular passageway may be led in a reversely turned path of flow and discharged into products of combustion approaching the discharge nozzle to provide a secondary flame initiating region at points appreciably spaced away from the said primary flame initiating region.

2. A structure according to claim **1** in which the said combustion chamber is formed with air passageways located at the extreme end of the combustion chamber in close proximity to the space through which nitrogen and oxygen is lead in a reversely turned path of flow into the stream of products of combustion in the combustion chamber, said air passageways at the end of the combustion chamber being arranged to direct jets of downstream air into the reversely turned path of flow of air passing through the nozzle in a manner to cooperate therewith and to increase high turbulence and promote secondary flame initiating at points separated from the said primary flame initiating region.

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