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Nakagawa et al.

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[54] **LIQUID FUEL COMBUSTION DEVICE**

[75] Inventors: **Masayoshi Nakagawa**, Nishinomiya; **Toshihiro Hirai**, Sakai; **Yuji Suzuki**, Amagasaki-shi; **Ryozaburo Kimura**; **Masamichi Okahara**, both of Takarazuka, all of Japan

[73] Assignee: **Daido Sans Kabushiki Kaisha**, Osaka-shi, Minami-ku, Unagidani-Nakano-cho, Banchi, Japan

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **431/10**
[51] **Int. Cl.** **F23l 7/00**
[58] **Field of Search** ....431/2, 8, 349, 284, 431/10, DIG. 21, 22, 23, 32; 239/403, 405, 406, 419, 419.3, 422, 424.4, 428, 429, 430, 433

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Primary Examiner—Meyer Perlin
Assistant Examiner—William C. Anderson
Attorney—Edwin E. Greigg

[57] **ABSTRACT**

Through a combination of

a. the supply of oxygen substantially in the form of pure oxygen in an amount far less than that theoretically required for combustion of liquid fuel to be burned in such a manner as to attain a very rapid combustion temperature rise,

b. with the strong activation of the liquid fuel by mixing and atomization of a part of the fuel liquid sufficiently with the oxygen, limited in quantity, closely adjacent to a liquid fuel nozzle thereby to form a high-temperature center flame very close to the nozzle.

c. a high-temperature flame having a large potential heat per unit volume thereof, that is, a flame of extremely high intensity, is obtained efficiently with a small supply of oxygen.

4 Claims, 5 Drawing Figures

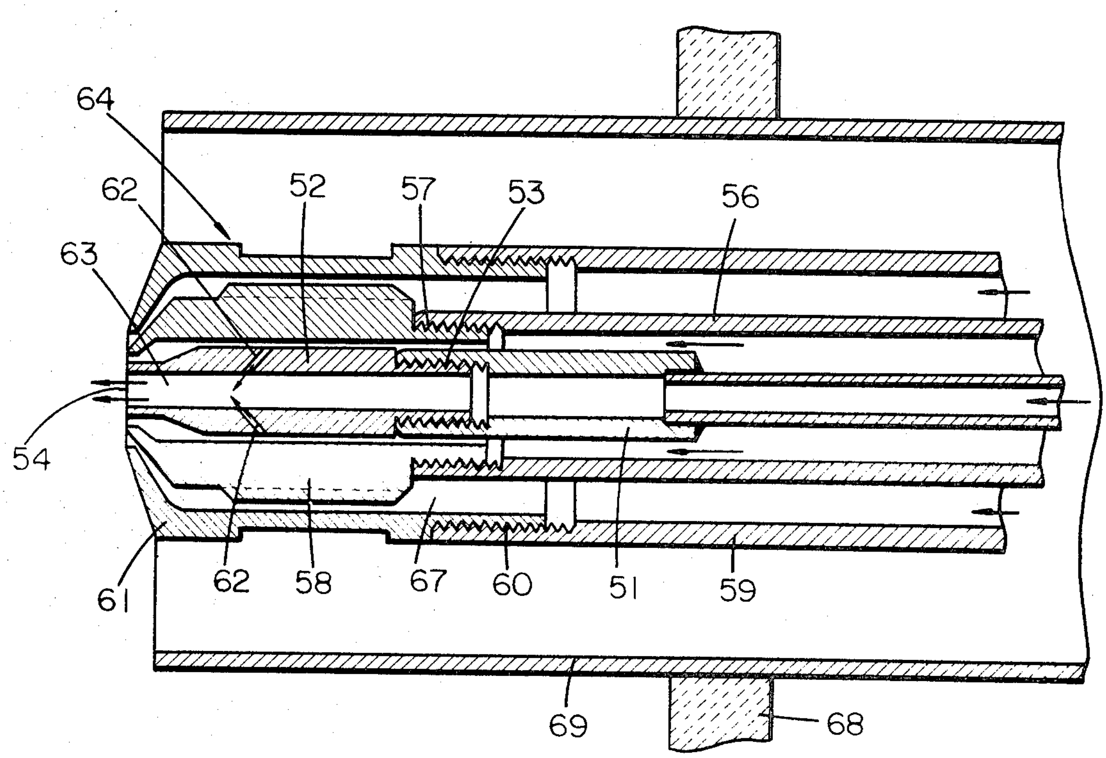


Fig. 1

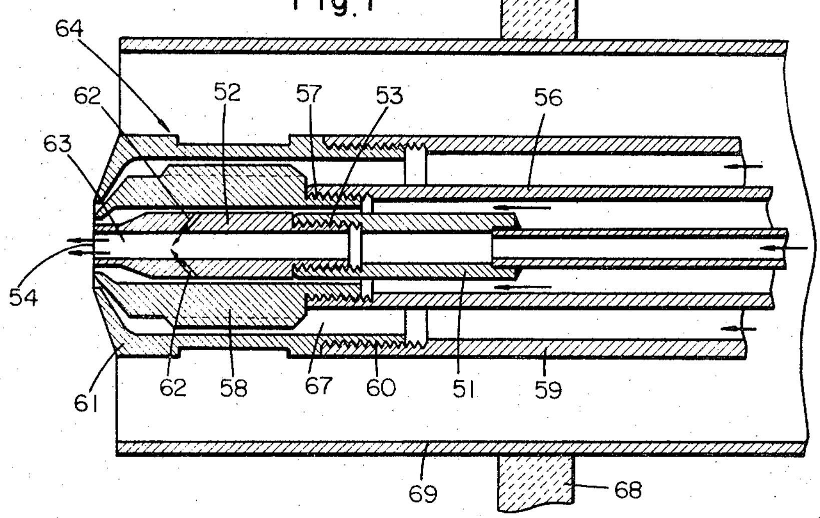
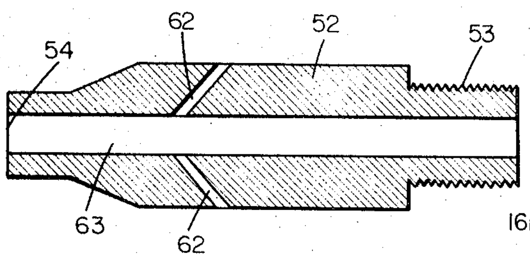


Fig. 2



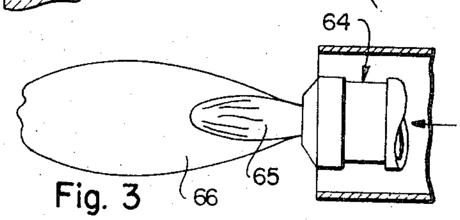
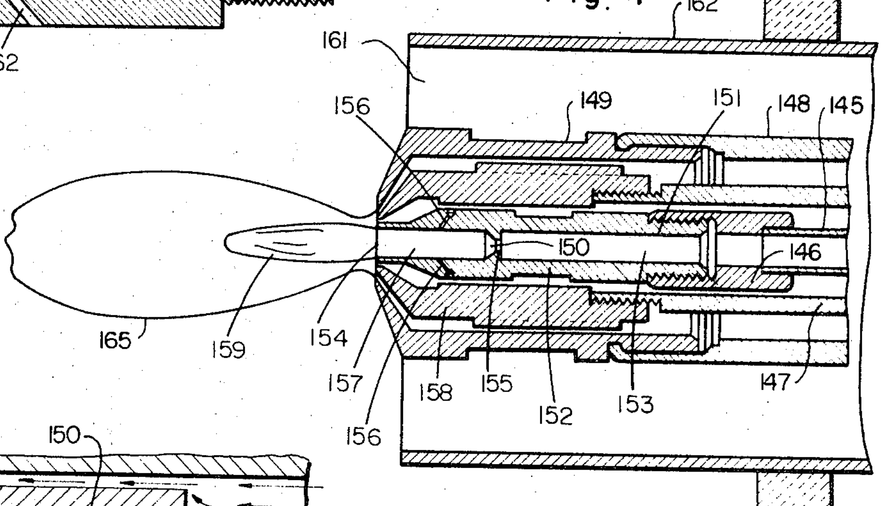


Fig. 3

Fig. 4



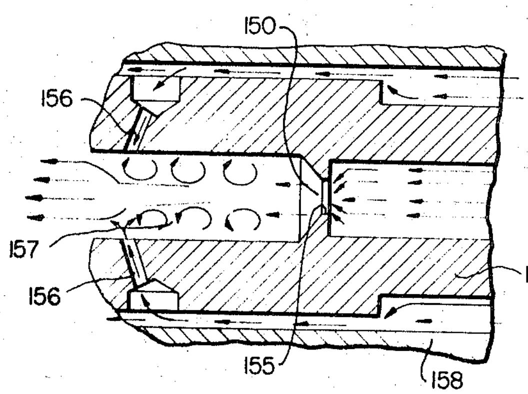


Fig. 5

LIQUID FUEL COMBUSTION DEVICE

This application is a division of U.S. application Ser. No. 794,221, filed Jan. 27,1969, now U.S. Pat. No. 3,610,537 Masayoshi Nakagawa et al, inventors.

BACKGROUND OF THE INVENTION

Combustion devices for burning liquid fuel by the addition of oxygen are required to minimize the issue and consumption of expensive oxygen gas for the combustion of the fuel, completely burn the liquid fuel issuing from the orifice and produce a high-temperature, intense flame (with a high calorific value per unit volume of the flame).

In conventional devices of the type described, the combustion efficiency and flame temperature can be increased by oxygen enrichment (i.e., by the addition of oxygen gas to air in order to bring a corresponding decrease of the amount or proportion of nitrogen in the air which takes part in the combustion). However, the combustion efficiency depends largely upon the manner in which the enrichment is made.

For example, some devices are so designed that oxygen gas is passed into the central part of the flame and, because the oxygen gas and liquid fuel are separately supplied without being pre-mixed, the increase of the nozzle velocity of oxygen gas above a certain value produces a jet of oxygen gas fast enough to blow the merging or mixing point of the gas and liquid fuel away from the nozzle tip. Consequently, oxygen gas and liquid fuel cannot be diffused and mixed thoroughly and rapidly notwithstanding the addition of oxygen gas. The arrangement is thus disadvantageous in that the oxygen gas fed in is only partly utilized and the flame thus obtained is not of a sufficiently elevated temperature.

As described above, it has hitherto been in practice to atomize liquid fuel beforehand and allow the atomized fuel to issue from an orifice in such a way as to simply entrain oxygen gas and carry it into the flame. Efforts have thus been centered on direct promotion of the combustion of the main flame through the addition of or enrichment with oxygen. Here it may appear at a first glance that the pre-atomization of liquid fuel will produce a high-temperature, high-intensity flame, but in reality the practice is merely contributory to complete combustion of liquid fuel. By the complete atomization the liquid fuel is widely diffused in the space, and the flame produced by combustion of this diffused liquid fuel is so thick and long that the calorific value per unit volume is below the level otherwise attained with the same quantity of heat, and the flame intensity is accordingly decreased. The flame of very large size also causes dissipation of heat over a wide area with a consequent drop of the flame temperature.

As will be appreciated from the foregoing, there has been no method and device for effecting the combustion of liquid fuel with a high flame intensity by the mere addition of a very small amount of pure oxygen.

This invention is directed to the provision of a liquid fuel combustion device which can satisfy all of the requirements above mentioned.

According to the present invention, the aforementioned disadvantages of the conventional devices are eliminated in the following way. First, a part of liquid fuel is burned with pure oxygen in an amount of less than the chemical equivalent in the central part of the nozzle tip of the combustion device to effect the combustion in an entirely pure oxygen atmosphere so as to produce a high-temperature, stable center flame there. The remainder of liquid fuel is then ejected through nozzle means so as to envelop the center flame and is instantaneously vaporized and decomposed by the extremely high heat of reaction of the center flame to produce, at the same time, a large amount of active radicals which rapidly diffuse in air serving to form a main flame. Altogether, a high-temperature flame of extremely great intensity is thus obtained. In other words, the combustion system of the invention is characterized in that the flame thereby produced includes a center flame and a main flame and that the pure oxygen added is not directly consumed for the combustion of the entire flame but it serves to form a center flame of an ultra-high temperature by the combustion of fuel in a totally pure oxygen atmosphere and then indirectly promotes the burning of the main flame with the aid of the center flame.

SUMMARY OF THE INVENTION

The liquid fuel combustion device according to the present invention pertains to a liquid fuel burner.

The device of the invention is characterized by a method and arrangement as represented by the first embodiment thereof shown in FIG. **1**, wherein an oxygen nozzle and a liquid fuel nozzle are separately provided in the central part of the combustion device, surrounded by a line for air or steam or their mixture, and a mixing chamber is provided near the tip of the oxygen nozzle in which a part of the liquid fuel is mixed with oxygen gas.

In this way it is made possible, in mixing and burning the liquid fuel with oxygen gas, to feed a part of the liquid fuel into the mixing chamber thereby to atomize, mix and burn the part of liquid fuel in that chamber, and also effect almost complete volatilization and decomposition of the rest of liquid fuel by the heat of reaction due to the partial combustion so that a flame as a whole at a high temperature and having a great intensity and stability can be produced.

As is well known, active radicals have important bearings upon the promotion of combustion. In accordance with the present invention, the active radicals are produced in a large quantity as the remainder or most of the liquid fuel is volatilized and decomposed around the stabilized center flame by the heat of reaction (i.e., the heat of combustion) of the center flame. This production of active radicals is combined with the transfer of heat from the high-temperature center flame that exists very close to the nozzle tip to promote the combustion of the main flame (i.e., the flame formed by the combustion of most of the liquid fuel in mixture with air or the like supplied through the gas line).

Thus, the combustion of a part of liquid fuel atomized and mixed with oxygen in the mixing chamber produces a small, highly-stable center flame at a high temperature at the nozzle tip, and the heat of reaction of the center flame in turn volatilizes and decomposes most of the liquid fuel to form a main flame around the center flame and very close thereto by the combustion upon diffusion with air or the like. Thus, a flame as a whole which is short in length can be obtained. By shortening the overall flame length in this way, the flame temperature can be raised and the quantity of heat per unit volume of the flame can be increased so as to heighten the flame intensity.

It is thus to be understood that the amount of pure oxygen that issues from the oxygen nozzle is controlled to a range (2 to 15 percent) that is far less than the theoretical amount of oxygen required for the combustion of the liquid fuel.

It is thus only necessary to supply from 2 to 15 percent of pure oxygen on the basis of the theoretical oxygen requirement in order to obtain a flame of high intensity.

In a further embodiment of the invention shown in FIG. 4, the oxygen nozzle is disposed inside the liquid fuel nozzle coaxially or substantially coaxially therewith, and an orifice portion for abruptly changing the pressure of oxygen gas thereby to cause a sudden increase of the oxygen flow velocity is formed in the central portion of the oxygen gas passage inside the oxygen nozzle away from the opening at the tip of the nozzle and at a point upstream of the flow direction of the oxygen gas, and a flow passage or passages branched from the liquid fuel nozzle are open in the oxygen nozzle at a point between the orifice portion and front end of the oxygen nozzle.

The orifice portion produces vortices of oxygen wherein a part of the liquid fuel is mixed. As a result, the mixing of the liquid fuel and oxygen gas is promoted and the ignitability is much improved and further a stabilized center flame is thereby formed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows in longitudinal cross section the essential part of the first embodiment of the liquid fuel combustion device of the present invention;

FIG. **2** is an enlarged longitudinal cross section of the oxygen nozzle shown in FIG. **1**;

FIG. **3** is an elevational view explanatory of the pattern of flame according to the first embodiment;

FIG. **4** shows in cross section a further embodiment of the invention disclosed in FIG. **1** and;

FIG. **5** is an enlarged longitudinal section of the oxygen nozzle of FIG. **4**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The construction of the liquid fuel combustion device according to the present invention will now be described in conjunction with FIG. **1** showing the first embodiment thereof. In the center of the device shown there is provided an oxygen line **51** to the front end of which is fitted an oxygen nozzle **52**. The two members are connected to each other through the engagement of threaded portions **53** detachably to the axis of the oxygen line **51**. This detachability of the oxygen nozzle **52** permits selective use of a plurality of interchangeable oxygen nozzles **52**. Through the oxygen line **51** and oxygen nozzle **52** high purity oxygen gas passes usually under a low pressure of about 0.3 to 2.0 kg/cm^2G and is emitted from the tip **54** of the oxygen nozzle **52**.

Oxygen line **51** is surrounded by a liquid fuel line **56**, to the front end of which is also fitted a liquid fuel nozzle **58** as if to envelop the oxygen nozzle **52**. This liquid fuel nozzle **58** is connected through the engagement of threaded portions **57** to the liquid fuel line **56** in such a manner that it can be detached therefrom. The detachability of this liquid fuel nozzle **58** serves the same purposes as those of the oxygen nozzle **52** already described. Through the liquid fuel line **56** and liquid fuel nozzle **58** flows a liquid fuel such as a heavy oil.

Liquid fuel line **56** is further surrounded by a gas line **59** which is connected at the front end with a gas nozzle **61** enveloping the liquid fuel nozzle **58**, detachably from the line through the engagement of threaded portions **60**. The detachability of this gas nozzle **61** permits the same functions as those of the oxygen nozzle **52** and liquid fuel nozzle **58**. Through the gas line **59** and gas nozzle **61** and via another line **67** passes air or steam or their mixture for atomizing the heavy oil. This gas for atomization use need not always be kept at a high pressure or run at a high velocity. Therefore, the feed arrangement may be of a relatively simple structure. Displacement of the nozzles with respect to one another enables the supply of gas to be shut off or adjusted where necessary.

Near the tip **54** of the oxygen nozzle **52** there is formed a mixing chamber wherein a part of the heavy oil is mixed with oxygen gas. As shown in an enlarged longitudinal section in FIG. **2**, the oxygen nozzle **52** is formed with one or a plurality of passages **62** for the introduction of the heavy oil that are open in the bore of the nozzle **52** close to the tip **54**. Thus, a mixing chamber **63** is defined which attracts a part of the heavy oil into the oxygen nozzle **52** by the injector action of the apertures under the influence of the flow of oxygen gas through the oxygen nozzle **52** at a flow rate within a certain range, and thus mixes the heavy oil so attracted by suction with the oxygen gas.

With the construction above described, the burner **64** is accommodated in a combustion-sustaining air line **69** coaxially or substantially coaxially therewith, usually penetrating altogether through a furnace wall **68** with the front end portion held inside the furnace.

Oxygen gas that flows through the oxygen nozzle **52** issues from the tip **54** past the mixing chamber **63**. As it passes along the heavy oil-introduced passages **62**, it induces an injector action thereby to attract by suction a part of the heavy oil in the liquid fuel nozzle **58** through the passages **62** into the oxygen nozzle **52**. The fraction of heavy oil thus attracted is atomized and mixed up by the oxygen gas passing through the mixing chamber **63** and in the atomized and mixed state it is thus blown out of the tip **54**. As shown in FIG. **3**, this atomized mixture upon ignition forms a high-temperature and well-stabilized center flame **65** due to combustion with pure oxygen gas adjacent to the tip center of the burner **64**.

The remainder of the heavy oil is emitted from the tip of the liquid fuel nozzle **58** into the atmosphere along the periphery of the center flame **65**. At this time, the heavy oil is atomized and dispersed by the gas also issuing out of the gas nozzle **61** surrounding the liquid fuel nozzle **58**. The liquid fuel thus atomized and dispersed is vaporized and decomposed around the center flame **65** by the high heat of reaction thereof and gives off a large amount of active radicals. The increased volume of active radicals combines with the high heat of reaction of the center flame **65** to promote the combustion of most of the liquid fuel so vaporized and decomposed. Around the center flame **65** and at a point quite close thereto, the vaporized and decomposed liquid fuel is burned in a state diffused by and mixed with the combustion air supplied from the combustion-sustaining air line **69**, thus forming a main flame **66**. On account of the high temperature of the center flame **65**, the mixing of the atomized liquid fuel after vaporization with oxygen in the surrounding air is rapidly accomplished due to the high molecular velocity. In this manner the gaseous mixture is burned at a high burning velocity.

Accordingly, the main flame **66** having the high-temperature center flame **65** at the tip of the burner **64** is so formed that the main flame **66** itself has a short overall length. The quantity of heat being the same, the short main flame **66** has a higher calorific value per unit volume than ordinary flames, and hence a greater flame intensity. Because the flame is short and the surface area is small, the heat-radiating area is accordingly limited and the heat of combustion can be supplied to a desired zone concentrically and efficiently without waste. Further, because the flame length is short and the main flame **66** is formed near the burner **64**, flame stability is attained without the possibility of lifting.

Combustion-sustaining air need not always be supplied through the air line **69** as illustrated in this embodiment, but it may be introduced from a separate route. In any case, it is most desirable that the air be fed in the direction toward the tip of the burner **64** or around the center flame **65**.

For the reasons above stated, it is possible according to the present invention that through a combination of

a. the supply of oxygen substantially in the form of pure oxygen in an amount far less than that theoretically required for combustion of liquid fuel to be burned so that a very rapid combustion temperature rise can be attained,

b. with the strong activation of the liquid fuel by mixing and atomization of a part of the fuel liquid sufficiently with the oxygen, limited in quantity, closely adjacent to a liquid fuel nozzle thereby to form a center flame at a suitable temperature very close to the nozzle,

c. a high-temperature flame having a large calorific value per unit volume thereof, that is, a flame of extremely high intensity, is obtained efficiently with a small supply of oxygen.

It is further to be noted that the nozzles are fitted to be adjustable relative to one another in the longitudinal direction by means of adjustment setting of the respective regulating handle (not shown in the drawings). This adjustment, together with readjustment of the respective fluid pressure, enables a single type of nozzle to meet any material changes in the amount of fuel oil and oxygen to be added, and permits adjustments of flame contour over an extensive range.

The construction of the additional embodiment will now be explained described.

To an oxygen line **145** disposed in the central part of the device is connected an oxygen nozzle **152** through a nozzle joint. Surrounding this oxygen line **145** there is provided a liquid fuel line **147**, to the front end of which is connected a liquid fuel nozzle **158**. The liquid fuel line **147** and liquid fuel nozzle **158** are arranged outside the oxygen line **145** and oxygen nozzle **152** coaxially or substantially coaxially therewith. Further outside the liquid fuel line **147** an air line **148** is disposed which has an air nozzle **149** at its front end. In the middle part of the oxygen gas passage **153** in the oxygen nozzle **152** there is formed an orifice **155** integrally with the oxygen nozzle **152** and which protrudes axially at a point fairly upstream of the oxygen flow direction from the tip **154** of the nozzle **152** and in the direction approaching the center of the oxygen flow passage **153** so that it can abruptly increase the flow velocity of oxygen gas. By the provision of this orifice **155** an abruptly changing portion **150** is formed in the oxygen flow passage **153**. In the space defined between the abruptly changing portion **150** and tip **154** of the oxygen nozzle **152** is provided one or a plurality of heavy oil passages **156** which are flow passages branched from the liquid fuel nozzle **158**, inclined or substantially perpendicular to the axis of the device. Inside the oxygen flow passage **153** of the oxygen nozzle **152** there is formed a mixing chamber **157** between the orifice **155** and tip **154**.

A burner **161** of the foregoing construction is held in a combustion-sustaining air line **162** coaxially or substantially coaxially therewith, with the frontal part usually penetrating through a furnace wall **163** and extending into the furnace.

With such an arrangement, a part of the heavy oil is fed into the oxygen nozzle **152** through the passages **156** and mixed with oxygen gas in the mixing chamber **157** and then the mixture is injected out of the tip **154** and burned to form a center flame **159**. The remainder of the heavy oil is injected from the tip of the liquid fuel nozzle **158** and is atomized by the atomizing air issuing from the air nozzle **149** and is then burned together with the combustion-sustaining air supplied from the air line **162**, whereby a main flame **165** is formed enveloping the center flame **159**. This condition will be more fully described with reference to FIG. **5**. The oxygen gas forced from the oxygen flow passage **153** toward the mixing chamber **157** is collected in the zone along the axial center of the oxygen flow passage **153** by means of the abruptly changing portion **150**. The oxygen gas so collected is abruptly injected into the mixing chamber **157** along the axial center zone thereof. A part of the oxygen gas surrounding the outer periphery of the jet is abruptly introduced into the chamber where it is made turbulent in the mixing chamber **157** and caused to form a vortex flow therein. The heavy oil fed through the passages **156** is involved in the vortex of oxygen gas, and the oxygen gas and heavy oil in the vortex flow move toward the tip opening **154** while being thoroughly mixed and perfectly atomized in the mixing chamber **157** before the gaseous mixture issues from the tip **154**.

Thus, the orifice **155** produces a fairly intense vortex flow and permits vigorous suction of liquid fuel through the passages **156** and very thorough dispersion and mixing of the liquid fuel with oxygen gas. The resulting mixture attains very good ignitability and flame stability within an extremely wide range of oxygen flow rate.

The advantage of this functional construction over the prior art is that the device of the construction according to the preferred embodiment is so modified in design as to supply pure oxygen in an amount of from 2 to 15 percent of the theoretical requirement. Therefore, the small volume of the flame is formed as above described, and the flame temperature is as high as about 1700° to about 2,200° C, or the flame has a correspondingly high intensity.

What is claimed is:

1. A method of producing a flame from an oil burner, which has a high intensity and a high calorific value per unit volume comprising the steps of

supplying high purity oxygen through a conduit to a first nozzle;

introducing liquid fuel through a concentrically disposed conduit to a second nozzle;

diverting a portion of the liquid fuel in said other conduit into the first nozzle supplying the air to the burner;

mixing the air and the diverted portion of liquid in the nozzle and emitting therefrom a flame having a temperature ranging between about **1700°C** to about **2200°C**;

and furnishing gas through a second concentrically disposed conduit to a third nozzle to complete atomization and dispersion of the oil being emitted from the second nozzle by the flame ejected from the first nozzle.

2. A method of producing a flame from an oil burner as claimed in claim **1**, further including the steps of emitting the oil and gas from their respective nozzles in a divergent direction and toward the flow line of the oxygen emitted from the first nozzle.

3. A method of producing a flame from an oil burner as claimed in claim **1**, wherein the oxygen is under low pres-sure of about 0.3 to 2.0 kg/cm^2 G.

4. A method of producing a flame from an oil burner as claimed in claim **1**, wherein the oxygen is introduced to the first nozzle in an amount between 2–15 percent of that theoretically required for combustion of the liquid fuel.

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