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Shular

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[54] **BURNER APPARATUS AND METHOD FOR FLAME PROPAGATION CONTROL**

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[52] **U.S. Cl.** **431/182,** 431/185, 431/186, 431/187, 431/351

[51] **Int. Cl.** **F23m 9/00**

[58] **Field of Search** 431/9, 182, 185–188, 431/351, 353

[56] **References Cited**

UNITED STATES PATENTS

1,788,716	1/1931	Hepburn	431/188
2,325,318	7/1943	Hendrix	431/185
2,385,153	9/1945	Morton	431/186
2,815,069	12/1957	Garraway	431/185
2,973,032	2/1961	Reilly et al.	431/188
3,050,112	8/1962	Saunders et al.	431/348
3,221,796	12/1965	Nesbitt	431/185
3,676,048	7/1972	Sellors et al.	431/187

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[57] **ABSTRACT**

A burner apparatus comprises a fuel burner and flame tunnel in combination. The tunnel is of a suitable refractory material and is substantially goblet-shaped in cross section, comprising a first substantially cylindrical section and a second cup-shaped section, both sections being disposed along a common, longitudinal axis. The first, substantially cylindrical section diverges in the direction of fuel and air flow at an angle of not more than about 3° and preferably about 1½° from a theoretical cylindrical surface. The second, cup-shaped section faces the furnace side of the tunnel and diverges from its longitudinal axis in a convexo-curved section, then a concavo-curved section and then terminates in a substantially cylindrical section at its outlet end. The outlet diameter is at least as great as the distance along the longitudinal axis of the curved segments of the second, cup-shaped section, and is at least two and one-half times and preferably four times as great as the inlet diameter of the first, substantially cylindrical section.

Fuel and a first portion of combustion air are introduced with a rotational motion into the first section of the flame tunnel. A second portion of combustion air is injected at high velocity into the fuel/air admixture in a direction substantially transverse to the direction of flow through the flame tunnel. Combustion takes place in the flame tunnel, and a high kinetic energy is imposed upon the burning gas and air mixture within the confines of the first substantially cylindrical section. The injected, high velocity second portion of combustion air and the expanded, cup-shaped flame tunnel provide a full cross section highly radiating flame within the flame tunnel.

3 Claims, 7 Drawing Figures

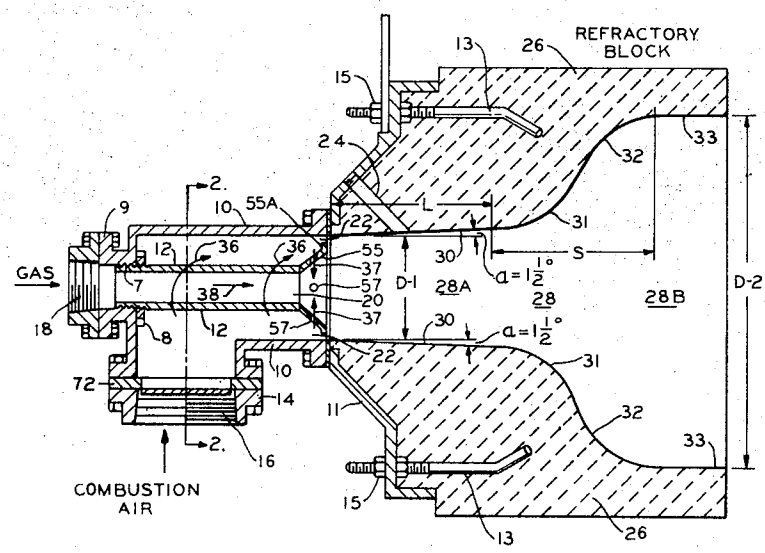

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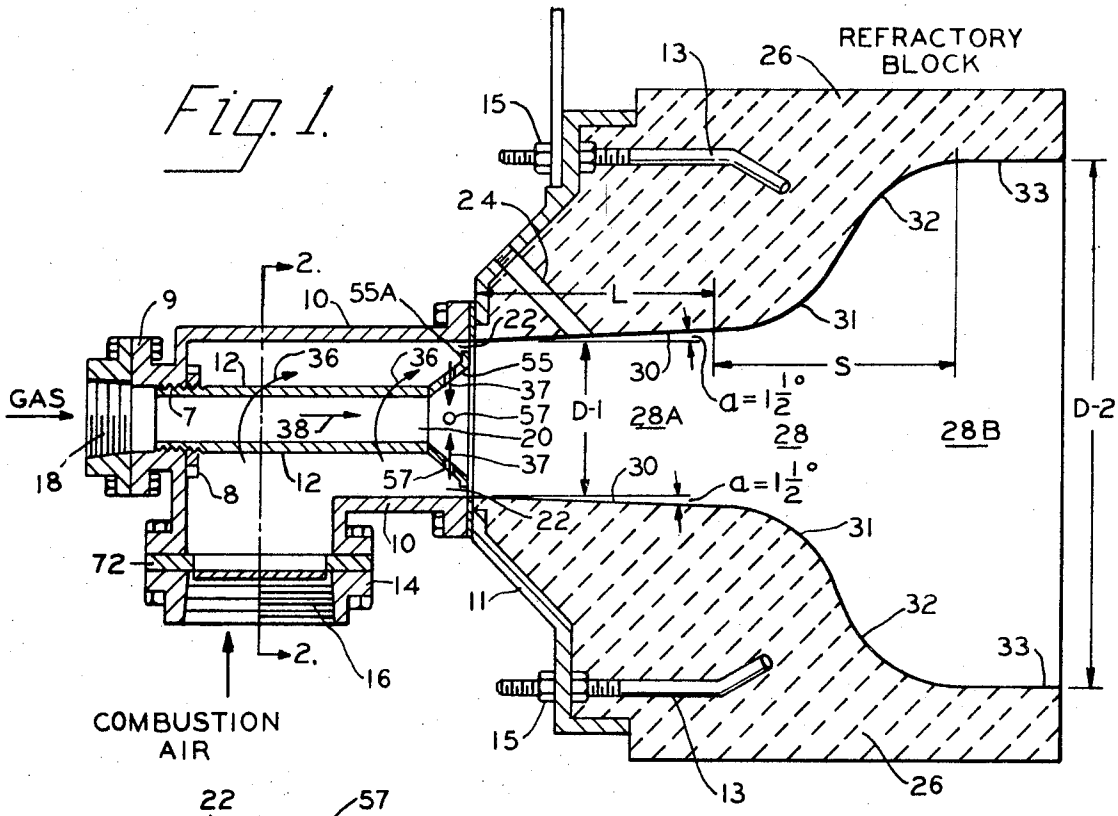
Fig. 1.



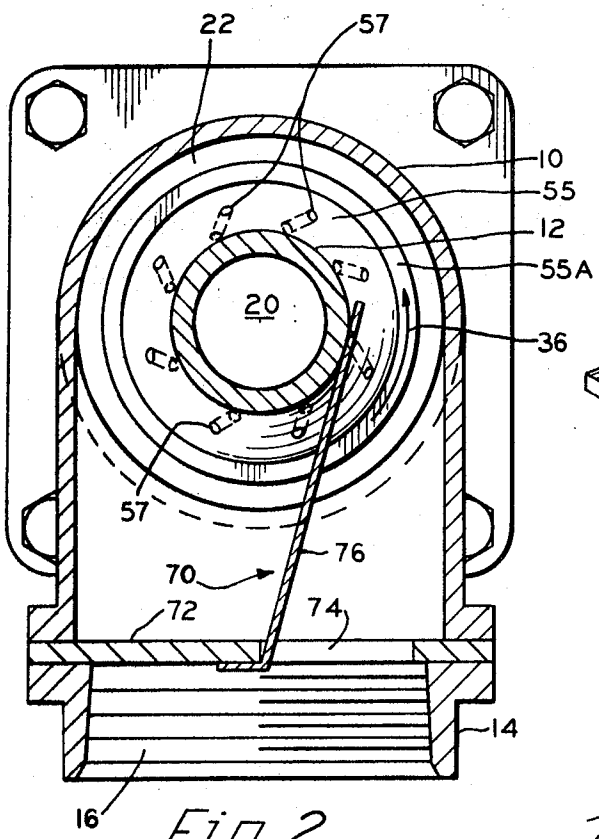


Fig. 2.

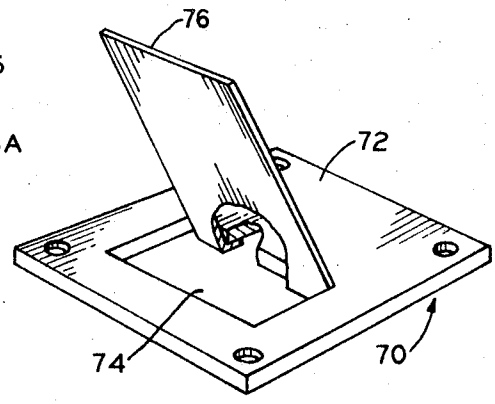


Fig. 6.

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Fig. 3.

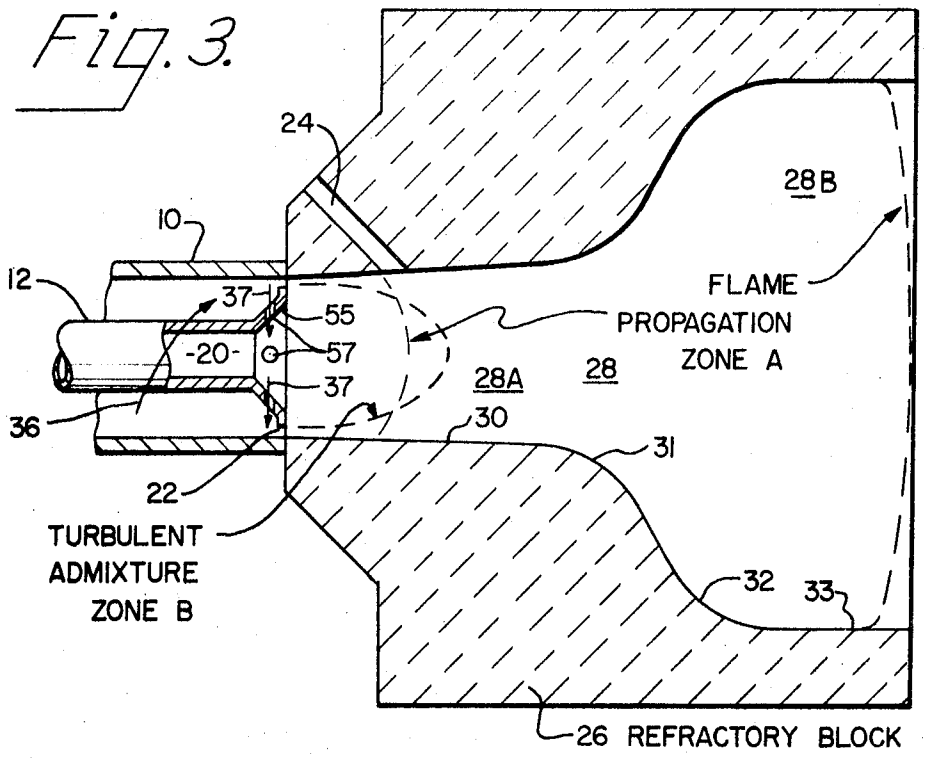

Fig. 7.

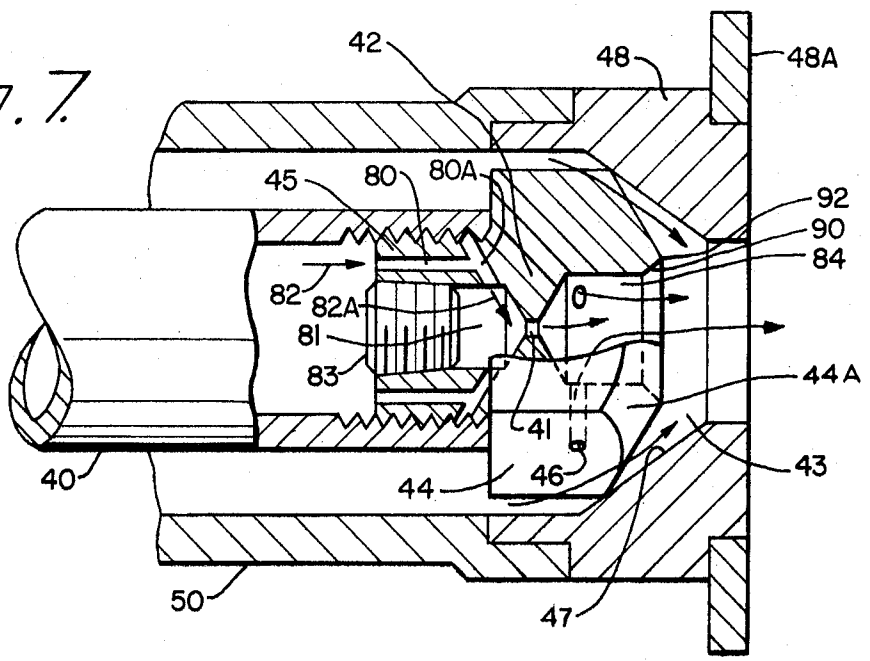

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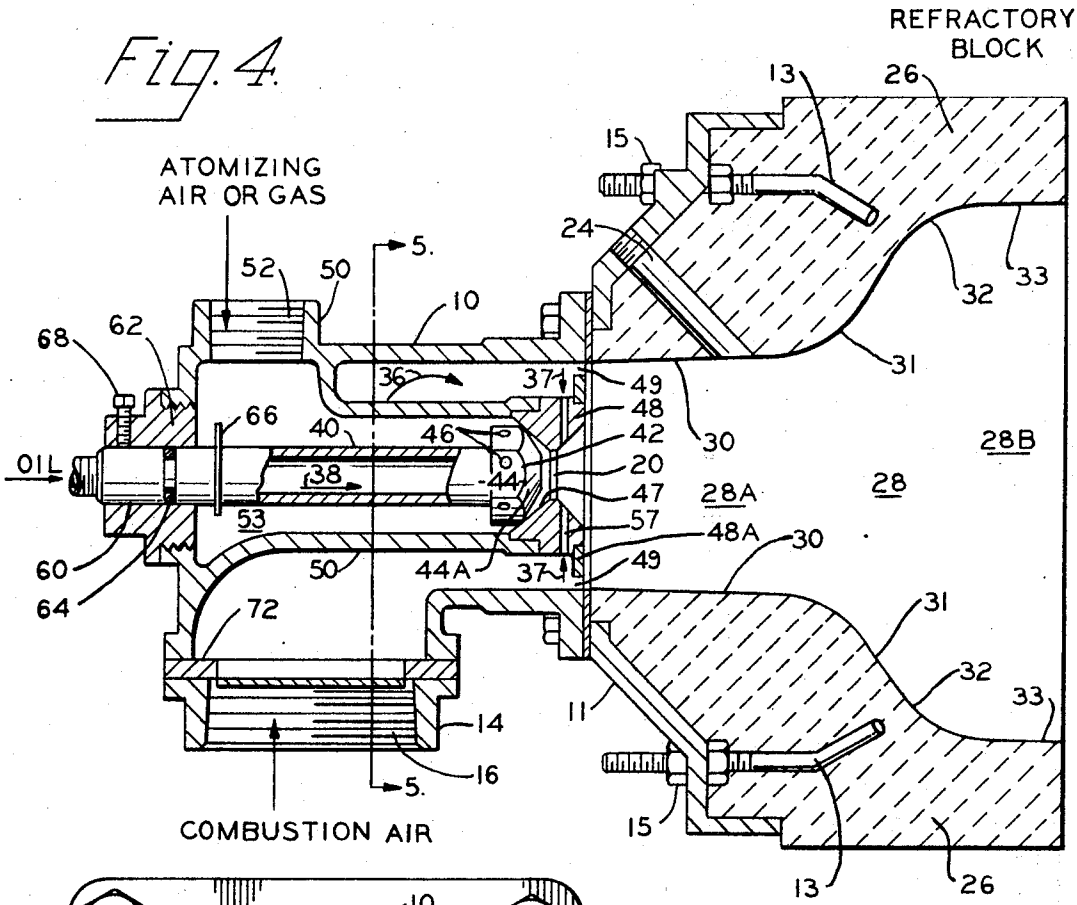
Fig. 4.



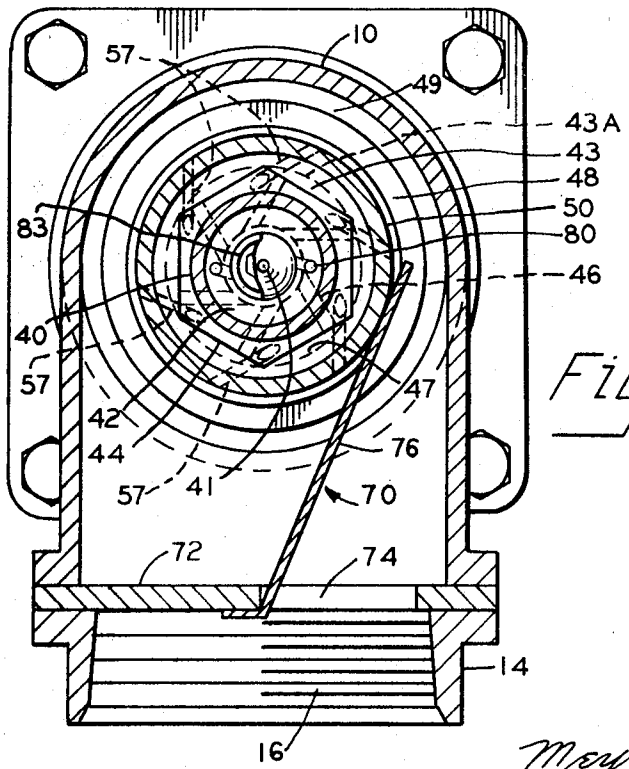


Fig. 5.

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BURNER APPARATUS AND METHOD FOR FLAME PROPAGATION CONTROL

THE DISCLOSURE

The present invention pertains to burners for the combustion of fuels, and,more particularly, to burners adapted to burn either gaseous or liquid hydrocarbon fuels. The invention is particularly applicable to gas or oil burners such as are employed for a wide variety of commercial process heating applications. Hydrocarbons which are normally liquid at ambient temperature and pressure are hereinafter referred to as "oil," and gaseous fuels such as natural gas, propane gas and the like, which are normally gaseous at ambient temperature and pressure, are hereinafter referred to as "gas."

Such burners generally comprise, in combination with a flame tunnel, a substantially cylindrical member containing a fuel inlet, an air inlet and a mixing nozzle. The fuel and air are admixed and injected into the flame tunnel, which is formed within a refractory block. In prior art burners the fuel and air are premixed. That is, they are admixed prior to entering the flame tunnel, to insure complete and thorough mixing of combustion air and fuel. Generally, at least a portion of the total combustion air to be used is premixed with the fuel at the fuel inlet into the burner body. Oil is broken up into tiny droplets to form a fine mist prior to combustion, usually by imparting a high velocity to the oil by injecting it through fine nozzles or by impacting it with a gaseous medium, such as air or steam. Combustion air is then admixed with the the vaporized oil. The vaporization, sometimes referred to as nebulization of the oil, is necessary in order to attain efficient and complete combustion of oil, and is usually accomplished by affixing a nebulizer nozzle to the oil conduit outlet. Prior art mixing nozzles usually comprise a nozzle through which the oil is sprayed and around which a portion of atomizing air is flowed to impact the oil spray emerging from the nozzle. The atomizing air is flowed through a passageway formed between the outer surface of the nozzle and the inner surface of an adjustable cap surmounting the nozzle, so that the size of the passageway can be varied to attain efficient nebulization of oil at different oil flow rates. Varying the size of the passageway to accommodate different oil flow rates is required because the flow rate of atomizing air usually is constant regardless of the firing (oil) rate of the burner.

Gas, being already in a gaseous state, need only be thoroughly mixed with combustion air, usually by forcing the gas or the air, or both, through restricted passageways and injecting one into the path of the other in order to obtain a rapid and complete mixing and combustion.

Burners and flame tunnels are designed to provide different flame configurations because of the differing demands of different heating processes. For example, it may be desired to have a short, relatively compact "short burst" flame, or an extended "long burst" flame. Heating may be accomplished by direct radiation from the flame to the surface being heated, by convection of hot gases from the flame over the object being heated, and, most often, by a combination of the two. Accordingly, it is important to control flame propagation without, however, interfering with the proper and complete combustion of the fuel, and without interfering with nebulization of oil when it is used as the fuel.

The present invention contemplates a new and improved burner and flame tunnel combination and method of operation thereof, which permits control of flame propagation without sacrificing excellent combustion characteristics. In accordance with the invention, a highly radiating "solid" flame, i.e., a flame in which combustion takes place throughout the entire cross section thereof, is attained by controlling the injection of combustion air and fuel into a flame tunnel of prescribed shape, which tends to "focus" the radiant energy from the flame in a desired direction.

In accordance with the present invention, there is provided a burner having a flame tunnel which comprises a first section which is substantially cylindrical in shape, and a second section which is substantially cup-shaped, diverging from the inlet to the outlet end thereof and terminating in a large diameter outlet at the furnace end thereof. The first and second sections have a common longitudinal axis. Fuel and a first portion of combustion air are introduced into the inlet end of the flame tunnel, preferably with a rotational motion about the common longitudinal axis. A second portion of combustion air is injected into the air/fuel admixture at high velocity and substantially transversely to the longitudinal axis of the flame tunnel. The transverse injection of air is of sufficient force and quantity to insure combustion throughout the entire cross section of the flame tunnel as the combustion mixture enters the expanded, second section thereof. Preferably, the second portion of air is introduced tangentially with respect to fuel conduit so that rotational motion of the fuel/air mixture is enhanced. The result is a full cross section, highly radiating flame.

The injected air may conveniently be, and preferably is, obtained by diverting a portion of the combustion air fed to the burner through suitable injection ports. Alternatively, a separate conduit to supply the injection ports with air may be provided, and reference in the specification and claims to combustion air injected through said ports shall be deemed to mean and include air from any source.

The second, cup-shaped section expands to a diameter which is sufficient to contain the entire flame within the flame tunnel, and is shaped with smooth, curved surface connects the substantially cylindrical first section with the outlet end of the cup-shaped second section. The outlet end of the second, cup-shaped section may be and preferably is substantially cylindrical in shape, although this is not essential. The curved portion of the second, cup-shaped section which connects the first section with the substantially cylindrical outlet end of the second section is referred to in this specification and claims as the "transition surface." The length along the portion of the longitudinal axis of the flame tunnel corresponding to the transition surface is referred to in this specification and claims as the "transition length."

In order to attain the desired solid, cup-shaped, full cross section flame in accordance with the invention, the outlet diameter of the flame tunnel must be at least as great as the transition distance and preferably between about one to two times as great, and the outlet diameter of the flame tunnel must be at least two and one-half , and preferably four times as great as the inlet diameter of the first section of the flame tunnel.

As used in the specification and claims, the "length" of the first and second sections of the flame tunnel refers to the length along their respective segments of

their common longitudinal axis; "inlet" and "outlet" used to describe the several diameters or ends of the sections refer to the movement of fuel and combustion air therethrough.

The high velocity attained by the combustion mixture in the elongated first section of the flame tunnel provides excellent mixing of the fuel and air, the first section of the flame tunnel thus serving as an extended fuel mixing throat.

Further, the high velocity attained by the combustion mixture in the substantially cylindrical portion of the flame tunnel causes the combustion mixture to reach the second section of the flame tunnel at an earlier stage of combustion than it otherwise would. In those cases where air is present in the furnace atmosphere, this feature makes such furnace air available to assist in completing the combustion of the fuel.

Further, the extended length of the first section provides an adequate distance between the fuel conduit outlet and the full section flame in the flame tunnel to avoid overheating the fuel conduit outlet. Such overheating, in the case of an oil fuel, can carbonize the fuel in the fine passageways of the nebulizer nozzle.

The present invention, accordingly, contemplates a new and improved burner and method of operation thereof which provides a controlled, full cross section, highly radiating flame which substantially fills the cup-shaped section of the flame tunnel and provides complete fuel combustion without interferring with nebulization of oil or proper mixture of fuel and air.

In accordance with the present invention, there is provided a burner in which combustion air admixed with fuel is passed into a flame tunnel which is substantially goblet-shaped and comprises first and second sections. The first section is substantially cylindrical in shape and the second section is substantally cup-shaped, increasing in diameter from the inlet to the outlet end thereof, in, preferably, a convexo-curved segment, a concavo-curved segment and a substantially cylindrical outlet segment.

The length of the convexo-concavo curved segments as measured along the longitudinal axis (the transition length) is, in accordance with one aspect of the invention, at least as great as the outlet diameter of the second section of the flame tunnel, and preferably between one and two times as great. This ratio of transition length to outlet diameter, in conjunction with injected combustion air, assures a rapid enough divergence of the cup-shaped second section to contain the flame as a full cross section highly radiating flame within the cup-shaped tunnel.

In accordance with another aspect of the invention, the substantially cylindrical first section diverges slightly in the direction of flame travel, preferably, so that the walls of the first section diverge at an angle of between ½° and 3°, more preferably at an angle between about 1° and 2°, from the walls of a theoretical cylinder placed concentric with the first section, and of a diameter equal to the inlet diameter of the first section.

In accordance with another aspect of the invention, the combustion air is introduced through a slotted, baffled entry-way wherein a high velocity and rotational movement is imparted to the air by means of the restricted slotted opening and baffle. The rotational and high velocity aid in obtaining turbulent mixing of injected combustion air to attain the full cross section flame.

The invention is applicable to gas burners, to oil burners and to burners adapted to burn either oil or gas.

When the fuel employed is oil which must, as aforesaid, be nebulized into fine particles in order to assure good admixtures with air and complete combustion, a nebulizer nozzle is employed. A preferred form of nebulizer nozzle is described in copending patent application Ser. No. 189,178, filed Oct. 14, 1971 and assigned to the assignee of this application, which describes a nozzle into which air is injected at high velocity to entrain the oil, passed in thin sheets or filaments over a chamfered surface terminating in a knife-edge. The filaments of oil are broken into fine particles by being impacted with atomizing air moving substantially transversely to the direction of travel of the oil filaments.

After nebulization, the oil particles, in admixture with combustion air, are introduced into the first section of the flame tunnel wherein the high velocity and turbulence sustained through the first, substantially cylindrical section of the flame tunnel completes nebulization of the oil, and the heat from the combustion gasifies the droplets of oil, assuring that no liquid persists and aiding complete combustion of the fuel.

The invention may take physical form in certain parts and arrangements of parts, an embodiment of which is described in detail in the following portion of the specification, and illustrated in the accompanying drawings, wherein:

FIG. 1 shows a longitudinal section view of a burner and flame tunnel in accordance with the invention, adapted to burn gas.

FIG. 2 is a section view taken along lines 2—2 of FIG. 1.

FIG. 3 is a schematic representation of the flame propagation and low pressure zones created by a burner in accordance with the invention.

FIG. 4 is a longitudinal section view of another burner and flame tunnel in accordance with the invention, adapted to burn either gas or oil.

FIG. 5 is a section view taken along lines 5—5 of FIG. 4.

FIG. 6 is a perspective view of an embodiment of a combustion air rotation means comprising a seal plate containing a slot and baffle, which means may be employed in connection with the burner of the invention.

FIG. 7 is an enlarged view in partial section of the nozzle 42 employed in the embodiment of FIGS. 4 and 5.

The burner of the apparatus of the invention may comprise a conduit for introducing fuel into the burner, the conduit being positioned within and substantially concentric to a combustion air inlet conduit. Combustion air enters the combustion air conduit via a branch section which joins the conduit at substantially a right angle thereto. The fuel conduit enters the combustion air conduit through an opening provided in the base thereof, the fuel conduit being seated snugly in the opening so that opening is air-tight with respect to air passing through the combustion conduit. The flow of combustion air through the combustion air conduit and the flow of fuel through its conduit are thus maintained isolated one from the other up to the respective exits therefrom, at which point the fuel and combustion air are commingled at the entrance to the first section of

the flame tunnel. It should be noted that the fuel and combustion air are not premixed, that is, they are separately conducted to the entrance of the flame tunnel and mixed at this point, not before. By employing this "nozzle-mixing"technique rather than premixing the fuel and combustion air, the danger of flash-back, i.e., premature combustion of the fuel/air mixture,which is always present with premixed feeds, is eliminated.

A secondary conduit to introduce atomizing air when oil is the fuel, or to serve as the conduit for introducing fuel into the burner when gas is the fuel, may be employed in addition to the fuel and combustion air conduits in embodiments of the invention adapted to burn oil as well as gas. In such a case, the secondary conduit may be positioned substantially concentrically with respect to the fuel conduit and combustion air conduits, so that the three substantially concentrically positioned conduits are maintained isolated from flow communication between one another except at the respective exits therefrom, at which point the admixed air and fuel are commingled at the entrance to the first section of the flame tunnel.

The outlet end of the fuel conduit preferably comprises a fuel nozzle of the nebulizer type wherein oil is sprayed into a fine stream and passed into the path of a gaseous medium, e.g., atomizing air, in order to disperse the oil into fine droplets. When it is desired to burn gas as a fuel, the secondary conduit may be employed to carry the gas, in which case the secondary conduit serves as the conduit for introducing fuel into the burner, atomizing air not being required for a gas fuel. (For uniformity, the secondary conduit is always referred to as such, even when it serves to conduct gas in a dual-fuel burner. The fuel conduit is also always referred to as such even though in a gas burner it conducts only gas, in oil burners it conducts only oil, and in a dual-fuel burner it normally serves to conduct only oil. The term "conduit for fuel" as used in the specification and claims is a general term which includes fuel conduit and secondary conduit in a dual-fuel burner.)

In a dual-fuel burner, it is advantageous to seat the fuel conduit adjustably within the burner so that the opening of the secondary conduit into the flame tunnel may be varied in size by adjusting the position of the fuel conduit. In such case, the nozzle of the fuel conduit serves in effect as a plug or nozzle for the gas introduced into the flame tunnel via the secondary conduit. In this manner, the use of low pressure gas is enhanced since the secondary conduit outlet may be increased in size to accommodate low pressure gas transmitted therethrough.

Referring now to FIG. **1**, the gas burner shown is seen to consist substantially of two concentrically positioned conduits **10** and **12**, the base **7** of conduit **12** being screwed into the base **9** of combustion air conduit **10**. Locknut **8** serves to hold the fuel conduit **12** in place.

Branch conduit **14** comprises a conduit of substantially circular cross section meeting combustion air conduit **10**, also of substantially circular cross section, at substantially a right angle. Combustion air is introduced, as described hereinbelow, via inlet **16** of branch conduit **14**.

A mounting plate **11** is employed to hold the burner assembly in place in refractory block **26** by means of lugs **13** and nuts **15**, the lugs **13** being molded within refractory block **26**.

Combustion air rotation means (indicated generally at **70** in perspective view in FIG. **6**) may consist of a seal plate **72** with a slotted opening **74** cut therein adjacent to a baffle plate **76**. As is best understood by referring to FIGS. **1, 2** and **6**, jointly, seal plate **72** is positioned within branch conduit **14** so that baffle **76**, which is substantially as wide as the inner diameter of branch conduit **14**, substantially completely blocks the opening of branch conduit **14** into the lower portion (as viewed in the drawings) of combustion air conduit **10**.

As best seen in FIG. **2**, the opening **22** of combustion air conduit **10** is substantially doughnut-shaped and concentric to the substantially circular opening **20** of fuel conduit **12**. Openings **20** and **22** lead into flame tunnel **28**, formed within refractory block **26**. The method of forming the flame tunnel within the refractory blocks forms no part of the present invention, and it suffices to state that the block is usually cast around a mandrel, the outer surface of which is shaped to form the inner surface of the flame tunnel.

An air deflector **55** of substantially conical shape is affixed to the outlet end of fuel conduit **12**. Air injection ports **57** are arranged around the periphery of air deflector **55** (as best seen in FIG. **2**). Opening **22** is formed between the rim **55A** of air deflector **55** and the inner surface of combustion air conduit **10**. Air injection ports **57** are seen to be positioned in a plane substantially perpendicular to the longitudinal axis of flame tunnel **28** and fuel conduit **10**, and tangentially with respect to the overall direction of flow of fuel and air emerging from and around nozzle **42**. Air introduced via ports **57** is thus tangentially injected, which enhances rotational flow of the fuel and air mixture.

A channel **24** leading into flame tunnel **28** contains a pilot light (not shown) which serves to ignite the fuel-/air mixture passing through flame tunnel **28**.

Referring particularly now to FIG. **1**, the inlet diameter of flame tunnel **28** is shown as the dimension D-1 and the outlet diameter as dimension D-2. The length along the longitudinal axis of the curved segments of the second section **28B**, i.e., the transition length, is shown by the dimension S. The length of first section **28A** is indicated by the dimension L.

Flame tunnel **28** comprises a first, substantially cylindrical shaped section **28A**, the surfaces of which are designated by the numeral **30**, and a second, substantially cup-shaped section **28B**, the surfaces of which are designated by the numerals **31, 32** and **33**. The surfaces **30** are seen to diverge in the direction of flame travel at an angle of about 1½° from the surface of a theoretical cylinder placed concentrically with, and of equal diameter with, the inlet diameter of the first section **28A**. The second section **28B** is defined by surfaces **31, 32** and **33** which flare outwardly in a convexo-curved segment **31**, a concavo-curved segment **32** and a substantially cylindrical segment **33**. The concavo-convexo-cylindrical sequence is not essential, but is preferred. Any smoothly curving configuration which expands the diameter of the flame tunnel abruptly in relation to its length so as to contain and focus a full cross section highly radiating flame will suffice. Sufficiently abrupt expansion is attained in accordance with the invention if outlet diameter D-2 is at least as great as transition length S, and preferably between one and two times as great.

In operation, combustion air enters conduit **10** via inlet **16** of branch **14** and passes through slotted open-

ings 74. Because of the small size of opening 74, a high velocity is imparted to the air passing therethrough. A rotational motion about conduit 12 is imparted to the air by baffle 76 (as best seen in FIG. 2) which deflects the incoming air, as indicated by the arrows in FIG. 2, over and around conduit 12. The combustion air progresses through conduit 10 as shown by the arrows 36 in FIG. 1, and a first portion thereof emerges through outlet 22. The rotational velocity imparted to the combustion air by deflector means 70, and the restricted opening between air deflector rim 55A and the inside surface of combustion air conduit 10, impart a high velocity to the (first) portion of combustion air entering flame tunnel 28.

Gas is introduced via inlet 18 of fuel conduit 12, passes therethrough as shown by arrow 38 and emerges via opening 20 wherein it is injected with a second portion of combustion air.

The second portion of combustion air passes through inlet ports 57 in a direction substantially tangential to the general direction of flow of fuel through opening 20 into the flame tunnel 28. The combustion air is injected into the gas at high velocity, because of the small size of injection ports 57. The high velocity admixture results in enhancing the turbulent, rotational flow of gas and combustion air through the entire cross section of first section 28A of flame tunnel 28. The injected air assists in attaining a full cross section flame by providing sufficient air to support combustion throughout the cross sectional area of flame tunnel 28, and by insuring turbulent mixing of fuel and air.

The pilot light (not shown) positioned within channel 24 of refractory block 26 serves to ignite the gas/air mixture, and combustion takes place within flame tunnel 28.

As the admixed gas and combustion air mixture enters the first section 28A of flame tunnel 28, the rotational velocity of the mixture along the length of flame tunnel 28 is maintained and enhanced as the mixture combusts and expands in the relatively long and narrow first section. The length of the first section provides room for thorough admixture of the air and gas; the flame formed tends to fill the entire first section 28A, forming thereby a full cross section flame as best seen with reference to FIG. 3, which is a schematic representation of a cross sectional view of the flame. As the flame, shown in cross section as Flame Propagation Zone A, progresses along flame tunnel 28, it passes over surface 30 and enters the second section 28B of flame tunnel 28. Surface 30 connects to convexo transition surface 31, concavo transition surface 32 and then cylindrical surface 33, thereby connecting first section 28A and second section 28B of flame tunnel 28 with a smooth, abruptly diverging surface. The expanding flame, because of the injected combustion air and abrupt expansion in cross section is contained within cup-shaped flame tunnel to provide the highly radiating focused flame attained in accordance with the invention.

A turbulent admixture zone B is indicated schematically in FIG. 3. This zone provides a thorough admixture of fuel and air before the mixture reaches the point of ignition at the outlet of pilot light chamber 24.

As aforesaid, it has been found to be preferable that the dimension D-2 should be at least two and one-half times as great as the dimension D-1, and, more preferably, at least four times as great as the dimension D-1. In addition, the dimension D-2 is preferably at least as great and more preferably at least about one to two times as great as the dimension S.

The divergence of the first section of flame tunnel 28 from a true cylindrical shape is conveniently measured by the angle a shown in the preferred embodiment of FIG. 1, at the most preferred value of 1½° . Angle a may range up to 3° and is preferably between 1° and 2°. The divergence of the surfaces 30 of the first section 28A of flame tunnel 28 provides additional volume to the elongated first section 28A to accommodate a portion of the expanding volume of combustion gases. A maximum divergence of not more than about 3° between the surface of the first section 28A and the surface of a theoretical cylinder concentric therewith and of a diameter equal to the inlet diameter of first section 28A is provided. A divergence longer than about 3° will unduly slow the progress of combustion gases through first section 28A of the flame tunnel, and no divergence at all may create manufacturing problems (by making it difficult to withdraw the mandrel from the refractory block) and result in too high a velocity being imparted to the combustion gases. A divergence of at least about one-half degree is therefore provided.

The particular sequence of concavo and convexo curvatures shown is not essential; it sufficies if the diameter expands abruptly in going from first section 28A to second section 28B. As hereinabove stated, an "abrupt" increase in diameter is attained if the outlet diameter D-2 is at least as great as the transition length S. The total length of flame tunnel 28 is not critical, except that it should be great enough to contain the entire flame within its confines, as indicated schematically in FIG. 3.

The embodiment of the invention illustrated in FIGS. 1 and 2 shows a burner adapted to burn only gas. FIGS. 4 and 5 show a burner in accordance with the invention adapted to burn either gas or oil. (It should be noted that similar elements of the various embodiments illustrated are identically numbered in the various FIGURES and their description not repeated, except insofar as is necessary to describe the various embodiments illustrated. The admixture and flame propagation zones of FIG. 3 apply in general, and thus applicable also to the embodiment of FIGS. 4 and 5.)

Referring now to FIGS. 4 and 5, combustion air conduit 10 has a branch 14, inlet 16 of which has a combustion air rotation means 70 positioned therein. As best seen in FIG. 5, baffle plate 76 and slotted aperture 74 are provided in a manner similar to that shown with respect to the embodiment of FIGS. 1 and 2.

Secondary conduit 50 is positioned within combustion air conduit 10, and substantially concentrically thereto. Air inlet 52 to secondary conduit 50 serves to introduce either atomizing air (when oil is introduced through conduit 40), or gas (when the burner operates on gas fuel), all as more fully explained hereinbelow. An air deflector 48, with a conical inner surface 47 is positioned at the outlet end of secondary conduit 50.

A combustion air deflector rim 48A is mounted on air deflector 48 and serves to restrict the size of opening 49, through which combustion air enters the first section 28A of flame tunnel 28.

Combustion air injection ports 57 are provided around the periphery of air deflector 48 as best seen in FIGS. 4 and 5. Injection ports 57 are positioned substantially tangentially to the general direction of flow of

fuel and air along the longitudinal axis of fuel conduit **40**.

Oil spindle or fuel conduit **40**, through which oil is fed to the burner, is equipped with a suitable oil control valve (not shown). Fuel conduit **40** is shown in partial section and is fitted near its outlet end with a nozzle **42**, the outer surface **44** of which is polygonal in shape. As best seen with reference to FIG. **4**, nozzle **42** is seated within air deflector **48**, the inner surface **47** of which is substantially conical in shape. A passageway **43** is thereby provided between polygonal surfaces **44** and curved surface **44A** of nozzle **42** on the one hand, and the conical inner surface **47** of air deflector **48** on the other. Dotted line **43A** (FIG. **5**) is a section line passing through the inner surface **47** of air deflector **48** to clearly indicate the shape of the passageway formed between conical surface **47** of air deflector **48** and the polygonal surface **44** of nozzle **42**.

The chamber **53** formed within secondary conduit **50** is seen to be air-tight with respect to fuel conduit **40** and combustion air conduit **10**. Chamber **53** is in flow communication with passageway **43** and, via opening **20**, with the first section **28A** of flame tunnel **28**.

Fuel conduit **40** is seated snugly but slidable in an opening **60** in base **62** of conduit **10**. An O-ring **64** serves to seal the opening and make it air-tight in respect to atomizing air or gas in chamber **53**. A stop ring **66** is affixed to fuel conduit **40** which serves to limit the rearward movement of conduit **40** so that it is not withdrawn an excessive amount. Set screw **68** serves to hold the conduit in any desired, preselected position. It will be seen that by moving fuel conduit **40** to the left (as viewed in the drawing), passageway **43** between the surfaces of nozzle **42** and air deflector **48** is increased accordingly. Movement to the right (as viewed in the drawing) will decrease the size of opening **43**.

Referring now particularly to FIGS. **4** and **7**, the stem **45** of nozzle **42** is seen to be threaded on both its outer and inner surfaces. The wall of the stem contains one or more small inlet passageways **80** which are substantially L-shaped in their effective dimensions, and adapted to introduce oil tangentially into receiving chamber **81**, formed in nozzle **42** by plug **83**. It will be noted that branch portion **80A** of conduit **80** is drilled through the wall of stem **45**. This is merely a manufacturing convenience to facilitate formation of the L-shaped passageway which the oil follows as indicated by the arrows **82**. The upper portion of branch **80A** is sealed during operation by oil conduit **40**. Similarly, the hollow construction of stem **45** is a manufacturing convenience to permit drilling out of nozzle aperture **41**. Stem **45** is sealed by plug **83** to define receiving chamber **81**, into which the oil enters tangentially, as shown by arrow **82A**.

Outlet **41** of nozzle **42** is a small opening connecting the center of receiving chamber **81** with the center of mixing chamber **84**. Atomizing air inlet ports **46** enter mixing chamber **84** substantially tangentially, as best seen in FIG. **5**. Each face of polygonal surface **44** has an atomizing air inlet port **46** drilled therethrough (FIG. **5**).

The outlet side of mixing chamber **84** has a chamfered surface **90** which terminates in a circular, knife-edge rim **92**.

In operation, oil introduced via fuel conduit **40** enters small passageway **80** as shown by arrows **82**, and is sprayed tangentially into receiving chamber **81**, emerging via nozzle aperture **41** into mixing chamber **84** as a fine, cone-shaped stream of oil.

Atomizing air is introduced through secondary conduit **50** via inlet **52** as shown by the arrow in FIG. **4**. A portion of the atomizing air enters inlet ports **46** contained in nozzle **42** which direct the air into mixing chamber **84** and the oil emerging via aperture **41** from receiving chamber **81**. Within mixing chamber **84**, the fine stream of oil is entrained by the air entering via inlet ports **46** and expelled outwardly over chamfered surface **90** and knife-edge rim **92**, as fine filaments or sheets of liquid.

Atomizing air passing through passageway **43** impacts the fine filaments of liquid at an angle substantially transverse to the direction of oil flow, as shown by the arrows in FIG. **7**, thus insuring the complete nebulization of the oil into fine droplets.

The atomizing air and oil then pass into first section **28A** of flame tunnel **28**.

Combustion air introduced via inlet **16** of branch conduit **14** has imparted to it a high rotational velocity by passing through slot **74** and around baffle **76** substantially as described with respect to the embodiment of FIGS. **1** and **2**. The rotating combustion air passes through opening **49** between air deflector lip **48A** and the inner surface of conduit **10** (as best seen in FIG. **4**). The nebulized oil and atomizing air are thus admixed with combustion air at the inlet to first section **28A** of flame tunnel **28**.

The admixed, nebulized oil and combustion air mixture is ignited by a pilot light (not shown) positioned within pilot light channel **24**. Thereafter combustion and attainment of the full cross section flame provided in accordance with the invention is as described with reference to the embodiments of FIGS. **1** and **2**.

The dimensions of flame tunnel **28** in the embodiments of FIGS. **4** and **6** may be different from those shown with respect to the embodiment of FIGS. **1** and **2**, but preferably they will meet the criteria that the dimension D-2 is at least two and one-half times and preferably four times as great as the dimension D-1, and the dimension D-2 is at least as great as,and preferably about one to two times as great as, the dimension S.

When oil is employed as a fuel, the relatively long length of the first section **28A** of flame tunnel **28** provides an opportunity for complete gasification of the nebulized fine droplets of oil so that by the time the fuel/air mixture reaches the end of the flame, the oil fuel is present in the form of a gas. This insures complete combustion of the fuel. The distance between the fuel nozzle **42** and the point of ignition, which is generally some distance downstream of the point at which pilot light chamber **24** meets the mixture, keeps the nozzle some distance removed from the heat of the flame which helps to prevent carbonization of the oil within the fine conduits of the nebulizer nozzle.

The ability to position fuel conduit **40** to adjust the size of the passageways **43** permits regulation of the flow of atomizing air therethrough, and when the dual fuel burner is operating with gas as a fuel, permits regulation of the amount of gas flow. When gas is employed in the embodiment of the invention shown in FIGS. **4** and **5**, the oil flow through fuel conduit **40** is closed off by a valve (not shown) and the gas is introduced into the burner via inlet **52** of secondary conduit **50**. The gas flows through chamber **53** and follows the same path that is followed by the atomizing air, that is, the

gas passes through passageway **43** and through inlets **46** of fuel nozzle **42.** The gas is admixed with combustion air passing through conduit **10** as shown by the arrow **36,** and thence into first section **28**A of flame tunnel **28.** The passageways **43** are increased in size when the gas supply is at low pressure so as to facilitate the passage of low pressure gas through the burner.

Introducing combustion air in rotation into the first section **28**A has the advantage of aiding the flame to expand outwardly in second section **28**B by the centrifugal force of the rotating gases. This helps to provide a full cross section flame in second section **28**B.

It is important that no residual oil remains in nebulizer nozzle **42** after a change from oil to gas fuel because such residual oil will tend to become carbonized by the heat of the flame. The passage of gas through atomizing air injection ports **46** assists in purging the nozzle **42** of residual oil after a changeover from oil to gas fuel.

Fuel burners in accordance with the invention are capable of operating with a large excess of air, that is, the amount of fuel introduced may be reduced to lower the firing rate while the air supply remains constant. A reduction in fuel supply from 100 percent to 10 percent of full capacity rate is attainable without disruption of the desired flame configuration. The dual fuel burners may be switched from one fuel to the other without significant interruption of service and the burner of the invention may operate efficiently with very low pressure gas.

Control of flame propagation and other advantages of the invention will be apparent to those skilled in the art upon reading and understanding the foregoing.

While the invention has been described with respect to preferred embodiments thereof, it will be apparent that many modifications and alterations to the embodiments shown will occur to those skilled in the art upon reading and understanding of the specification. It is intended to include all such modifications and alterations within the scope of the appended claims or the equivalents thereof.

I claim:

1. A burner apparatus comprising a fuel burner and a flame tunnel in combination, said fuel burner comprising a conduit for fuel, and a combustion air conduit, said conduits being structurally associated one with the other to pass admixed fuel and air into said flame tunnel, the improvement comprising,

said flame tunnel has first and second sections arranged along a common longitudinal axis,

said first section is substantially cylindrical in shape, and has its inlet adjacent said burner and its outlet adjacent said second section,

said second section includes a transition surface which increases in diameter from the inlet towards the outlet end thereof, and defines a transition length along said longitudinal axis,

the outlet diameter of said second section is at least as great as the transition length,

a combustion air deflection means is structurally associated with said combustion air conduit to impart rotational velocity about said longitudinal axis to combustion air entering said flame tunnel,

said combustion air deflection means comprises a seal plate with an aperture therein, said seal plate being positioned substantially transversely to the flow of combustion air through said combustion air conduit, so that substantially the entirety of said flow passes through said aperture, a baffle plate positioned adjacent to said aperture and positioned with respect to said combustion air inlet so that substantially the entire flow of said combustion air is directed through said combustion air conduit in rotational motion about said conduit for fuel.

2. The burner apparatus of claim **1** wherein said fuel conduit is disposed within and substantially concentrically to said secondary conduit, and said secondary conduit is positioned within and substantially concentrically to said combustion air conduit.

3. A burner apparatus comprising a fuel burner and a flame tunnel in combination, said fuel burner comprising a fuel conduit for the passage of air therethrough, a secondary conduit for the passage of atomizing air or gas therethrough, and a combustion air conduit, said conduits being structurally associated one with the other to pass admixed fuel and air into said flame tunnel,

said flame tunnel comprising first and second sections arranged along a common longitudinal axis,

said first section being substantially cylindrical in shape, and having its inlet adjacent said burner and its outlet adjacent said second section,

said second section including a transition surface which increases in diameter from the inlet towards the outlet end thereof, and defines a transition length along said longitudinal axis,

the outlet diameter of said second section being at least as great as the transition length,

nozzle means being attached to the outlet of said fuel conduit, said nozzle means restricting the size of the outlet from said secondary conduit, and said fuel conduit being adjustable along its longitudinal axis in relation to said secondary conduit, so that such adjustment varies the size of the outlet from said secondary conduit.

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