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[54] **GAS BURNER**

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[51] **Int. Cl.**[2] **F23M 9/00**

[58] **Field of Search** 431/9, 182, 183, 184, 185, 431/115, 116, 353; 239/404, 552, 487, 488

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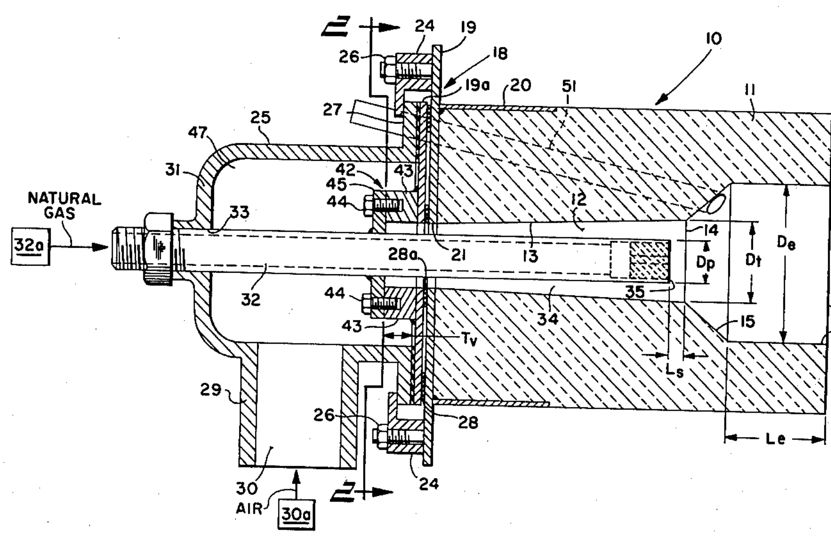
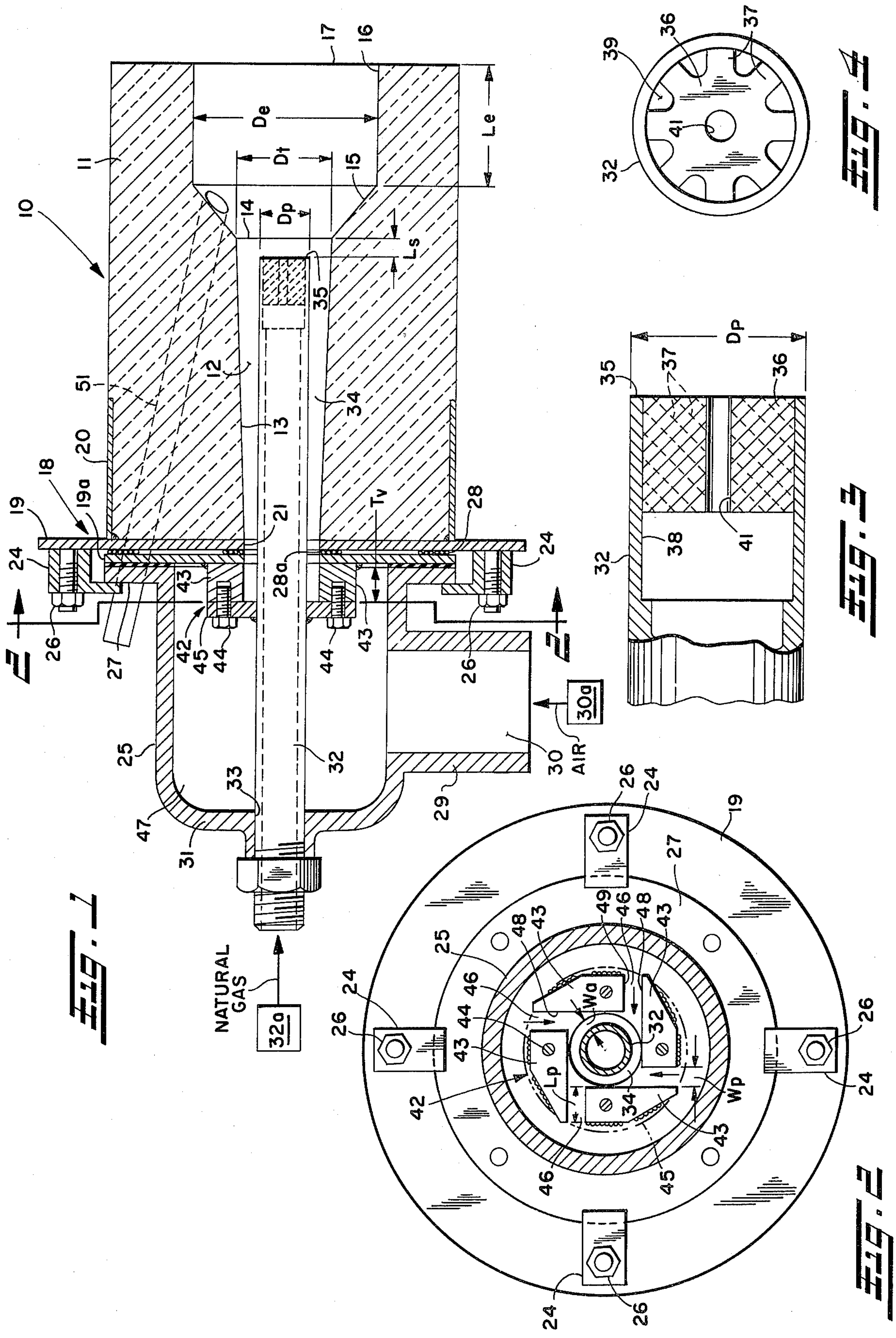
[57] **ABSTRACT**

An industrial gas burner especially suitable for operation with oxygen-enriched combustion air is constructed and arranged to discharge concentric and complementary spinning streams of gas and oxygen-enriched combustion air acting to create a recirculation and intermixing zone spaced outwardly from the burner mouth to provide aerodynamic flame stabilization in space. The burner flame is thus outwardly removed from and out of contact with the burner, thereby avoiding excessive heating of the burner.

11 Claims, 5 Drawing Figures

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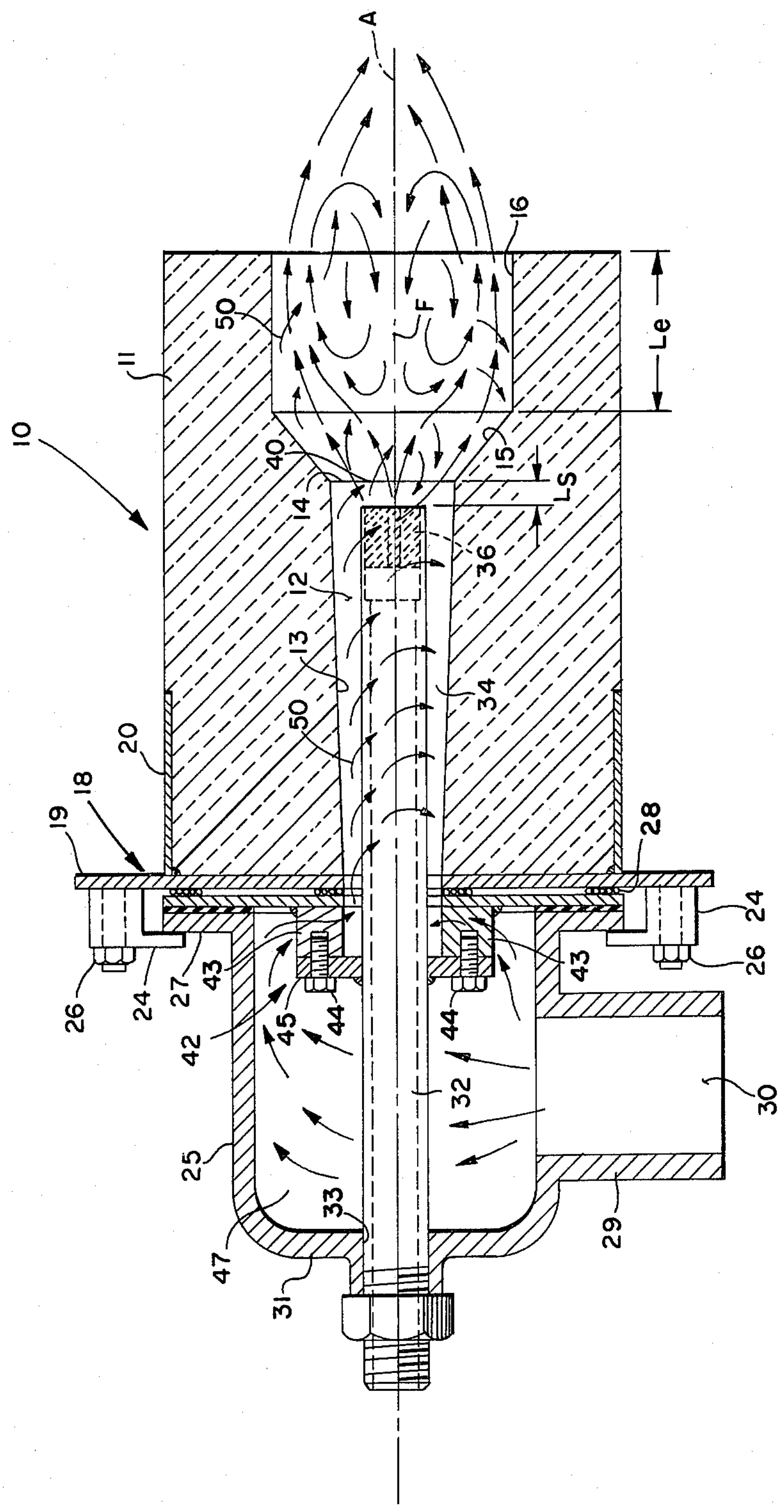

FIG. 5

GAS BURNER

This invention relates generally to a gas burner and, more particularly, to a gas burner of the industrial type.

The invention is particularly applicable to a burner which uses oxygen-enriched combustion air for high temperature applications and will be described with particular reference thereto. However, as will be appreciated by those skilled in the art, the invention has broader applications and may be used in any industrial burner application including those which do not operate at high temperature or those which do not use oxygen-enriched air.

Generally, burner design considerations require that a gaseous fuel be mixed with a predetermined percentage of oxygen, preferably in stoichiometric relationship, to achieve desired combustion characteristics. Accordingly, it has been known that an increase in the oxygen content of air, which by definition normally includes a somewhat fixed percentage of oxygen, will increase the fuel efficiency of the burner. That is, oxygen-enriched combustion air reduces the mass of air otherwise required for mixing with gaseous fuel to decrease the total volume or mass of the exhaust gases which in turn results in less heat loss in the flue products. Because of the additional amount of oxygen available and the resulting higher flame temperatures, burners operated with oxygen-enriched combustion air are ideally suitable for high temperature burner applications.

High temperature applications of oxygen-enriched burners, however, have not experienced widespread commercial success because of the inability of the burner construction to withstand such high temperature. More particularly, the burner must propagate the flame in a stable manner and flame stability has heretofore been achieved by originating or directing the flame from some fixed point in the burner construction, be it the burner tube, refractory material, baffles, or otherwise. Because the high temperature flame thus propagated must directly impinge against such burner parts, the parts eventually fail from thermal stress, thermal fatigue or both.

The prior art has recognized this problem and has attempted with varying degrees of success to alleviate same. Thus, exotic materials have been employed in burner constructions at the flame stabilization points therein. Besides the expensive cost of such materials, exotic type materials have generally not been satisfactory because of their unreliability to withstand temperature fluctuations to which they are subjected. To increase reliability of such material, complicated external cooling means such as cooling air or water jacket mechanisms have been employed in the burner design. As a practical matter, such designs are objectionable not only because of their high construction cost but also because of the operating and maintenance problems associated therewith.

In addition to the major problem of thermal stress failure of burner components as noted above, other problems have likewise plagued oxygen-enriched gas burners. One such problem may be defined as objectionably high operating noise levels attributed to the rapid oxidation of the burner gas discharged from the gas nozzle.

It is thus an object of the subject invention to provide a burner arrangement which aerodynamically stabilizes the burner flame in space to prevent direct flame impingement against any part of the burner apparatus.

It is another object of the subject invention to provide a gas burner for operation with oxygen-enriched combustion air at high temperatures which apparatus is characterized as being comprised of conventional metallic and refractory burner components.

Yet another object of the invention is to provide in a gas burner for operation with oxygen-enriched combustion air, aerodynamic flame stabilization means which inherently direct oxygen-enriched combustion air along the burner components to cool same.

Still another object of the invention is to provide in a gas burner for operation with oxygen-enriched air, a design structure which permits the gas burner to operate at a sound level below or at most approximately equal to that of standard air-gas burners of equivalent capacity.

Still another object of the invention is to provide a gas burner for operation with oxygen-enriched combustion air which is constructed in such a manner so as to be interchangeable with standard air-fuel burners while possessing performance characteristics which are equal to or better than said standard air-fuel burners.

Briefly stated, in accordance with one aspect of the invention, an industrial gas burner suitable for operation with oxygen-enriched combustion air is provided with respective gas and combustion air spin generator means for creating a spinning annulus of combustion air from an annular air supply tunnel or passageway through the refractory burner block and concentrically enveloping a central column of burner gas which is discharged from a co-axial gas supply tube in the passageway into and spinning complementary with the core of the spinning annulus of combustion air. The air supply passageway in the burner block is abruptly widened to a substantial diameter out to its mouth end, from a location slightly downstream from the gas nozzle end, to cause the concentric complementary spinning columns of gas and air to spread laterally outward from the core or burner axis and thus create an underpressure (i.e., a pressure lower than atmosphere, a vacuum) at the core which then acts to draw the spinning gas and air columns back inwardly toward the burner axis to form a recirculation zone out in space, and removed from the burner block walls, where the gas and air columns thoroughly intermix to effect flame propagation thereat. Aerodynamic flame stabilization in space is thereby achieved so that the exceedingly high temperature burner flame, which is characteristic of gas burners operating with oxygen or oxygen-enriched combustion air, is outwardly removed from and out of contact with the refractory burner block and other burner parts, thereby avoiding the overheating and damage of these burner components.

In accordance with a further aspect of the invention, the oxygen-enriched combustion air is disposed axially of the gaseous fuel to effect a cooling of the burner components.

In accordance with yet another aspect of the invention, the aerodynamic propagation of the flame is accurately positioned within a cylindrical chamber in accordance with predetermined geometry considerations to reduce the noise level of the burner to acceptable limits.

The invention may take form in certain parts and arrangement of parts, a preferred embodiment of which will be described in detail herein and illustrated in the accompanying drawings which form a part hereof and wherein:

FIG. 1 is a longitudinal section of a gas burner comprising the invention;

FIG. 2 is a transverse section on the line 2—2 of FIG. 1;

FIG. 3 is a fragmentary longitudinal section, on an enlarged scale, of the nozzle end of the gas burner tube of the gas burner shown in FIG. 1;

FIG. 4 is an end view, on an enlarged scale, of the nozzle end of the gas burner tube; and

FIG. 5 is a schematic longitudinal sectional view of the gas burner comprising the invention showing the flow pattern of the burner gas and combustion air emanating therefrom during the burner operation.

Referring now to the drawings wherein the showings are for purposes of illustrating a preferred embodiment of the invention only and not for the purpose of limiting same, there is shown in FIG. 1 a gas burner **10**. Gas burner **10** comprises an elongated burner block or housing **11** which may be of approximately square exterior cross section and made of a suitable heat-refractory material such as any of the conventional castable refractory materials commonly employed for the burner blocks of standard air-gas industrial burners and having a use limit of 2800°F. or thereabouts. For definitional purposes "high temperature" as referred to herein shall mean temperatures resulting from direct combustion of natural gas and combustion air or oxygen-enriched combustion air having a flame temperature near or greater than the use limit of common refractory material. Furthermore, "combustion air" shall mean normal air at atmospheric pressure which by definition includes a sufficient, definable percentage of oxygen to support combustion and "oxygen-enriched combustion air" shall mean combustion air having a greater percentage of oxygen, supplied by external means, than that normally encountered in combustion air, and for purposes of explanation may contain total oxygen by volume of from around 21 to about 45 percent and preferably from 25 to 35 percent.

Burner block **11** is formed with a tubular combustion air supply tunnel or first chamber **12** of circular cross section and extending longitudinally therethrough. Tunnel **12** is defined by refractory wall section **13** of a few inches in length, e.g., around 6½ to 9½ inches, extending from the upstream end of the tunnel. Wall section **13** may be either of plain cylindrical form throughout its length, or slightly flared out in the downstream direction as shown, for example, at a taper angle of around 1½° to 4° to the tunnel or burner axis A, for manufacturing purposes. At its downstream outlet end **14**, wall section **13** of tunnel **12** merges into an abrupt outwardly expanding throat or flared chamber section **15** which may be of conical form as shown and flaring out in a downstream direction, e.g., at a flare angle in the range of about 30° to 55° to tunnel axis A, to a substantial diameter D_e relative to the diameter D_t of wall section **13** at its outlet end **14**. The flared or conical chamber section **15** terminates at its downstream end into a cylindrical chamber section or tunnel extension **16** terminating at the mouth end **17** of burner tunnel **12**. Burner block or housing **11** is thus defined by a first chamber **12** contiguous with a second chamber defined by outward-expanding throat section **15** and a cylindrical chamber section **16**. For the purposes of the invention, the diameter D_e of tunnel extension **16** should be so proportioned to the diameter D_t of outlet end **14** of wall section **13** that the ratio D_e/D_t preferably lies within the approximate range of 1.8 to 2.1.

Burner block **11** is received and supported within a metallic holder **18** comprised of a backplate **19** with axially extending housing flanges **20** within which the burner block is received and mounted. Backplate **19** extends radially beyond housing flanges **20** and is provided with a central circular air passage opening **21** therein coaxially aligned with and of the same diameter as the adjacent circular upstream end of tubular wall section **13** of air passageway or tunnel **12**. Backplate **19** is also formed with a plurality of outlying, circumferentially spaced threaded studs (not shown) which provide means for securing the burner to a furnace wall (not shown). Burner block **11** is securely held in place within holder **18** as by cement, for instance.

A metallic housing or burner casting **25** of circular cross section is secured to burner block **11** for supplying oxygen-enriched combustion air to air supply tunnel **12** of burner **10**. Burner casting **25** is mounted to a mounting plate **19***a* by means of a group of fastening assemblies **26** extending from the back side of backplate **19** which clamp an annular flange **27** of the housing to mounting plate **19***a* and backplate **19**, with suitable gasket means **28, 28***a* interposed therebetween. Housing **25** is provided with a radial air inlet **29** into the opening **30** of which is connected an air supply pipe (not shown) through which oxygen-enriched combustion air is supplied to the housing under slight pressure from a known air supply source shown schematically and identified herein as **30***a*.

Extending into housing **25** through its back end wall **31** in a substantially air-tight manner, as by being screw-threaded thereinto, is a gas supply tube or nozzle **32** suitably formed of stainless steel pipe and constituting the gas nozzle of burner **10**. Gas nozzle tube **32** extends axially through cylindrical housing **25** and the axial opening **33** in its front end, and precisely axially into and through wall section **13** of air supply tunnel **12** in burner block **11** so as to form, in conjunction with the circular cross-section wall of wall section **13**, an annular combustion air supply chamber **34** through the throat section of the burner block. To this end, the outer wall surface of gas nozzle tube **32** is of straight, i.e., continuous cylindrical form throughout its length, in the manner characteristic of conventional stainless steel or other like pipe. The axial centering of gas nozzle tube **32** in wall section **13** of combustion air tunnel **12** is one of the critical tolerance dimensions to proper operation of burner **10** in the manner according to the invention. Too great a misalignment of gas nozzle tube **32** in wall section **13** will cause burner flame attachment to the wall of burner block tunnel **12**, or throat section **15** or cylindrical chamber section **16** resulting in severe hot spots thereon during burner operation. With the high flame temperature which is characteristic of gas burners operating with oxygen-enriched combustion air, such flame contact against the walls of first **12** or second chambers **15, 16** of burner block **11** would soon result in the destruction of most refractories employed for burner block **11**.

Externally of housing **25**, gas nozzle tube **32** is connected to a known suitable gas supply source shown schematically at **32***a*. Gas supply **32***a* could be natural gas or other conventional type burner gas at a relatively low pressure in the range of around 17 to 27 inches w.c. (water column), depending on the design capacity of burner 10 and on the oxygen concentration of the combustion air. Thus, for burners 10 having respective rated capacities of approximately 0.5, 1.0, 2.0 and 4.0 MM (million) Btu per hour and operating with combustion air having approximately 35 percent total oxygen content by volume, the pressure of the gas necessary to operate the burner at rated capacity is about 17 inches w.c. above atmospheric pressure. Operation of such burners 10 above rated capacity with higher oxygen content combustion air requires higher gas pressures. Thus, operation of burners 10 with 45 percent total oxygen content combustion air requires a gas pressure of about 27 inches w.c. over atmospheric pressure. Also, in the case of burners 10 having the above indicated approximate rated capacities of 0.5, 1.0, 2.0 and 4.0 MM Btu per hour, gas nozzle tube 32 thereof may have respective pipe sizes of around ⅜, ¾, 1 and 1½ inches, for example. Correspondingly, wall sections 13 of circular cross-section air supply tunnels 12 of such rated capacity burners 10 may have a diameter D_t at their downstream or outlet ends 14 of around 1-7/16, 2, 2-13/16 and 3-21/32 inches, respectively, for example. The desired burner flame shape and gas and air flow pattern from burner 10 is dependent, however, on the ratio D_t/D_p of the outside diameter D_p of gas nozzle tube or pipe 32 to the diameter D_t of outlet end 14 of wall section 13 being within the approximate range of 1.9 to 2.2.

Gas nozzle tube 32 extends into and through burner tunnel 12 nearly the full length of wall section 13 thereof but with its inner or nozzle end 35 set back or upstream from outlet or downstream end 14 of wall section 13 a predetermined slight distance L_s (FIG. 1). The location of nozzle end 35 is critical for the proper operation of burner 10 in the intended manner according to the invention inasmuch as it greatly influences two very important initial design parameters. First is the proper mixing of the gas fuel from gas nozzle 32 with oxygen-enriched combustion air or oxidant from annular air supply passageway 34. That is, within relatively wide limits, if the nozzle end is placed too close to tunnel flare section 15, poor intermixing of the gas fuel with the oxidant results and if the nozzle end is placed too far upstream from outlet end 14 of wall section 13 of burner tunnel 12 the oxidation or mixing rate of the fuel with the air is dangerously accelerated. This mixing effect, balanced against the second design parameter of burner sound or operating noise level (which is more critical), thus determines the proper location of gas nozzle end 35 for the purposes of the invention. The sound level design parameter for burner 10 according to the invention is that it possess a sound level no greater than and preferably below that of a standard air-gas burner of equal capacity. However, the attainment of this object is particularly difficult in view of the well known fact that rapid oxidation of the gas fuel with the oxygen-enriched combustion air produces high operating noise levels. Nevertheless, we have determined that, for burners 10 of approximately 0.5, 1.0, 2.0 and 4.0 MM Btu per hour rated capacity, both of the above mentioned design parameters for the burner are satisfied when nozzle end 35 of gas nozzle tube 32 is set back distances L_s from outlet end 14 of wall section 13 of approximately 1¼ inches for the 4.0 MM Btu per hour burner 10 and approximately ¼ inch for the other three rated capacity burners 10.

As a necessary condition to the operation of burner 10 in the manner according to the invention, both the burner gas forced through gas nozzle tube 32 and the oxygenated combustion air forced through annular air supply passageway 34 are discharged therefrom in complementary spinning or swirling flow paths for the purpose of inducing a recirculation flow pattern of these gas and air streams at a region out in space, i.e., outwardly removed from the end of gas tube 32 (see FIG. 5). To this end, respective spin generator means such as known spin vanes may be employed for imparting the desired spinning motion to the gas and to the combustion air discharged into burner tunnel 12. In the preferred embodiment illustrated, the spinning motion of the burner gas discharged from nozzle end 35 of gas nozzle tube 32 may be suitably imparted thereto by a tube closure member in the form of an ordinary commercial metallic helical gear 36 (FIGS. 3 and 4) fitting tightly, axially within nozzle end 35 of gas nozzle tube 32 and fixedly secured therein as by welding, for example, The spaced helical teeth 37 of gear 36 form, in conjunction with the encasing cylindrical inner wall 38 of gas nozzle tube 32, a plurality of helical gas discharge or outlet passageways 39 (i.e., an annulus when viewed from the end) in gas nozzle tube end 35 corresponding in number to the number of gear teeth 37 on the gear. Thus, the burner gas forced under pressure through gas nozzle tube 32 is separated, by the several helical gas passageways 39, into a corresponding number of individual high velocity gas streams which are discharged from nozzle end 35 in a helical path concentrically disposed about axis A of burner 10 and gas nozzle 32, as indicated by the arrows in FIG. 5.

The particular form of helical gear 36 employed for the gas spin generator means is selected first to have enough passages 39 as determined by gear teeth 37 to impart an effective spin motion to the gas. In this respect, two passages would not develop an efficient spin which would recirculate the gas in an effective pattern, four passages would probably be marginal and the preferred embodiment utilizes eight passages. After the number of passages have been determined, the area of same is determined by their total cross section which would produce the required pressure drop in gas spin gear 36 necessary to attain the rated burner capacity with the desired low operating gas pressure of, for example, 17 inches w.c. above atmosphere. In the event that the passageway area is insufficient to develop this predetermined pressure drop, it has been found that an axial hole 41 through the center of the gear may be provided without adversely disturbing the circulatory mixing pattern developed by the spin generating means. Obviously there is an upper limit to the diameter of hole 41 which, if exceeded, would adversely affect burner operation and it is believed that this limit would be approximately 25–30 percent of the flow area through passageways 39. In the case of a burner 10 of a rated capacity of 1 MM Btu per hour and having the specific sizes mentioned hereinabove for gas nozzle tube 32 and wall section 13, a conventional helical gear 36 having eight helical gear teeth 37 will provide the required cross-sectional open area or helical gas passageway areas 39 therethrough necessary to enable the operation of burner 10 with the above mentioned relatively low gas operating pressure of around 17 inches w.c. above atmosphere. However, with burners **10** of **0.5**, **2.0** and **4.0** MM Btu per hour rated capacity and having the specific sizes mentioned hereinabove for gas nozzle tube **32** and wall section **13**, operation thereof with a gas pressure of around **17** inches w.c. requires the addition to such an eight-tooth helical gas spin gear **36** of a supplementary axial gas port or bore opening **41** therethrough having diameters, respectively, of around **0.154**, **0.288**, and **0.375** inch.

The spinning motion of the oxygenated burner combustion air passing through burner tunnel **12**, in a spin direction complementary to that of the burner gas discharged from gas nozzle end **35**, may be imparted thereto by spin generator means **42** located within burner housing **25** and comprising a group (four in the particular case illustrated) of spin vane members **43**, as shown in FIGS. **1** and **2**. Spin vanes **43** are disposed in a circular pattern concentrically about gas nozzle tube **32**, and in correspondingly oriented and uniformly spaced apart position therearound, at the entrance of upstream end of burner tunnel **12**. Spin vanes **43** are clamped, as by means of fastening bolts **44**, flatwise to and between the back face of a mounting plate **19*a*** adjacent backplate **19** (and sealed by rope gasket **28*a***) and a flat annular collar **45** fitted over gas nozzle tube **32** and suitably secured thereto, as by an annular weld therearound, to form an air-tight seal therewith. Thus, spin vanes **43** block off the annular space around gas nozzle tube **32** and being located between backplate **19** and collar **45** except for the spaces between adjacent ones of spin vanes **43** thereby form air inlet slots or passageways **46** leading from the combustion air chamber **47** of burner housing **25** into backplate opening **21** and inlet end of air supply tunnel **12**.

As shown in FIG. **2**, each spin vane **43** is formed with an extended length flat inner side edge **48** and a shorter flat end or heel edge **49** extending generally perpendicular to one another. The group of spin vanes **43** are secured in place on mounting plate **19*a*** with their flat side edges **48** extending approximately tangential to, and defining an imaginary square circumscribed by an imaginary circle concentric with gas nozzle tube **32** and corresponding in diameter to circular opening **21** in backplate **19** and to the circular inlet end of burner tunnel **12**. In their mounted position on backplate **19**, spin vanes **43** are further located with their flat heel edges **49** positioned opposite but spaced from and extending parallel to flat side edges **48** of the next adjacent spin vane **43**. The spaced opposing side and end edges **48**, **49** of adjacent ones of spin vanes **43** thus form, in conjunction with the flat sides of mounting plate **19*a*** and collar **45**, the afore-mentioned combustion air slots or passageways **46** extending tangentially of the annular inlet end of the annular combustion air supply passageway **34** which extends through burner block **11** around gas nozzle tube **32** therein. In the case of burners **10** having respective rated capacities of approximately **0.5**, **1.0**, **2.0** and **4.0** MM Btu per hour, spin vanes **43** are formed with respective thicknesses T_r (FIG. **1**) of approximately ½, ¾, **1-1/16** and **1½** inches. Also, the width W_p (FIG. **2**) of combustion air slots **46** of such burners **10** is preferably so proportioned relative to the width W_a of the annular combustion air passageway formed by the circular outside wall of gas nozzle tube **32** and the rim of concentric circular air passage opening **21** in backplate **19** as to produce a ratio W_a/W_p in the range of approximately **1.2** to **1.7**. The length L_p of combustion air slots **46** also is preferably so proportioned relative to their width W_p as to maintain the ratio L_p/W_p in the range of approximately **1.8** to **3**.

In the operation of burner **10**, the oxygenated combustion air in air supply chamber **47** of burner housing **25** is forced, by the pressure thereof, out of chamber **47** through air slots **46** of combustion air spin generator means **42** which slots, because of their extending tangentially to air passageway **34**, then discharge the air into passageway **34** in the form of individual gas streams directed tangentially of such passageway, thereby imparting a spinning movement or flow of the combustion air thereinto and therethrough, as indicated by the arrows **50** in FIG. **5**. The direction in which air slots **46** extend tangentially to annular air passageway **34** is the same, e.g., clockwise in the particular case shown in FIG. **2** and as viewed from its inlet end, as the downstream direction in which helical gas passageways **39** in gas spin generator gear **36** extend about burner axis A, in order to thereby spin the combustion air discharged into passageway **34** in the same, i.e., complementary, direction as that in which the gas stream from gas nozzle **32** is spun by gas spin generator gear **36**.

In place of fabricating the combustion air spin generator means or assembly **42** from a number of separate parts, i.e., the several spin vanes **43**, collar **45**, fastening bolts **44** and plate **19a**, the spin generator may be formed instead as a unitary structure with either burner housing **25** or backplate **19**, as by being cast integral with one or the other of these members, for example. In this way, simplification of the burner design and saving in burner manufacturing cost can be realized.

In order to provide ignition means for the combustible mixture formed by the mixing of the gas and the oxygenated combustion air from gas nozzle **32** and annular air passageway **34**, burner block **11** and backplate **19** are provided with an angular opening **51** therethrough which opens into flare section **15** of burner tunnel **12** and receives the usual sparkplug (not shown) whose electrodes extend up to the mouth end of flare section **15**. Additionally, a sight glass (not shown) may be provided on backplate **19** to provide visual examination of the burner flame, for supervision purposes, through a similar angular opening (not shown) extending through backplate **19** and burner block **11**.

As noted above and referred to throughout the specification, the operation of burner **10** of the present invention will be such that the oxygen-enriched combustion air will mix with the gaseous fuel in a recirculating manner as shown within a zone designated as F in FIG. **5** wherein a burner flame will be propagated. More particularly and as will be explained, recirculation zone F, herein defined as a flame stabilization zone, may be accurately positioned at any desired distance within the burner block and the flame developed thereby will occur out in space and be so directed so as not to impinge against any of the burner components while constantly recirculating a portion of the fuel-air mixture to insure stabilization. That this flame stabilization zone F will occur and can be regulated in the manner indicated will be explained first with reference to the burner block geometry and then with reference to the effect of the spin generating means on the burner construction.

Neglecting for the moment the spin generating means and viewing burner **10** from the right as shown in FIG.

5, it should be clear that at the intersection of wall section **13** with first annular chamber **12** there is a volume of air defined as an annulus which is axially moving by virtue of air supply means **30***a*. Similarly, at the outlet end of the tube **32** there is an annulus volume of gaseous fuel defined by passageways **39**, which gaseous fuel is axially moving by virtue of gas supply means **32***a*. As the air and gaseous fuel move axially towards the right as viewed in FIG. **5** and flow through throat section **15** and cylindrical chamber section **16**, they will rapidly expand in a radially outward direction and entrain themselves within one another. The rate of radial expansion of the gaseous fuel and air is a function of their pressures from their respective supply sources, the cross-sectional flow areas involved hereinbefore expressed as D_t/D_e and D_p/D_e and the radial component of the swirl angle as explained in detail hereinafter. The outwardly expanding throat section **15** is not critical to this radial expansion and its purpose is only to assure a smooth transition from a small area to a relatively large area. The entrainment or aspiration of the air and fuel will occur at the boundary line of the two mixtures. That is, the gas at the outer periphery of the fuel will mix at the inner periphery of the air annulus until a preferred mixture occurs (i.e., at or near stoichiometric) and combustion takes place. It should be clear that this entrainment will occur equally as well if the gaseous fuel surrounded the air instead of vice versa as shown. However, when the annulus of air surrounds the annulus of fuel, the outer periphery of air is available to cool the refractory material of the burner block, gas tube **32** and nozzle end **35**, especially so when it is realized that the combustion will propagate radially outwardly as the boundary layer interactions increase. If the burner of the present invention were designed in this manner without anything more, the flame propagation would not be stable because of inefficient recirculation. It should also be noted that as the gases rapidly expand radially outward into second cylindrical chamber section **16**, an underpressure or vacuum is created at the center of chamber **16** due to the outward suction of the gases. Thus there will be some backward recirculation motion imparted thereto. It has been found that this backward recirculating motion will not be sufficient to establish the aerodynamic stabilized flame of the subject invention.

With the problem thus defined, it has been particularly determined by the present invention that imparting a spin characteristic to either the air or the gaseous fuel will result in a utilization of the vacuum created by the radial expansion of the gases to cause a sufficient portion of said gases to recirculate and establish a stabilized flame in the recirculation zone F shown. That is, spinning either the air or the gass in a helix (as shown) or spiral or sinusoidal shape, at a predetermined angle imparts a tangential velocity component to the gas thus spun which in turn causes sufficient recirculation of that gas and importantly the portions of the other gas mixed therewith into the circular type recirculation path shown at zone F. The dimension of the recirculation path is believed to be a function of the angle of the tangential velocity of the spun gas in combination with the burner block design and fluid pressure. Furthermore, tests have indicated that the recirculation path defined at zone F will occur if only one of the gases is spun but that control or stabilization of the recirculation is more effective if both of the gases are spun. Control will thus be improved if the gases are spun either complementary to one another as illustrated or countercurrent to one another. If the gases are spun countercurrent, there will be a more thorough mixing between the air and the gaseous fuel although eddy currents established at the boundaries between the air and the gas will not impart as good a stabilized flame as when the gas and air are spun complementary to one another. For this reason the gases are shown spinning complementary with one another in the embodiment illustrated. In particular, it has been determined that when oxygen-enriched combustion air and gaseous fuel are spun complementary to one another as described in detail above, an extremely stable flame is aerodynamically propagated in zone F and controlled to such limits whereby the flame thus propagated does not impinge against any part of burner **10**.

Furthermore, in accordance with another feature of the invention, the noise formed by the combustion process in the present burner can be adequately controlled by positioning the flame stabilization zone F in about the middle of second annular chamber **16**. This positioning can be controlled by axially displacing the outward end **35** of gas tube **32** away from the intersection or line of demarcation between first annular chamber **12** and throat section **15** of the second chamber. Importantly, it should be noted that this displacement of gas tube **32** defined as L_s is nonlinear with respect to the other dimensions of the burner arrangement. All other dimensions giving rise to the ranges set forth above are believed to be linear. That is, given the capacity of the burner to establish the fuel and oxygen-enriched combustion air volumes to be supplied to burner **10** and the pressures at which the air and fuel are to be supplied, the remaining dimensions of the apparatus such as passageways **39**, the air spin means, the relationships between the D_t, D_p and D_e are all linear. Furthermore, the helix angle or tangential component of spin is believed to be associated with the diameter dimension D_e of cylindrical chamber section **16**.

The invention has thus been described with reference to a preferred embodiment. It is apparent that modifications and alterations will occur to others upon a reading and understanding of the specification. It is our intention to include all such modifications and alterations insofar as they come within the scope of the present invention.

It is thus the essence of the invention to provide in a burner an orificing arrangement in combination with a mechanism for spinning at least one of the gaseous fluids supplied thereto to impart a tangential component to such gaseous fluid whereby the vacuum created by the orifice arrangement is efficiently utilized to aerodynamically propagate, in space, a stable flame.

Having thus described the invention, we claim:

1. A gas burner for operation with a mixture of natural gas and oxygen-enriched combustion air, said burner comprising:

a burner block of heat refractory material having an axial tunnel of circular cross section extending therethrough and comprised of a throat section terminating at its downstream end in an abruptly widening flare chamber section flaring out to a diameter appreciably greater than that of said throat section;

a gas nozzle tube of cylindrical outer contour extending axially through said tunnel from the inlet end thereof and in spaced relation to the wall thereof to form therebetween an annular combustion air passageway through the said throat section of the tunnel;

said gas nozzle tube having a nozzle end set back a slight distance upstream from the downstream end of said throat section;

means for supplying gas fuel under a slight positive pressure to the inlet end of said gas nozzle tube;

means for supplying oxygen-enriched combustion air under a slight positive pressure to the inlet end of said annular air passageway;

respective gas and combustion air spin generator means respectively associated with said gas nozzle tube and with said annular combustion air passageway for imparting spinning motion in complementary directions about the tunnel axis to the gas column discharged endwise from said gas nozzle and to the combustion air discharged endwise from said annular air passageway and enveloping the spinning gas column whereby to cause said gas and air columns to spread laterally outward from the tunnel axis on passage through the said flare chamber section of said tunnel and subsequently to be drawn back inwardly toward the tunnel axis to thereby create a gas and air recirculation and flame stabilization zone located entirely out in space and outwardly removed from the walls of said burner block; and

the ratio of the diameter of the downstream end of said tunnel throat section to the outside diameter of said gas nozzle tube is within the approximate range of 1.9 to 2.2.

2. A gas burner for operation with a mixture of natural gas and oxygen-enriched combustion air, said burner comprising:

a burner block of heat refractory material having an axial tunnel of circular cross section extending therethrough and comprised of a throat section terminating at its downstream end in an abruptly widening flare chamber section flaring out to a diameter appreciably greater than that of said throat section;

a gas nozzle tube of cylindrical outer contour extending axially through said tunnel from the inlet end thereof and in spaced relation to the wall thereof to form therebetween an annular combustion air passageway through the said throat section of the tunnel;

said gas nozzle tube having a nozzle end set back a slight distance upstream from the downstream end of said throat section;

means for supplying gas fuel under a slight positive pressure to the inlet end of said gas nozzle tube;

means for supplying oxygen-enriched combustion air under a slight positive pressure to the inlet end of said annular air passageway;

respective gas and combustion air spin generator means respectively associated with said gas nozzle tube and with said annular combustion air passageway for imparting spinning motion in complementary directions about the tunnel axis to the gas column discharged endwise from said gas nozzle and to the combustion air discharged endwise from said annular air passageway and enveloping the spinning gas column whereby to cause said gas and air columns to spread laterally outward from the tunnel axis on passage through the said flare chamber section of said tunnel and subsequently to be drawn back inwardly toward the tunnel axis to thereby create a gas and air recirculation and flame stabilization zone located entirely out in space and outwardly removed from the walls of said burner block; and

the nozzle end of said gas nozzle tube is set back upstream from the downstream end of said tunnel throat section a distance of at least approximately ¼ inch.

3. A gas burner as specified in claim 2 wherein the ratio of the diameter of the downstream end of said tunnel throat section to the outside diameter of said gas nozzle tube is within the range of approximately 1.9to 2.2.

4. A gas burner as specified in claim 3 wherein the ratio of the diameter of the downstream end of the said flare chamber section of said tunnel to the diameter of the downstream end of the said throat section of said tunnel is within the range of approximately 1.8 to 2.1.

5. A gas burner as specified in claim 1 wherein the ratio of the diameter of the downstream end of the said flare chamber section of said tunnel to the diameter of the downstream end of the said throat section of said tunnel is within the range of approximately 1.8 to 2.1.

6. A gas burner for burning a mixture of natural gas with oxygen-enriched air, said burner comprising:

a burner block of heat refractory material having an axial tunnel of circular cross section extending therethrough and comprised of a generally cylindrical throat section terminating at its downstream end in an abruptly widening flare chamber section flaring out to a diameter appreciably greater than that of said throat section;

a holder supporting said burner block at its rearard end and including a backplate having a circular air supply opening therethrough coaxial with and approximately corresponding in diameter to the inlet end of said tunnel;

a combustion air supply housing mounted on said backplate for supplying a mixutre of oxygen and atmospheric air under slight positive pressure to the inlet end of said tunnel;

a gas nozzle tube of cylindrical outer contour mounted on said housing and extending therethrough and axially into said tunnel from the inlet end thereof and in spaced relation to the wall therreof to form an annular combustion air supply passageway in said tunnel;

said gas nozzle tube being connected to a source of burner gas under slight positive pressure and having its nozzle end set back a slight distance upstream from the downstream end of said throat section, gas spin generator means located within said gas nozzle tube at its nozzle end for imparting to the gas stream discharged therefrom a spinning motion concentrically about the said tunnel axis; and

combustion air spin generator means mounted in said housing for discharging the pressurized combustion air therein tangentially into the said annular combustion air passageway to impart thereto a spinning motion complementary in direction to that of said burner gas discharged from said gas nozzle end, said combustion air generator means including a collar mounted on said gas nozzle tube with an air-tight connection therearound and spaced rearwardly from said backplate, and a plurality of spin vanes clamped tightly between said backplate and said collar and positioned around said gas nozzle tube in spaced apart relation to define a plurality of combustion air outlet passageways extending tangentially to said annular combustion air supply passageway whereby to discharge the combustion air from said housing tangentially into said annular passageway to impart spinning motion to the combustion air entering and passing through said passageway.

7. A burner for operation with a mixture of gaseous fuel and combustion air comprising:

a housing, said housing having a generally cylindrical passage with an open inlet and open outlet end, and an abruptly flaring wall surface adjacent said passage outlet end, said flaring surface opening out into space;

a gas tube within said passage having an open outlet end generally adjacent said passage outlet end and concentric therewith;

gas supply means associated with said tube for supplying a source of axially moving gaseous fuel to said tube at a predetermined pressure;

air supply means for supplying a source of axially moving combustion air to said passage at a predetermined pressure;

air spin means associated with said air means and operable to form said combustion air injected into said passage into a plurality of swirling annular streams having a predetermined tangential velocity component;

gas spin means associated with said gas supply means and operable to form said gaseous fuel into a plurality of swirling annular gas streams at the outlet end of said tube, said streams having a predetermined tangential velocity component;

said air spin means and said gas spin means interacting with one another when said air and gas streams are injected into space to establish stable recirculation and mixing of air and gas streams in a flame stabilization zone to produce combustion located out in space and out of contact with said burner housing; and

ignition means including an open passage in said flaring surface for igniting a portion of said gaseous fuel as said air and fuel exit said passage and said tube.

8. The burner of claim **7** wherein said tangential velocity components of said gas and air spin means are complementary with one another.

9. The burner of claim **8** further including muffle means for reducing the noise emitted and controlling the shape of the flame generated in said stabilization zone, said muffling means including said housing further having a generally cylindrical chamber adjacent and concentric with said flaring wall surface, said cylindrical chamber of sufficient length to surround at least a portion of said stabilization zone and appreciably greater in diameter than the outlet of said passage.

10. The burner of claim **9** wherein said burner further includes means for positioning said outlet end of said tube relative to said outlet end of said passage for positioning said stabilization zone within said cylindrical chamber.

11. A burner for operation with a mixture of gaseous fuel and combustion air comprising:

a housing, said housing having a generally cylindrical passage with an open outlet end, and an abruptly flaring wall surface adjacent said passage outlet end, said flaring surface opening out into space;

a gas tube within said passage having an open outlet end generally adjacent said pasage outlet end and concentric therewith;

gas supply means associated with said tube for supplying a source of axially moving gaseous fuel to said tube at a predetermined pressure;

air supply means for supplying a source of axially moving combustion air to said passage at a predetermined pressure;

air spin means associated with said air means and operable to form said combustion air injected into said passage into a plurality of swirling annular streams having a predetermined tangential velocity component;

gas spin means associated with said gas supply means and operable to form said gaseous fuel into a plurality of swirling annular gas streams at the outlet end of said tube, said streams having a predetermined tangential velocity component;

said air spin means and said gas spin means interacting with one another when said air and gas streams are injected into space to establish stable recirculation and mixing of air and gas streams in a flame stabilization zone to produce combustion located out in space and out of contact with said burner housing;

ignition means including an open passage in said flaring surface for igniting a portion of said gaseous fuel as said air and fuel exit said passage and said tube; and

said gas means includes a helical gear inserted at said outlet end of said gas tube, said gear optionally including an axially extending opening therethrough.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,905,751

DATED : September 16, 1975

INVENTOR(S) : Klaus H. Hemsath, Frank J. Vereecke

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 9, line 54, change "gass" to -- gas --.

Column 12, line 42, change "mixutre" to -- mixture --.

Column 14, line 17, after "open" insert -- inlet and open --.

Signed and Sealed this

twentieth **Day of** *January 1976*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks