

July 10, 1951

W. J. BLOOMER

2,560,074

METHOD AND APPARATUS FOR BURNING FUEL

Filed Dec. 21, 1948

2 Sheets-Sheet 1

Fig. 1.

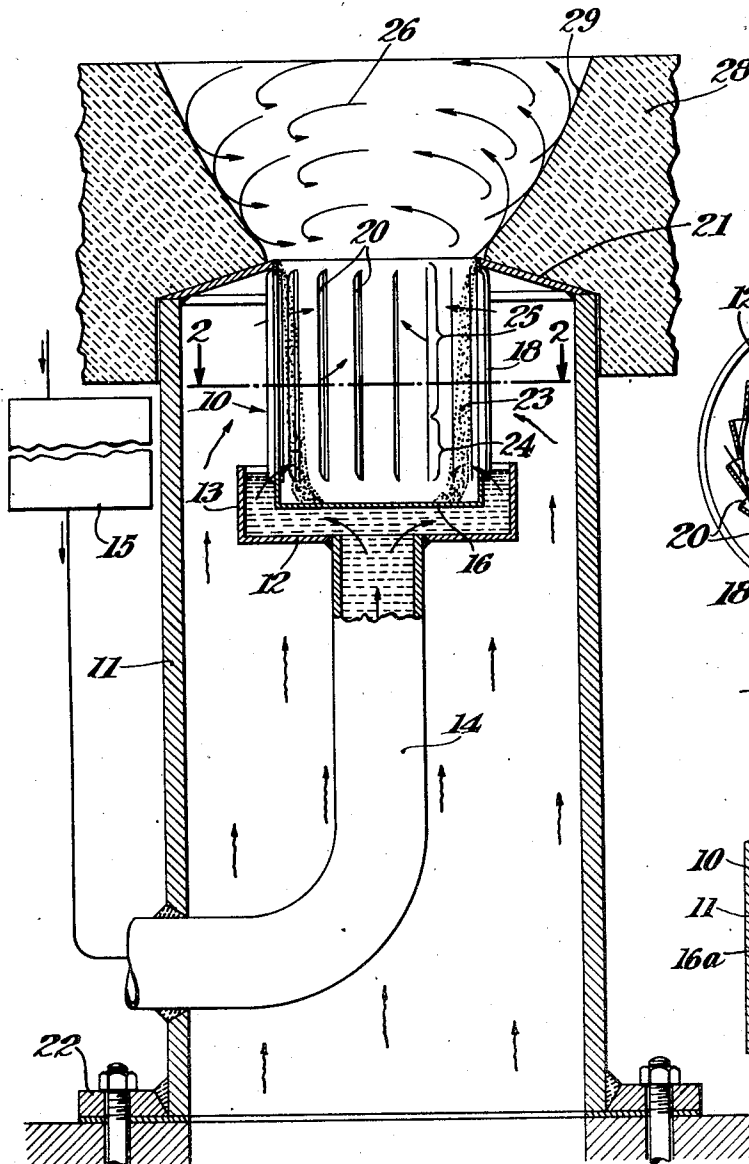


Fig. 2.

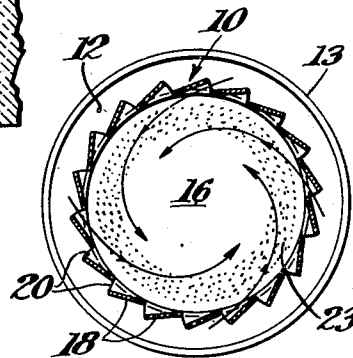
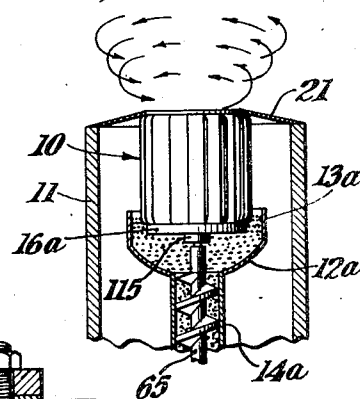


Fig. 2a.



INVENTOR.
Ward J. Bloomer
BY *Nathaniel Ely*
ATTORNEY

July 10, 1951

W. J. BLOOMER

2,560,074

METHOD AND APPARATUS FOR BURNING FUEL

Filed Dec. 21, 1948

2 Sheets-Sheet 2

Fig. 3.

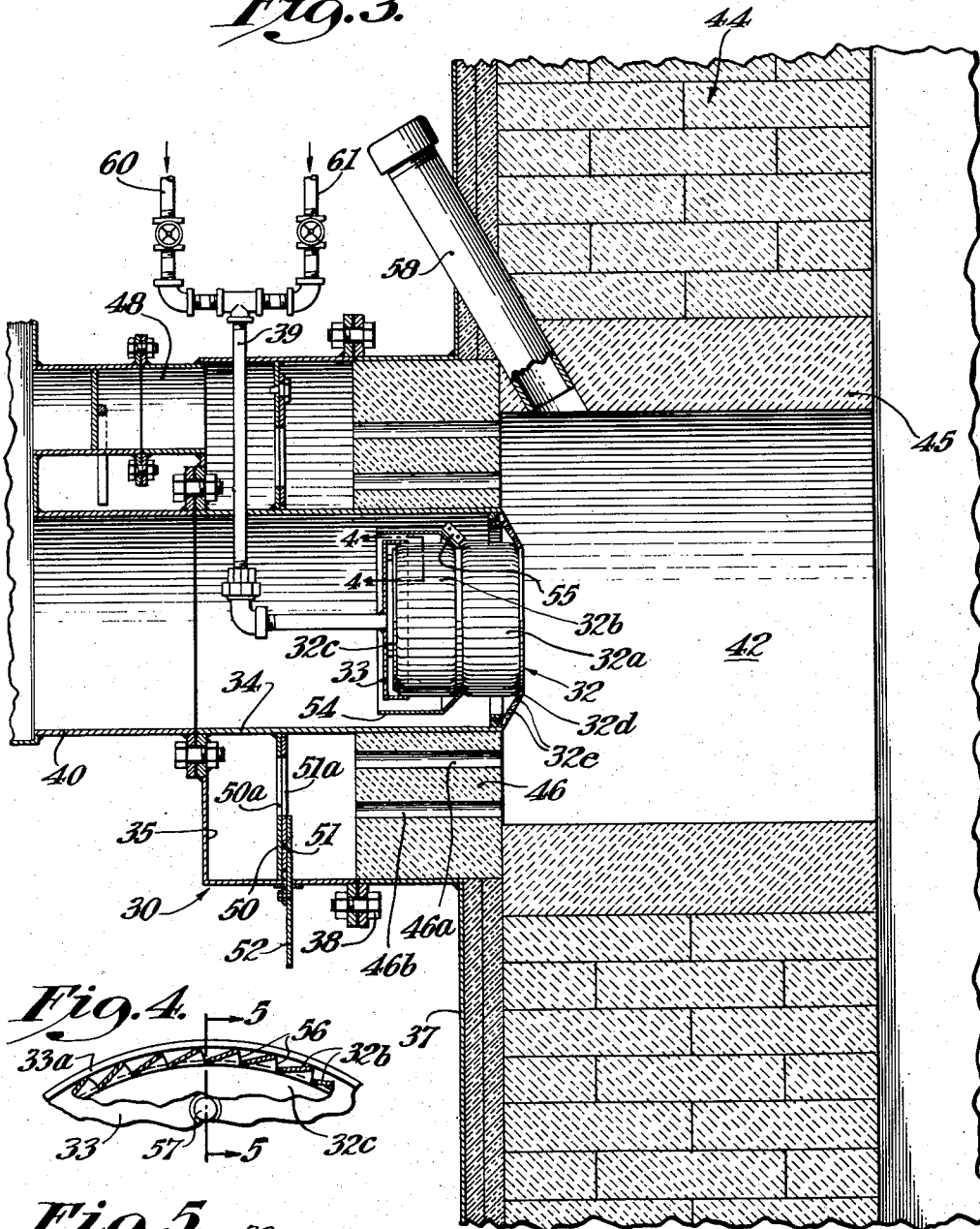


Fig. 4.

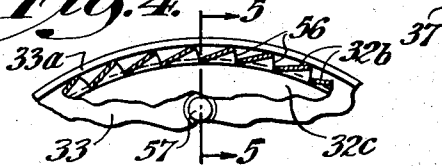
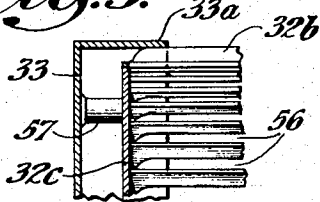


Fig. 5.



INVENTOR.

Ward J. Bloomer

BY

Nathaniel J. ...

ATTORNEY

UNITED STATES PATENT OFFICE

2,560,074

METHOD AND APPARATUS FOR BURNING FUEL

Ward J. Bloomer, Westfield, N. J., assignor to The Lummus Company, New York, N. Y., a corporation of Delaware

Application December 21, 1948, Serial No. 66,445

24 Claims. (Cl. 110-28)

1

This invention relates to improvements in a method and apparatus for burning fuel and is a continuation in part of and improvement on my copending applications Serial No. 550,933, filed August 24, 1944; Serial No. 650,284, filed February 26, 1946; and Serial No. 22,982, filed April 24, 1948; each forementioned application is now abandoned.

In my copending application, Serial No. 550,933, I have described a new and improved method of burning fuel wherein an extremely high degree of efficiency and completeness of combustion is achieved. This is accomplished through thorough mixing of the fuel with air in a vortical stream or hollow column in which the fuel is entrained and by which the fuel is supplied to a combustion zone totally outside and spaced from the fuel burner. Thereby the temperature of the burner is substantially less than that of the combustion temperature and the burner and associated equipment are relieved of the necessity for withstanding high destructive temperature in operation.

In this construction all of the air utilized to entrain liquid fuel and break, separate or atomize it into a mist or suspension comprising small air-borne fuel particles is utilized also as combustion air, i. e., wherein a volume of low pressure air is made to perform the multiple functions of breaking the fuel into discrete particles of such size as are readily combustible, of entraining the aforesaid particles and suspending them therein, and conveying the aforesaid particles in suspension to a burning zone, separated or spaced from the zone or zones wherein they are mixed and entrained, while supplying the air necessary for combustion.

The physical apparatus which aids to carry out the aforesaid methods is preferably a fixed type of tuyère having shallow tangential blades between which low pressure air passes, thus creating a centrifugal effect and forming a hollow envelope or hollow column in the nature of a vortex with a relatively small axial component inward of the center of the tuyère. This gives a most intimate mixing of the fuel and air during the movement of the rapidly swirling mass in a relatively long helical path through which it moves before discharging from the tuyère.

In my copending application Serial No. 650,284, I have further provided for maintaining this intimate suspension of the air with entrained fuel after the mass passes out of the tuyère by providing a restricted cross section combustion chamber which will maintain the high efficiency

2

of mixing resulting from the creation of the hollow rotating envelope or column of fuel and air. I have found that this combustion chamber materially improves the efficiency of combustion and also prevents periodic fluctuations of combustion which otherwise intermittently or periodically result from incomplete combustion.

As described in my copending applications the type of fuel may be a liquid or gas or comminuted solids so long as it may be entrained or picked-up by the low pressure air and carried into the whirling vortex so that an intimate fuel-air mixture results. In my copending application Serial No. 22,982 I have also shown a modified form of apparatus of the horizontal or end fired type which may likewise be fed with a fluid or fluidized fuel in a manner such that a horizontal axis of the vortex of the fuel-air mixture can be directly provided for those installations requiring a wall burner rather than a floor type burner.

The principal object of this invention is to more clearly set forth the importance of the factors entering into the design and construction of a continuous fuel burner for industrial purposes, to set forth the range of the separate elements, to coordinate the disclosures of the prior applications, and to establish the preferred form of embodiment of the invention.

A more specific object of the invention is to provide an improved method and apparatus for burning fuels hitherto considered of low grade in industrial furnaces by establishing a vortex or hollow air-fuel column whereby higher efficiency of combustions can be obtained with a great range of operation in a highly simplified construction using no continuously moving parts.

A further object of the invention is to provide a commercial burner assembly including associated wind box, primary and secondary air controls, fixed cylindrical tuyère and mounting plate whereby the entire assembly can be readily attached to a furnace.

Further objects and advantages of my invention will appear from the following description of preferred forms of embodiment thereof, taken in conjunction with the attached drawings in which:

Fig. 1 is a partial diagrammatic vertical central section through a burner and combustion chamber.

Fig. 2 is a horizontal cross section taken substantially along the line 2-2 of Fig. 1.

Fig. 2a is a partial vertical section of a modified form of burner.

Fig. 3 is a substantially central vertical sec-

3

tion through a part of a furnace setting showing a modified arrangement of burner.

Fig. 4 is a partial vertical cross section from the inside of the tuyère, taken on the line 4—4 of Fig. 3.

Fig. 5 is an enlarged vertical section of the feed end of the tuyère taken on the line 5—5 of Fig. 4.

Referring to the drawing in detail and as particularly shown in Figures 1 and 2, the burner comprises a tuyère generally designated 10, surrounded by a shell or casing generally designated 11, through which a column or stream of low pressure air passes between the vanes or blades of the tuyère 10, as hereinafter described. A fuel pan or container 12 having a continuous annular side wall 13 surrounds the lower end portion of the tuyère 10. The bottom of the container 12 has an orifice for the fuel feed pipe or inlet 14 which is connected to a suitable source of fuel 15. While diagrammatically shown, this fuel source may include a gravity feed tank for liquid fuel, or a powdered fuel hopper, or in case of gas, it may include a gas blower. Liquid fuel may of course, also be fed by a liquid fuel pump.

The tuyère 10, is of generally cylindrical form, being open at one end and closed at the other by a solid wall 16, the side thereof being formed by a plurality of generally tangential shallow vanes or blades 18 extending throughout substantially the entire length of the tuyère proper. These blades form a plurality of elongated substantially rectangular air inlets 20 disposed between adjacent blades 18.

The tuyère 10 may be provided with an annular, substantially frusto-conical plate 21 provided with a central orifice the full diameter of the tuyère opening and secured at its outer edge to the tubular shell 11 by suitable means.

At its lower end, the shell or casing 11 may be provided with a flange 22 which may be bolted or otherwise secured to a foundation or inlet conduit or other device through which air is forced through the shell or casing 11 upwardly, whence it passes inwardly through the air inlets 20 formed by the blades or vanes 18 of the tuyère 10 to form a swirling, hollow envelope, stream or column of air in the tuyère 10 for the purpose hereinafter described in detail.

As the fuel in the pan 12 flows through the blade openings, it is then entrained in the vortex inside the blades to form a fuel-air suspension in the form of a swirling hollow column designated 23. This hollow column 23 is open throughout its length to establish a linear velocity component of the fuel particles which thus travel in a spiral or helix through the tuyère, becoming thoroughly mixed with or in suspension in air, from the entrainment and mixing zone to the burning zone.

The liquid pick-up and entrainment zone is designated 24 and comprises an annular zone inside the tuyère 10 adjacent the lower end of the blades 18 and the fuel surface in the fuel pan 12. The mixing zone is designated 25, and is inside the tuyère 10, and is in the form of a generally cylindrical hollow column which is open at the bottom of the tuyère as shown in Fig. 2.

Perhaps the fuel air column 23 might more accurately or mathematically, be described as truncated paraboloidal with its theoretical vertex lying outside the closed end wall 16 of the tuyère 10, or in other words, a hollow column having its inner surface defined by a parabola of revolution wherein the theoretical vertex of the parabola is spaced outside the tuyère 10,

4

whereby the lower end of the column is maintained open. However, this envelope 23 shall be described herein as "generally cylindrical," as hollow and open throughout, since I have found these are the properties necessary in such a fuel-air column to achieve the objects and advantages of this invention.

The burning zone or combustion zone is generally designated at 26 and as described above, is so spaced from the casing or shell 11 and other parts of the burner, as to relieve these parts of the necessity for withstanding combustion temperatures. This spacing of the zone of combustion 26 from the mixing zone 25 and entrainment zone 24 is achieved through the avoidance of forces acting in opposition to the vertical or linear velocity component of the swirling hollow generally cylindrical fuel air column 23. The separate particles of fuel pass, generally speaking, in spiral or helical paths in fully dispersed air-surrounding condition into the zone of combustion, whereby complete combustion thereof, i. e., an extremely high degree of combustion efficiency is achieved in the combustion zone.

If the above described forces in opposition to the vertical or linear velocity of the fuel envelope did exist, there would be a tendency for these separate or discrete fuel particles to fall out of suspension, which would materially impair the efficiency of combustion since the uniformity of the fuel-air suspension supplied to the combustion zone 26 would be impaired or destroyed, resulting in periodic fluctuations intermittently or periodically producing incomplete combustion. The closing of the column 23 at the bottom of the tuyère 10 due to an insufficient initial air velocity imposed on the tuyère would result in production of such above described deleterious forces in opposition to the aforesaid vertical or linear velocity component of the swirling fuel-air column and consequent impairment of the uniformity of the suspension and the uniformity of the vertical component of this velocity which are the factors upon which uniformity of combustion is dependent.

The distance of the aforesaid spacing of the combustion zone from the entrainment and mixing zones is controllable by varying the air pressure in the casing 11. It is also dependent upon the ratio of the diameter of the tuyère 10 to the length of the blades 18. For example, doubling the tuyère diameter and halving the blade length, with the same air inlet area, pressure drop and air capacity in the burner provides four times the cross sectional area in the orifice defined by the upper end of the tuyère 10. For this reason, the net axial discharge velocity would be reduced, and the pattern of the combustion zone would thus be varied accordingly by variation of the diameter-height ratio. Ordinarily I find that a ratio of greater height than diameter is the most advantageous construction in giving more efficient atomization.

I find that it is not only necessary to provide the previously described envelope of helical moving air-fuel mixture, but that great care must be used to prevent a premature discharge of the fuel from the air which may occur from a sudden change of velocity as the mixture moves out of the restricted tuyère area. As one most effective manner of accomplishing this, I provide a curb or refractory chamber adjacent the end of the tuyère. This is generally shown at 28 and is adapted to embrace and be mounted upon the top of plate 21 of the tuyère.

5

In small furnaces with relatively low heat input, and with air pressures and velocities near the minimum that will successfully operate with this type of burner, I consider it especially desirable to form the inner wall 29 of the curb as a surface generated by rotation of a parabola about an axis common to the tuyère so that the increase in cross sectional area is comparatively slow. In such a construction unusually good combustion results, with a brilliant torus of flame.

The refractory curb or combustion chamber permits a stable sustained combustion in part because of the re-radiation of the heat back from the curb to the burning fuel particles or vapors and because the whirling action of the air-combustion gas mixture maintains these burning fuel particles in suspension until combustion is complete. The whirling flame will serve to re-ignite the mixture if the tendency were for the burning flame to be quenched with the admission of greater amounts of air.

The vortical movement of the fuel and air within the tuyère causes a low pressure central region in which the pressure is so low as to induce into the central path a body which is held over the center of the tuyère. This vortical movement thus tends to induce some of the hot gases from the combustion chamber as well as a portion of the flame itself into the tuyère so that the heat from the combustion chamber thus heats the mixture of the fuel and air within the burner for some preheating. This results in highly efficient combustion.

The angle of the blades and their relative length and the effective opening will vary for different results, but in general I find it desirable to keep the blades about 0.39 inch in width, with an opening of $\frac{1}{16}$ ". Generally a blade angularity of about 13° 55' on a 7" diameter tuyère is appropriate. The essential element, however, is the relatively high velocity of air required to pick up the fuel. While I have operated at as low as 30 feet per second, usually I find a minimum of 50 feet per second to be necessary for safety and the top range may be 100 feet per second or more. Higher ranges of 150 feet per second have been used but the pressure drop is excessive and if such a large fuel capacity is required, then a larger tuyère should be used. For practical purposes the range of my burner is about 70% of design capacity to 140% of design capacity. The pressure drop in such case will vary from about 3" of water to about 12" of water. With one pound per square inch gauge which is equal to 27.7" of water, I obtained 216% of designed working range.

The following table gives the approximate size of burners heretofore constructed and tested:

Height of tuyère.....	3 1/4"
Diameter of tuyère.....	3"
Number of blades.....	18
Width of blades.....	0.525 inch
Area of inlets, total.....	4.08 sq. in. or 0.0284 sq. ft.
Cross sectional area of tuyère.....	7.06 sq. in. or 0.049 sq. ft.
Ratio inlet area to cross sectional area.....	0.58
Diameter of casing 11.....	6 inches
Diameter of fuel pan.....	4 inches
Air pressure in casing 11.....	0.58 lb. per sq. in.
Air feed rate.....	200 cu. ft. per minute
Fuel gas heating value.....	550 B. t. u. per cu. ft.
Fuel rate.....	44.5 cu. ft. per minute
Combined feed.....	244 cu. ft. per minute
Volumetric ratio of air to gas.....	4.5 to 1
Combined feed velocity.....	8,640 ft. per minute
Combined vertical feed velocity.....	5,000 ft. per minute
Pressure drop through tuyères.....	16 inches of water
Minimum pressure drop for satisfactory operation.....	3 inches of water
Heat release.....	1,468,000 B. t. u. per hour

In the above case, the ratio of inlet area to cross sectional area of 58% will result in a low

6

forward component of the fuel-air vortex. My experience has been that with ratios of from 120% to 130%, a much greater forward velocity could be obtained which in certain cases, provides a better flame pattern.

The same burner, under the same conditions using 41.3° A. P. I. kerosene weighing 6.818 lb. per gal. and having a heat value of 19,810 B. t. u. per lb., burned 8.8 gal. per hour equal to a heat release of 1,128,600 B. t. u. per hour.

The same burner, when charged with powdered coal of 12,000 B. t. u. per lb., supplied at the rate of 64.5 lb. per hour, the other conditions being the same, gave a heat release of 769,000 B. t. u. per hour.

A further example of capacity is illustrated by a somewhat larger tuyère. In this case a tuyère of 5 3/4 inches in height and 5 in diameter mounted in an 8 inch casing was supplied with a gas of 550 B. t. u. per cu. ft. heat value at the rate of 181.7 cu. ft. per minute to release 6,000,000 B. t. u. per hour.

While, as above described, the low pressure air which entrains the fuel becomes combustion air, i. e., all of it takes part in fuel combustion, other, secondary air may be added to this low pressure air where the combustion air requirements are greater than this low pressure air. Such additional or secondary air may be supplied by a booster or other means as in Fig. 3. The fuel feed may also be increased, if desired, by increased pressure on the air passing through the tuyère blades.

The application of the foregoing general principles to a horizontal type of burner is disclosed in my copending application Serial No. 22,982 above referred to. It was found that while it could be expected that a fluid fuel would normally tend to drain away from the high point of the tuyère, with a non-uniform flame, this was not a fact if the feed pan closely fit the end of the tuyère. In such a case the feed of fuel is suitably accomplished at only sufficient head to maintain the feed pan full and by starting the air first, the flame is uniform.

The advantage of this discovery is of major importance for many furnace installations require a wall burner, not only for accessibility but also for uniformity of heating. A commercial burner mounting of this type which is adaptable to a furnace side wall is shown in Figures 3 to 5. The burner mounting 30 in this case includes the tuyère 32, its feed pan 33, the primary air duct 34, the wind box 35 and the controls all in an integral unit. In this manner, the entire burner mounting 30 may be bolted to the furnace plate 37 as by bolts 38 and the entire unit is in place. It is only necessary to connect the fuel line at 39 and the air intake at 40 and the unit can be placed in operation at once. A fixed position of the burner from the combustion chamber 42 is assured and operating variables are reduced to a minimum.

More specifically referring to Figure 3, it will be noted that the forward end of the primary air casing 34 in which the tuyère 32 is mounted, extends to the outer edge of the combustion chamber 42 formed in the furnace wall 44 by the lining 45. The diameter of the combustion chamber 42 is preferably from two to three times the diameter of the tuyère opening and it should be about as long in front of the tuyère as it is in diameter. The tuyère 32 itself is thus actually outside of the furnace and in a zone of relatively low temperature. It is generally surrounded with re-

fractory at 46 which may have a plurality of rows of secondary air ports 46a and 46b connecting the wind box 35 with the combustion chamber.

The secondary air may be brought into the windbox through port 48 and I prefer to use a louvred portion 50 with a movable louvred valve plate 51 to vary the air. This plate 51 may have a handle 52 to permit adjustment during operation if necessary bringing more or less of the fixed louvre openings 50a into coincidence with the movable openings 51a.

The tuyère 32 may have two sets of blades 32a and 32b and be provided with a generally cylindrical skirt 54 which closely embraces the blades near their center line and is secured in position by the clip 55. The skirt has an effective diameter such that approximately equal amounts of air passing through the main air duct 34 go through the respective blade banks. In large type units, operating under high air velocity, there might otherwise be a tendency to channel the air which may easily be corrected by this device.

As in the prior case the blades may be struck out of a suitable metal which need not be completely heat resistant itself. I find that although temperatures of several thousand degrees Fahrenheit are generated in front of the burner, the rapid passage of air tends to keep the blades relatively cool. Long life of blades has been attained by using the various alloy steels such as 18% nickel, 8% chrome, and others. Preferably the blades are straight throughout their length to simplify their fabrication.

The fuel pan 33, is conveniently spaced from the closed end 32c of the tuyère as by the blocks 57. The feed pan side wall 33a as previously mentioned, is mounted tight against the tuyère blades thereby forming small openings generally indicated at 56 with the end of the tuyère blades all around the periphery as shown in Figures 4 and 5. The wall 33a of the pan extends approximately one-half inch to one inch beyond the end of the blades and thereby forms the uniformly spaced restricted crifices 56 which are directly in the air path. As a result, each particle of fuel is promptly entrained in a substantial quantity of air and due to the high velocity of the air entering the tuyère a very rapid vortical movement of air and fuel is accomplished.

Although this very intimate mix carries the fuel particles in a number of turns in a helical path through the tuyère, the path itself is substantially smooth and uniform with a minimum of pressure drop. The air undoubtedly moves faster than the fuel particles however, so that there is a complete dispersion of the fuel particles in a highly atomized or mixed form.

After the desired amount of mixing, the air-fuel mix is thrown out into the combustion chamber 42 in whirling fashion where it is initially ignited by suitable means, as for example, a pilot flame in tube 58. Combustion takes place substantially entirely within the range of the length of the combustion chamber. The shortness of flame and completeness of combustion without the presence of smoke indicates the substantially perfect air-fuel mixture.

As shown in Fig. 3, I have found it desirable in some cases to provide two complete rows of apertures in the tuyère face plate 32d. These are generally indicated at 32e and in a plate of 11 3/4 inch diameter, I have used 60 1/8 inch holes on the 10 3/4 inch circle and 100 1/8 inch

holes on the 7 5/8 inch circle. The tuyère opening was 7 3/4 inch inside diameter. The amount of air that passes through these openings is relatively small but it tends to aid the flame pattern and to avoid coke formation either in the combustion chamber or on the tuyère face itself.

In general, I have found that combustion is so complete and effective that secondary air as generally understood is not necessary. However, I find it desirable to use a small amount of secondary air, as for example, from 10% to 20% to avoid overheating of the refractory throat of combustion chamber 42. The small amount of air is sufficient for this purpose and it does not detract from the general efficiency of the furnace.

I have heretofore suggested the flexibility of the burner in using various fluid or fluidized fuels. In one installation that was particularly successful, I introduced gas through line 60 and oil through line 61 to the single fuel line 39. In starting up, it was most convenient to use the gas and when the combustion chamber 42 was hot, the oil could be ignited without difficulty. As both fuels can be burned at once as well as either fuel burned alone, it makes possible a single installation which is adaptable to various market conditions of fuel oil and gas, using whichever is in plentiful supply and most economical.

I have also successfully burned powdered coal as previously mentioned by adapting the burner for such fuel as shown in Fig. 2a. The feed pan 12a was provided with a continuous annular wall 13a extending above the lower ends of the tuyère blades as in Fig. 1 but the lower wall was flared downwardly and made generally frusto-conical or funnel-like to accommodate the powdered or comminuted fuel. A bearing 115 is suitably secured to the bottom or lower wall 16a of the tuyère 10, which bearing supports the upper end of a conveyor screw or worm member 65 which fits closely in the modified feed pipe or inlet 14a. The lower end of the feed screw will of course, be driven by any suitable means, not shown, and the fuel which may be coal or coke or other material may be fed to the feed pipe by any means, such as by gravity from a hopper, not shown, but otherwise well understood in this art.

Alternatively, the powdered fuel may be fluidized with air and conveyed direct to the fuel pan as is the case of the gas or other fluid fuel.

Some fuel, to be fluid, must be partially heated, and it will be understood that preliminary heating can be accomplished in any well known manner. In the case of asphalt of 96 penetration, which I have burned most effectively, the temperature of the fuel was raised to 400° F. and in such case, it could be pumped or gravity fed without difficulty. The use of preheated air is advantageous with this high melting point asphalt to avoid any premature chilling of the asphalt as it passes through the blade openings. It is also usually desirable to completely scavenge the end of a run as with normally liquid fuel such as kerosene. It will be appreciated that combustion of asphalt is a valuable advance in this field and of substantial economic value as fuel is normally bought on a liquid basis but its heat value is on the weight basis which gives heavy residues and asphalts an advantage.

My burner is also particularly adapted to household or domestic type merely by reducing the diameter and height to an appropriate size

and providing a pilot to permit repeated starting. A unit burning 1.5 gals. per hour of furnace oil will be of approximately $1\frac{1}{2}$ inch diameter and about $1\frac{1}{2}$ to 2 inches in height. Provision may be made for adjustment of the fuel pan with respect to the bottom of the tuyère to expose or cover more or less of the blades, if desired.

Summary

The principle of operation of my burner as I now understand it is based on the high velocity tangential flow of combustion supporting gases over an exposed fuel surface in such a manner that a vortex of fuel and gas is developed within the tuyère. This is so intimately mixed in its helical path through the tuyère that a nearly perfect combustion results in the combustion chamber beyond the burner itself. The vortical effect clearly induces some of the combustion gases into the tuyère in such a manner as to preheat the envelope or column of fuel and air therein. The resulting combustion is thus completed within a few feet of the tuyère and yet the tuyère itself is comparatively cool even though the flame and furnace gas are recycled to the whirling combustion zone. Secondary air may be used to avoid furnace decomposition but is not essential for completion of combustion. The application to fluid or fluidized fuels is accomplished in a common unit by the mere change of valves.

The range of burner sizes for various duties is generally found in the following table, it being understood that by varying the air velocity, a range of operation of from 70 to 140% may be obtained in any burner.

Capacity	1 MM ¹	4.8 MM ¹	7.2 MM ¹	10.6 MM ¹	12MM ¹
Tuyère Diameter	3	7½	7½	10	8.7
Tuyère Length	3	6	9	9	12
Curb Diameter	10	20	22¾	28	30
Curb Length	18	20	27	27	30
Fuels, Gals. per hour—Bunker "C"	7½	32	48	72	80

¹ MM is equal to 1,000,000 British thermal units.

It will be appreciated that modifications may be made to my invention and I therefore desire such an interpretation thereof as will come within the scope and spirit of the description herein and of the claims appended hereinafter.

I claim:

1. In a fuel burner, a hollow tuyère having a closed end wall, and a side-wall provided with a plurality of blades forming inwardly convergent air paths, the end of the tuyère opposite the closed end being open, a fuel container having a sidewall surrounding a portion of said tuyère side wall, means for continuously feeding fuel to said fuel container and means for supplying an air current adjacent the surface of the fuel in said container and through said air paths between said blades for entraining fuel and mixing it with the air of said current, and discharging the mixture through the open end of the tuyère.

2. In a fuel burner, a tuyère having a solid bottom wall and a side wall provided with a plurality of blades forming inwardly convergent air paths, a fuel container surrounding the lower end of said tuyère side wall, means forming an enclosure surrounding said tuyère and said fuel container and capable of guiding air currents upwardly over fuel in said fuel container and through said air paths formed by said blades for

entraining fuel and mixing it with the air of said currents, means for supplying air to said enclosure forming means for producing said currents, and inlet means for receiving fuel to said fuel container for entrainment by said air currents outside said tuyère and passage through said convergent air paths to be mixed with the air of said currents to form a swirling fuel-air column in said tuyère, said column conveying said fuel in suspension to a combustion zone spaced from said tuyère.

3. In a fuel burner, a casing connected with a source of air, a tuyère supported in said casing and providing communication between the interior of said casing and the exterior thereof, said tuyère being open at the outer end and having a continuous side wall formed by a plurality of blades and having a solid inner end wall closing the inner end of the tuyère side wall formed by said blades, and fuel supply means forming a fuel supply surrounding the inner tuyère end wall and the inner ends of said blades, said tuyère being adapted to receive air and entrained fuel from said casing, to form therein a hollow swirling fuel-air column and deliver the fuel-air mixture of said column to a combustion zone spaced from said tuyère.

4. The combination of a fuel burner, comprising a tuyère having a solid bottom wall and a side wall provided with a plurality of blades forming inwardly convergent air paths, said tuyère having an outlet opposite the solid wall, a fuel container having a side wall surrounding a portion of said tuyère side wall, means for continuously feeding fuel to said fuel container and means for supplying an air current upwardly over the surface of the fuel in said container and through said air paths between said blades for entraining fuel and mixing it with the air of said current, and a truncated paraboloidal combustion chamber of refractory material superposed on said tuyère, said chamber registering with the outlet of said tuyère.

5. The combination of a fuel burner, comprising a tuyère having a solid bottom wall and a side wall provided with a plurality of blades forming inwardly convergent air paths, said tuyère having an outlet opposite the solid wall, a fuel container having a side wall surrounding the lower end of said tuyère side wall, means for continuously feeding fuel to said fuel container and means forming a shell spaced from said tuyère for supplying an air current upwardly over the surface of the fuel in said container and through said air paths between said blades for entraining fuel and mixing it with the air of said current, and a truncated paraboloidal combustion chamber of refractory material superposed on said tuyère, said combustion chamber having an opening greater than the diameter of the tuyère outlet and registering therewith.

6. The combination of a fuel burner, comprising a tuyère having an end wall and a plurality of blades forming a side wall, said tuyère having an outlet opposite the end wall, said blades being angularly spaced to form inwardly convergent air paths, a fuel container surrounding and adjacent said end wall and in communication with the inside of said tuyère, means for continuously feeding fuel to said fuel container whereby said fuel enters said tuyère adjacent the outer edge thereof, means for supplying an air current over the surface of the fuel in said container and through said air paths between said blades for entraining fuel and mixing it with

the air of said current and a truncated paraboloidal combustion chamber of a refractory material superposed on said tuyère and registering with the tuyère outlet and restricting the path of the fuel-air mixture in the combustion zone.

7. The combination of a fuel burner, comprising a tuyère having an end wall and a plurality of blades forming a side wall, said tuyère having an outlet opposite the end wall, said blades being angularly spaced to form inwardly convergent air paths, a liquid fuel container adjacent said end wall and in communication with the inside of said tuyère surrounding the side wall, means for continuously feeding fuel to said fuel container whereby said fuel enters said tuyère adjacent the outer edge thereof, means for supplying an air current through said air paths between said blades for forming a vortex therein and for entraining fuel and mixing it with the air of said current and a combustion chamber having an internal surface of revolution of a refractory material having an outlet diameter of between 2 and 3 times the diameter of the tuyère and having a length approximately the same as its diameter, said combustion chamber being contiguous to said tuyère and registering with the tuyère outlet and laterally restricting the path of the liquid fuel-air mixture in the combustion zone.

8. In a fuel burner, a tuyère open at its upper end and having a solid bottom wall and a side wall provided with a plurality of blades forming inwardly convergent air paths therebetween, a fuel pan enclosing the lower end of said tuyère side wall, a casing closed at its upper end and surrounding said tuyère and said fuel pan and terminating at the upper open end of said tuyère, said casing guiding an air current upwardly over fuel in said fuel pan and through said air paths between said blades for entraining fuel and suspending it in the air of said current, means for supplying air to said casing for producing said current, and fuel supply means for maintaining a predetermined fuel level in said fuel pan for entrainment of said fuel by said air current outside said tuyère and passage through said convergent air paths for suspension in the air of said current to form a hollow cylindrical swirling column in said tuyère conveying said fuel-air suspension to a combustion zone spaced from said casing surrounding said tuyère and said fuel pan.

9. The structure defined in claim 8 wherein said fuel supply means comprises a gas blower connected with a fuel gas source.

10. The structure defined in claim 8 wherein said fuel supply means comprises a liquid fuel pump connected with a source of liquid fuel and with said fuel pan.

11. The structure defined in claim 8 wherein said fuel supply means comprises a powdered fuel hopper and a power operated screw conveyor connected between said hopper and said feed pan.

12. In a method of burning fuel in an open tuyère having an open end, a closed end and plural generally tangential blades forming its wall, which comprises providing a uniform supply of fuel outside said tuyère, providing a low pressure column of flowing air outside said tuyère, and directing said low pressure air over said fuel for entrainment of fuel particles thereby, thence through said blades to impart a rotary component to said column and form within said tuyère a hollow generally cylindrical mixing and atomizing zone for suspending said fuel particles uni-

formly in said air, while applying sufficient linear component in said column in an axial direction outward of the tuyère adjacent the wall thereof to maintain the fuel-air column in said mixing zone unclosed throughout its length and form a combustion zone spaced from said tuyère and maintained so spaced by said axial linear component.

13. In a method of burning fuel with an upright tuyère having an open top, a closed bottom and plural generally tangential blades forming its side which comprises maintaining a supply of fuel adjacent the lower ends of said blades outside said tuyère, directing a low pressure column of upward flowing air outside said tuyère, and directing said low pressure air over said fuel for entrainment of said fuel thereby, thence through said blades to impart a rotary component to said column and form a hollow generally cylindrical mixing zone in said tuyère for suspending said fuel particles in said air, while regulating the linear component of air in said column in an upward direction adjacent the inner wall of the tuyère and the linear component of air in a downward direction adjacent the center of the tuyère to maintain the fuel-air column in said mixing zone hollow and unclosed throughout its length and discharging the fuel-air mixture to form a combustion zone spaced from said mixing zone.

14. The method defined in claim 13 wherein said fuel comprises a finely divided combustible solid material.

15. The method defined in claim 13 wherein said fuel comprises a combustible gas.

16. A method of burning a fluid fuel, which comprises introducing air under low pressure through the tangential sides of a cylindrical tuyère whereby a rotating truncated-parabolic column of air is created with a relatively small axial component inward of the center of the tuyère and a linear component out of the tuyère adjacent the wall thereof, with every fluid particle taking a helical path, restraining the radially outward movement of the column by the continuous tangential feed of low pressure air to the column substantially throughout its length, the inner wall of the column being formed by the centrifugal force of rotation, maintaining a body of fluid fuel adjacent the outside of the tuyère at one end of the column, and entraining the fluid fuel into said hollow column adjacent the outer wall thereof at a zone opposite the discharge end substantially entirely by the low pressure air, whereby the fuel particles will be introduced into said rotating air column and carried through a plurality of complete turns so that said fuel is intimately mixed with said air.

17. A method of burning a fluid fuel, which comprises introducing air under low pressure through the tangential sides of a cylindrical tuyère whereby a truncated-parabolic column of air is created with a relatively small axial component inward of the center of the tuyère and a linear component out of the tuyère adjacent the wall thereof, with every fluid particle taking a helical path, restraining the radially outward movement of the column by the continuous tangential feed of the low pressure air to the column substantially throughout its length, the inner wall of the column being formed by the centrifugal force of rotation, maintaining a body of fluid fuel adjacent the outside of the tuyère at one end of the column, entraining the fluid fuel into said hollow column adjacent the outer wall thereof

at a zone opposite the discharge end substantially entirely by the low pressure air, whereby the fuel particles will be introduced into said rotating air column and carried through a plurality of complete turns to mix said fuel intimately with said air, discharging the intimately mixed air-fuel column longitudinally and laterally into a chamber of greater cross-sectional area than the column, and preheating the inner wall of the column by the products of combustion which radiate heat into the center thereof.

18. A method of burning a fluid fuel, which comprises introducing air under low pressure through the tangential sides of a cylindrical tuyère whereby a semi-parabolic column of air is created with a relatively fixed radius and a relatively small axial component, with every component taking a helical path, restraining the outer wall of the column by the continuous tangential feed of low pressure air to the column substantially throughout its length, the inner wall of the column being formed by the centrifugal force of rotation, maintaining a body of fluid fuel adjacent the outside of the tuyère at one end of the column, entraining the fluid fuel into said hollow column adjacent the outer wall thereof at a zone opposite the discharge end, whereby the fuel particles will be introduced into said rotating air column and carried through a plurality of complete turns so that said fuel is intimately mixed with said air, passing said mixture into a combustion zone, and restricting the column to a truncated paraboloidal path of slowly increasing diameter with respect to its length in the combustion zone.

19. A burner as claimed in claim 3 in which the tuyère is provided with a face plate extending from the outer end to said casing, said face plate having a series of openings around the periphery communicating with the casing whereby a small amount of the air will purge the face plate of the tuyère.

20. In a horizontal fuel burner, a tuyère having a closed end wall and a side wall provided with a plurality of blades forming inwardly convergent air paths, a fuel container having a portion closely surrounding a portion of said tuyère side wall, means for continuously feeding fuel to said fuel container, and means for supplying an air current through said air paths between said blades for entraining fuel and mixing it with the air of said current.

21. In a fuel burner, a tuyère having a solid end wall and a substantially cylindrical side wall provided with a plurality of angularly opened blades forming inwardly convergent air paths, said tuyère having a horizontal axis, a fuel container having a sidewall surrounding and closely embracing the outer edges of the blades of said tuyère, said blades and said embracing container sidewall forming a plurality of peripherally spaced fuel feed openings between the blades, means for continuously feeding fuel to said fuel container and means for supplying an air current through said air paths between said blades for entraining fuel and mixing it with the air of said current.

22. In a fluid fuel burner, a substantially cylindrical tuyère on a horizontal axis having its side wall formed by a plurality of spaced blades extending substantially throughout the length of the tuyère and forming inwardly directed air inlets therebetween, said tuyère being open at one end and closed at the other end, fuel feeding means adjacent the closed end, said fuel feeding means comprising a substantially

cylindrical chamber having a side wall closely embracing the outer edges of the tuyère blades and forming a plurality of small apertures there-with, means for supplying fuel through said fuel feeding means to said apertures adjacent the edges of said air inlets at the end of the blades remote from the open end of the tuyère, means for supplying air under pressure through said air inlets between said blades over said fuel for entraining said fuel and forming a swirling outwardly moving column adjacent the inner wall of said tuyère, said column having a central low pressure area, said column comprising a combustible fuel-air mixture.

23. In a fuel burner, a substantially cylindrical hollow horizontal tuyère having a closed fuel feeding end, an open fuel discharging end, and a side wall including a plurality of projecting tangential blades forming air openings therebetween, means to apply air to said tuyère to establish a whirling column within the tuyère, said column having a low pressure central portion and being confined by the inflow of air through the tuyère blades, and means to uniformly distribute fuel to the column adjacent the closed end of the tuyère whereby the fuel is entrained in and moves outwardly with the air column to the fuel discharging end, said fuel distributing means including a fixed container having a wall portion surrounding the closed end of the tuyère and closely embracing the blades, said container wall portion forming with the tangential blades of the tuyère, a series of uniformly spaced external openings adjacent the closed fuel feeding end of the tuyère whereby the fuel is presented to the slowest axially moving part of the air column.

24. In a method of burning fuel with a horizontal tuyère having an open end, a closed end, and a plurality of generally tangential blades forming its side, which comprises maintaining a supply of fuel to the portion of said blades adjacent said closed end and between a portion of the blades, directing a low pressure column of flowing air outside said tuyère, directing said low pressure air through said blades and over said fuel for entrainment of said fuel thereby, and to impart a rotary component to said column and form a hollow generally cylindrical mixing zone in said tuyère for suspending said fuel particles in said air, and regulating the linear component of the air in said column adjacent the inner wall of the tuyère in a direction away from said closed end and with a sufficient linear component of air in the opposite direction adjacent the center of the tuyère to maintain the fuel-air column in said mixing zone hollow and unclosed throughout its length, and discharging the fuel-air mixture to form a combustion zone spaced from said mixing zone.

WARD J. BLOOMER.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
120,680	Smith	Nov. 7, 1871
1,297,138	Gardner	Mar. 11, 1919
1,468,008	Dyson	Sept. 18, 1923
1,591,679	Hawley	July 6, 1926

(Other references on following page)

2,560,074

15

UNITED STATES PATENTS

Number	Name	Date	Number
1,618,808	Burg -----	Feb. 22, 1927	1,969,371
1,656,907	Bansen -----	Jan. 24, 1928	1,986,914
1,657,698	Schutz -----	Jan. 31, 1928	1,994,461
1,657,725	Schutz -----	Jan. 31, 1928	2,044,296
1,674,282	Fletcher -----	June 19, 1928	2,096,765
1,698,555	Molz -----	Jan. 8, 1929	2,097,255
1,726,870	Trent -----	Sept. 3, 1929	2,126,417
1,795,454	Van Brunt -----	Mar. 10, 1931	2,138,246
1,823,381	Sherwood -----	Sept. 15, 1931	2,284,906
1,870,026	Rosencrants -----	Aug. 2, 1932	2,302,751
1,892,053	Heaton -----	Dec. 27, 1932	
1,943,286	Burg -----	Jan. 16, 1934	Number
1,950,980	Frisch -----	Mar. 13, 1934	Country
1,963,358	Foltz -----	June 19, 1934	Date
1,967,673	Kennedy -----	July 24, 1934	

16

Name	Date
Hawley -----	Aug. 7, 1934
Avery -----	Jan. 8, 1935
Boland -----	Mar. 19, 1935
Hardgrove -----	June 16, 1936
Saha -----	Oct. 26, 1937
Saha -----	Oct. 26, 1937
Sharp -----	Aug. 9, 1938
Sorg -----	Nov. 9, 1938
Kerrick -----	June 2, 1942
Don Howe -----	Nov. 24, 1942

FOREIGN PATENTS

Country	Date
Denmark -----	May 27, 1931
Great Britain -----	Apr. 18, 1929
Great Britain -----	July 15, 1929
Germany -----	Feb. 18, 1933