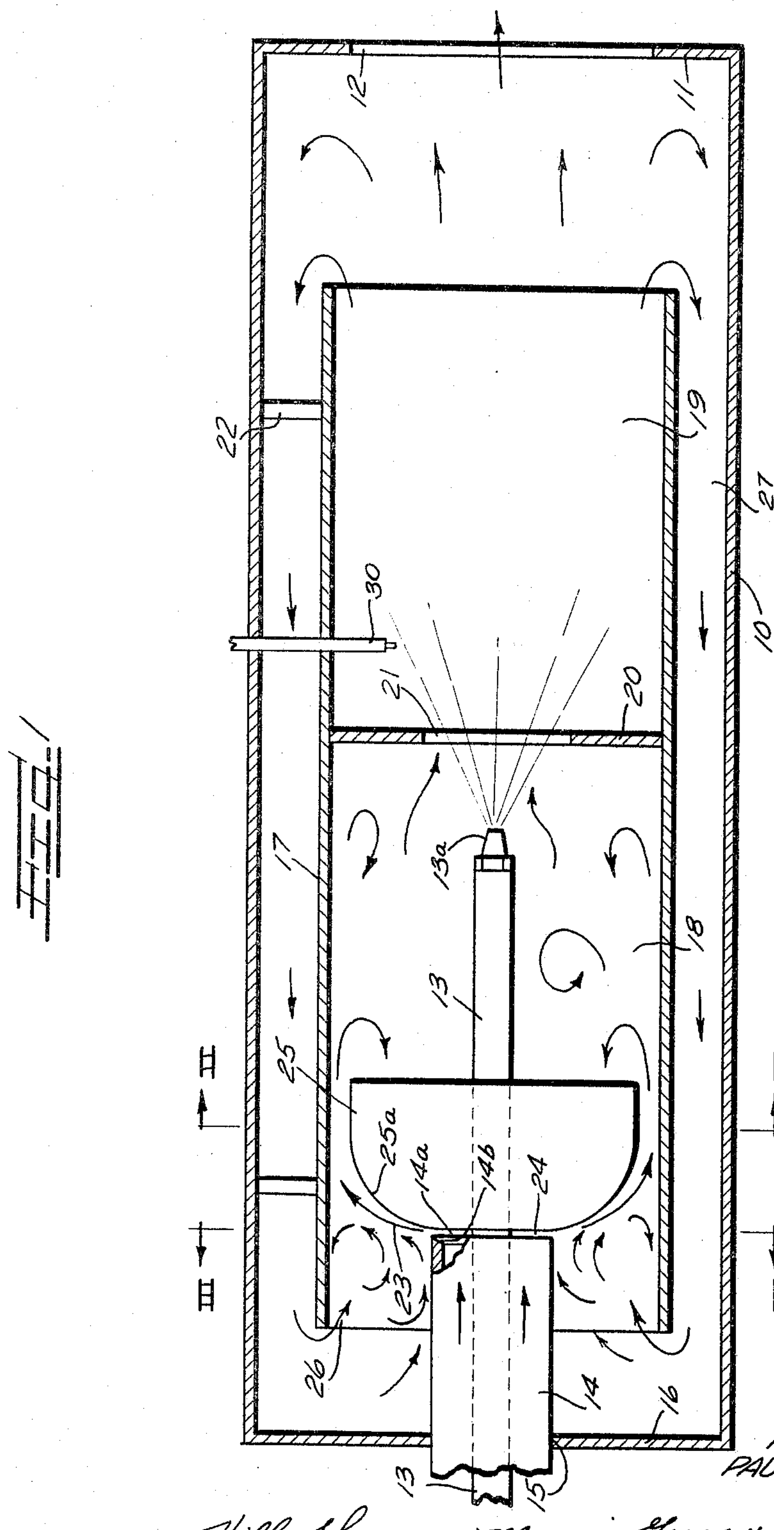


INVENTORS
IMANTS REBA
PAUL W. COOPER

BY Hill, Sherman, Meroni, Gross & Simpson
ATTORNEYS

May 16, 1967 I. REBA ET AL 3,319,692

OIL BURNER

Filed June 1, 1965 2 Sheets-Sheet 2

FIG. 2

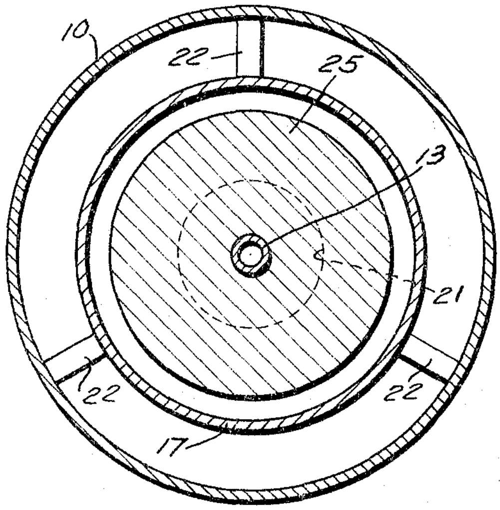
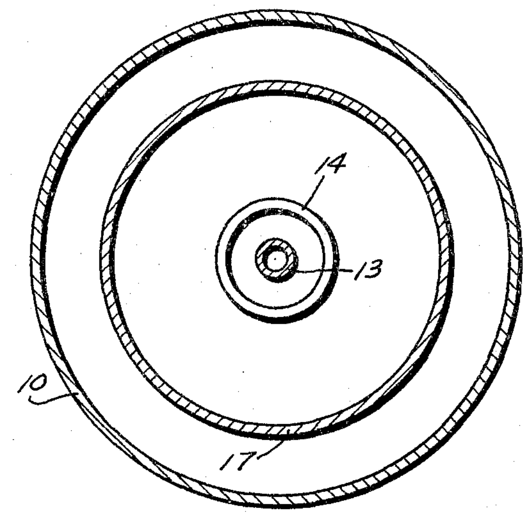


FIG. 3



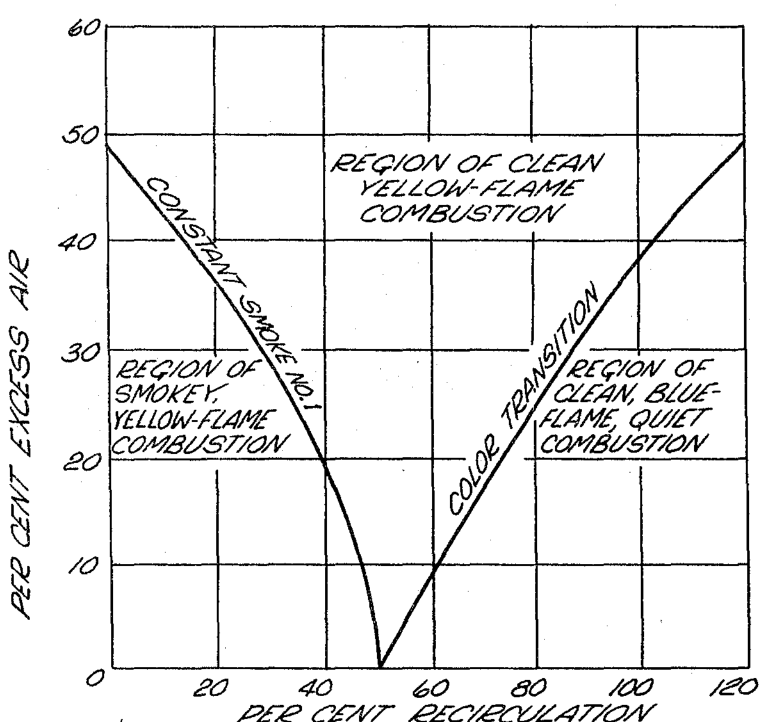


FIG. 4

INVENTORS
IMANTS REBA
PAUL W. COOPER

BY Hill, Sherman, Meroni, Gross & Simpson
ATTORNEYS

United States Patent Office 3,319,692
Patented May 16, 1967

3,319,692
OIL BURNER

Imants Reba, Chicago, Ill., and Paul W. Cooper, Albuquerque, N. Mex., assignors to IIT Research Institute, Chicago, Ill., a corporation of Illinois

Filed June 1, 1965, Ser. No. 460,054
8 Claims. (Cl. 158—1)

The present invention relates to oil burner devices and is, more particularly, concerned with the provision of a simple, compact burner unit capable of highly efficient use in homes, or the like. The burner of the present invention is constructed primarily for the non-commercial, relatively low cost heating installation while at the same time it is designed to produce blue-flame operation with oil of the household grade, commonly known as No. 2 Heating Oil, and at low air pressures.

As those familiar with the art of oil burner construction are aware, much development work has been undertaken in this field in the last twenty years. With such development work, substantially increased performance has been achieved. However, in spite of the forward strides of the heating industry, important deficiencies have existed in heating systems of the relatively inexpensive type designed to operate on residential type heating fuels. More particularly, a truly satisfactory low cost-low pressure burner capable of combustion with a blue or non-luminous flame has not heretofore been successfully achieved. In burner systems utilizing heating oil, the combustion processes have been carried on in the presence of a yellow flame, the best of which has been essentially a clean yellow flame, while the worst has been a yellow flame including substantial smoke propagation. The desirability of providing a blue or non-luminous flame has been generally recognized but the elimination of the smoke and yellow color accompanying prior art devices has eluded those working in the field.

In accordance with the present invention, an oil burner is provided in which smoke has been substantially completely eliminated and the burner operates with an ultimate degree of cleanliness, in the presence of a blue or non-luminous flame. This has been achieved without in any way sacrificing over-all safety of the burner, since operation is intended to be, and is readily accomplished, in a condition of excess combustion air so that carbon monoxide (CO) is eliminated from the combustion gases.

In accordance with the present invention, the products of combustion are recirculated in large proportion in the burner system. By providing a novel primary air flow system and simple vaneless, air flow control device, a very high rate of recirculation of the products of combustion is achieved with a highly efficient blue-flame burning condition.

In accordance with the present invention, extremely simple structural components are employed. The burner comprises a generally cylindrical outer housing open at the downstream end to provide flue gas exhaust. Air and oil are introduced at the upstream end and a cylindrical intermediate diameter body is positioned within the outer cylindrical housing providing an annular recirculation path about its outer peripheral surface and a combustion zone within its internally facing surface. Air is introduced axially into the housing but is radially ejected upstream of and immediately adjacent to a flow directing body comprising, preferably, a solid of revolution from providing a surface generally curved, or relieved in the downstream direction. This surface causes a radially outwardly directed stream of air to deflect toward and adjacent to the solid body under the phenomenon generally known as the Coanda effect. As a result of the phenomenon, no upstream air flow deflecting vanes are required. Instead, as a result of the simple configuration, air flows downstream along the surface of revolution and acts as a pump to entrain a relatively high percentage of recirculated products of combustion. These products, along with primary air, are directed past the solid of revolution into a mixing chamber where they are mixed with atomized oil from a high pressure oil nozzle. The intermixed oil, air and recirculated combustion products pass into the combustion zone where, upon ignition, they are burned in an efficient manner. A portion of the combustion gases are, preferably after complete combustion has occurred therein, recirculated, in the manner above described, thereby providing a particularly efficient combustion system operating without any trace of yellow in the flame.

It is, accordingly, an object of the present invention to provide an improved burner for the combustion of household heating oil.

Another object of the present invention is to provide a simple generally cylindrical, oil burner capable of operation at blue or non-luminous flame conditions in the presence of an excess of air.

Still another object of the present invention is to provide a simple, highly efficient burner construction for the combustion of household fuel, and which has no vanes or moving burner components.

A feature of the invention resides in the provision of a Coanda flow control mechanism for the control of air flow through the burner system.

Another feature of the invention resides in the utilization of a simple, yet highly efficient, recirculation system for recirculating a substantial portion of combustion gases within the combustion area of the burner.

Another feature of the invention resides in the provision of a separation aperture between the fuel and air mixing chamber and the combustion zone providing a pressure differential operative to enhance the recirculation of the products of combustion into substantially direct contact with incoming fuel and air.

Still other and further objects and features of the present invention will at once become apparent to those skilled in the art from a consideration of the attached sheets of drawings wherein one embodiment of the invention is shown by way of illustration only, and wherein:

FIGURE 1 is a generally cross-sectional view, in schematic form, of a burner constructed in accordance with the provisions of the present invention;

FIGURE 2 is a cross-sectional view taken along the line II—II of FIGURE 1;

FIGURE 3 is a cross-sectional view taken along the line III—III of FIGURE 1; and

FIGURE 4 is a chart illustrating certain fuel-air relationships discovered to be important in the successful propagation of a blue-flame oil burner.

As shown on the drawings:

We have discovered as a result of extensive experimentation, including operation of full-size oil burner configurations, that oil may be burned with sufficient efficiency to provide a blue-flame in the presence of excess air. A preferred embodiment of our construction may be seen from a consideration of FIGURES 1 through 3 where our improved burner is shown in a somewhat schematic form.

As may be seen from FIGURES 1 through 3, the burner of the present invention comprises an outer housing generally indicated at **10**, constructed in a generally cylindrical form. Closing off the downstream end of the main housing **10**, is an end plate **11** having an exhaust aperture **12** therein. Oil is introduced under relatively high pressure by way of a conduit **13** leading to a conventional high pressure atomizing nozzle **13*a***. Primary air for combustion purposes is introduced into the cylindrical housing **10** by way of a generally cylindrical conduit **14** which enters the housing **10** by way of an opening **15** in the upstream closure wall **16**. Primary air under a relatively low fan induced pressure of two inches of water has been found satisfactory and may be supplied from any conventional low pressure fan or blower, not illustrated.

Within the central area of the housing **10** a generally cylindrical shroud **17** is rigidly secured. The shroud **17** is divided into two generally cylindrical chambers, indicated at **18** and **19** and comprising, respectively, a mixing chamber and a combustion chamber separated by a separation plate **20** having a separation orifice **21** therein. The shroud **17** may be fixedly positioned within the outer chamber **10** by any conventional means, such as for example a plurality of generally radial spider elements **22** providing a recirculation passageway **27**. Air entering the housing by way of conduit **14** is radially directed outwardly in the direction indicated by the arrows **23**, leaving an annular slit **24** formed by the upstream surface of a body **25** having a curved surface of revolution **25***a*, and the downstream or trailing edge **14***a* of the inlet conduit **14**. The body **25** is rigidly secured in place within the mixing zone **18** by any convenient construction. For example, in the embodiment illustrated, the solid of revolution **25** is rigidly mounted directly on, and to, the fuel oil inlet conduit **13**. It will be understood, however, that the body of revolution **25** may be supported within the mixing zone by securing it directly to the shroud **17** by a spider, in the same manner as indicated at **22** with respect to the shroud **17**.

As shown, air entering the mixing zone by way of the conduit **14** passes through slit **24** radially outwardly in the direction of the arrow **23**. The presence of the curved upstream surface of the solid of revolution **25** causes, as a result of the known Coanda effect, an attachment of the air stream to the surface **25***a* with the resultant flow of the air outwardly along the surface **25***a* and downstream to the mixing zone. It has been found as a result of our experimentation that this tendency of the air toward attachment to the surface **25***a* causes a pumping action or entrainment of air or other gaseous material located in the area **26** immediately upstream of the curved body **25**. In fact, the entrainment provides an efficient pump for causing forced draft recirculation of products of combustion by way of the passageway **27**. This entrainment is improved significantly by providing a sharp edge **14***a* on conduit **14** in the manner shown at **14***b*.

Due to the positioning of the separation plate **20** and the mixing of primary air with the atomized fuel immediately upstream of the separation plate **20**, ignition of the combustible mixture may satisfactorily be accomplished by an electrode **30** positioned in the combustion chamber **19** or immediately upstream of the ignition orifice **21**. This provides for the burning process in chamber **19**, and, as will be more fully set forth below, the combustion chamber length is preferably sufficiently great to provide complete combustion of the fuel prior to movement of the combustion gases downstream and out of the combustion chamber. As a result of this relationship combustion gases, that are recirculated upstream by way of the annular passageway **27** back into the shroud at area **26** for entrainment with the primary air passing about the flow body **25**, are substantially completely burned prior to movement through passage **27** and addition to the primary air. It has been found that for the purposes of providing a blue or nonluminous flame condition, substantially complete combustion of the recirculated gases is desirable.

Operation of the system hereinabove broadly disclosed is based upon discovered relationships relative to the recirculation of combustion gases. As may be clearly seen from a consideration of the chart, FIGURE 4, various conditions of excess air and percentage of recirculation of combustion products provide significantly different flame characteristics. As may be seen, at levels of burner operation providing greater than 50% recirculation of combustion products and moderate amounts of excess air, the flame propagated is clean, blue or nonluminous, and quiet. It is extremely desirable to provide for such a clean, blue-flame and, accordingly, apparatus capable of satisfying these requirements at reasonable cost provides a major contribution in the burner field. The burner illustrated in applicants' FIGURES 1 through 3 fully satisfies these requirements both as to burning characteristics and as to expense.

In further considering the chart, FIGURE 4, it will be observed that percent recirculation identified by

$$R=\frac{\text{standard c.f.m. of recirculated combustion products}}{\text{standard c.f.m. of stoichiometric air}}\times 100$$

The stoichiometric condition, in which no excess air is present, can theoretically produce a clean blue-flame. Although such stoichiometric combustion would be highly desirable from the standpoint of maintaining high unit efficiency, it is considered important to provide excess air under substantially all furnace operation conditions to reduce the dangers of carbon monoxide. Accordingly, it is preferred that the system be operated at conditions of excess air. For example, it has been found through operation of a burner constructed in accordance with the present invention, and in the form illustrated in the drawings hereof, operation at approximately 15% excess air with an inlet air pressure of 2.7 inches of water and $R=75\%$, no carbon monoxide appeared at the exhaust and the burner was operating at a substantially smokeless condition with an essentially blue-flame. These results were achieved employing a firing rate of .95 gallon per hour of No. 2 Distillate Fuel Oil with a nozzle temperature of 300° F. and a temperature in the annular flow recycle path **27** of approximately 1000° F. Further, at stoichiometric conditions and with a blue-flame only 10 to 20 p.p.m. CO was present. These characteristics coincided with the expectations indicated from the chart of FIGURE 4 and were accomplished with a burner constructed in accordance with the structure of FIGURES 1 through 3 and having the following dimensions:

Length of housing **10**	24".
Length of shroud **17**	18".
Spacing between shroud **17** and housing wall **16**	2".
Diameter of shroud	6".
Diameter of housing	8".
Diameter of air inlet conduit **14**	2".
Diameter of flow body **25**	5", with curvature of surface **25***a* comprising 1½" radius fillet.
Axial dimension of slit **24**	1/16".
Oil pipe **13**	½" pipe.
Nozzle **13***a*	.75 gallon per hour, 60° solid spray nozzle spaced 1⅛" upstream of separation plate **20**.
Separation orifice **21**	2⅞" diameter.
Exhaust opening **12**	5¾" diameter.
Length of shroud downstream of separation wall **21**	11".

During the experimental work, it became apparent that variations may be made in the shape of the body **25** and the surface **25***a* thereof, with some effect on entrainment efficiency. However, that addition of axial extension of the flow body after it attains its maximum diameter made no signifiacnt difference in operation. Variations in various of the components will affect operation of the system somewhat and the preferred embodiments of the invention will conform generally to the system equation:

$$\frac{2\pi A_d S}{A_a^2}\int_{r_1}^{r_2}\frac{rdr}{\Phi(r)}-\frac{g_c A_d^2 \Delta P_0}{0.4\rho A_a^2 V_a^2}=(1+E)^2\frac{A_d}{A_e}E^2$$

in which the first term defines the geometry of the system, the second term contains the flow parameters and the terms at the right of the equality sign relate to the entrainment ratio. In the formula the terms are defined as follows:

A_a=area of inlet air slit, square inches
A_d=annular area at exit plane of flow body **25**, square inches
S=inlet in slit width, inches
r_1=radius of inlet air slit
r_2=radius of flow body **25**, inches
r=radius
$\Phi(r)$=radius of curvature of flow surface *25a* as a function of radius of flow body **25**, inches
g_c=conversion factor, 32.2 foot-lbs. mass/lbs.-force sec.^{2}
ΔP_0=pumping pressure of attached jet system, inches of water
V_a=velocity through slit **24**, feet per second

$$E=\frac{\text{entrainment ratio, standard c.fm. entrained gas}}{\text{standard c.f.m. primary air}}$$

A_e=annular area between shroud and inlet air tube **14**, square inches.

It has been found from experimentation that a burner constructed in accordance with the form illustrated in the drawings fully satisfies successful operation under the formula and provides a very high percent of recirculation, necessary to the provision of a blue or non-luminous flame. At the same time, it has been found that operation of the burner is successful at very low primary air inlet pressures. These pressures may be on the order of 2 inches of H_2O which, when compared with the much higher air pressures employed in commercial burner installations, clearly places the burner of the present invention in the category of the inexpensive home oil burner type of apparatus. Accordingly, we have found that calculation of a burner in accordance with the formulae above set forth, permits utilization of an extremely inexpensive design at a cost sufficiently low to permit its widespread use in ordinary residential operation. Of course, design considerations suggest that a relatively simple construction be employed if possible. Toward this end, the design of a specific installation for any given need suggests that a number of the factors in the formula be considered as predetermined by the economics of commercial manufacture. Thus, in designing a burner along the lines of the burner illustrated in the drawings of the present application, certain areas may be predetermined from presently accepted practice. Thus, by using the chart, FIGURE 4, and employing a fixed predetermined firing rate for the fuel, a fixed air flow rate to provide the percent excess air, the amount of inlet air is calculatable and the flow rate of the recirculated products may readily be determined. The diameter of the separation orifice is chosen in accordance with present accepted practice for high pressure type oil burners, i.e., between 2.5 and 3.0" for operation in the range of one gallon per hour. The position of the nozzle upstream of the separation orifice is, similarly, determined by a conventional practice and as such, is on the order of slightly over an inch from the separation orifice. The shape of the flow body may be modified somewhat but choice of the generally circular solid of revolution provides a simply calculatable form having very adequate performance. The diameter of the flow body and the diameter of the shroud is readily computed by equating the sum of the recirculation and inlet air flow rates, combined to the estimated flame velocity such that the flame is stabilized within the shroud. As above noted, the shroud is constructed of sufficient length to encompass substantially complete combustion whereby recirculated gases are essentially completely burned prior to their recirculation. A factor of importance in design consideration, which was determined experimentally, is the fact that the shroud should, for excellent performance, extend at least one inch upstream of the inlet air slit **24**. A lesser dimension provides incomplete entrainment while greater length of shroud upstream of the flow body produces substantially no improvement of entrainment. The utilization of a dimension of 1½" for this factor has proved very satisfactory in operation.

It will be apparent from the discussion above, that it is extremely important, in the propagation of a blue or nonluminous flame, in connection with low pressure primary air combined with household fuel oil to provide high percentages of recirculated products of combustion. It has been found that the vaneless entrainment established by the structure herein illustrated provides a completely satisfactory burner capable of successfully employing low pressure primary air available from inexpensive home-use type blowers, conventional household fuel oil, and extremely inexpensive construction to provide blue-flame operation. It will be clear to those skilled in the art that the recirculation of combustion gases may be accomplished in manners different from that shown in the embodiment illustrated herein. It is, accordingly, our intention that the present invention be limited solely to that scope set forth in the appended claims.

We claim as our invention:

1. In combination in a fuel burner, a generally cylindrical housing, a generally cylindrical shroud fixedly secured within said housing providing an axially extending passage between said housing and said shroud, an axially extending open-ended tubular conduit introducing primary air under positive pressure axially into one end of said cylindrical shroud, means closing said one end of said housing around said conduit, a flow directing body in said shroud intermediate the ends thereof and immediately downstream of the open end of said conduit and combining therewith to provide an annular radially opening slit for the passage of air from the conduit in a direction radially outwardly adjacent said body, means providing an opening between the interior of said shroud and said passage upstream of said body, the upstream surface of said body being gradually curved in the downstream direction whereby air leaving said slit attaches to said surface for deflection downstream in said shroud and for entrainment of gas in said shroud upstream of the body, means introducing fuel into said shroud downstream of said body for mixture with air flowing downstream around said body, means for igniting said mixture in said shroud to provide combustion at the downstream end of said shroud and an opening in the downstream end of said housing providing for the escape of exhaust gases following combustion.

2. In combination in a fuel burner, a generally cylindrical housing, a generally cylindrical shroud fixedly secured concentrically within said housing and spaced therefrom providing an axially extending annular passage between said housing and said shroud, an axially extending open-ended tubular conduit introducing primary air under positive pressure axially into one end of said cylindrical shroud, means closing said one end of said housing around said conduit, a flow directing body in said shroud intermediate the ends thereof and immediately downstream of the open end of said conduit and combining with the open end of said conduit to provide an annular radially opening slit for the passage of air from the conduit in a direction radially outwardly adjacent said body, means providing an opening between the interior of said shroud and said passage upstream of said body, the upstream surface of said body being gradually curved in the downstream direction whereby air leaving said slit attaches to said surface for deflection downstream

in said shroud and for entrainment of gas in said shroud upstream of the body, means introducing fuel into said shroud downstream of said body for mixture with air flowing downstream around said body, means for igniting said mixture in said shroud to provide combustion at the downstream end of said shroud, and an opening in the downstream end of said housing extending beyond the downstream end of said annular passage and providing for the escape of exhaust gases following combustion.

3. In combination in a fuel burner, a generally cylindrical housing, a generally cylindrical shroud fixedly secured concentrically within said housing and spaced therefrom providing an axially extending annular passage between said housing and said shroud, an axially extending open-ended tubular conduit introducing primary air under positive pressure axially into one end of said cylindrical shroud, means closing said one end of said housing around said conduit, a flow directing body in said shroud intermediate the ends thereof and immediately downstream of the open end of said conduit and combining with the open end of said conduit to provide an annular radially opening slit for the passage of air from the conduit in a direction radially outwardly adjacent said body, means providing an opening between the interior of said shroud and said passage upstream of said body, the upstream surface of said body being gradually curved in the downstream direction whereby air leaving said slit attaches to said surface for deflection downstream in said shroud and for entrainment of gas in said shroud upstream of the body, an annular separating plate providing a separation orifice intermediate the ends of said shroud dividing the shroud into a mixing chamber upstream of a combustion chamber, means introducing fuel into said shroud downstream of said body and upstream of said plate for mixture with air flowing downstream around said body, means for igniting said mixture in said shroud to provide combustion in said combustion chamber and an opening in the downstream end of said housing providing for the escape of exhaust gases following combustion.

4. In combination in a fuel burner, a generally cylindrical housing, a generally cylindrical shroud fixedly secured concentrically within said housing and spaced therefrom providing an axially extending annular passage between said housing and said shroud, an axially extending open-ended tubular conduit introducing primary air under positive pressure axially into one end of said cylindrical shroud, means closing said one end of said housing around said conduit, a flow directing body in said shroud intermedaite the ends thereof and immediately downstream of the open end of said conduit and combining with the open end of said conduit to provide an annular radially opening slit for the passage of air from the conduit in a direction radially outwardly adjacent said body, means providing an opening between the interior of said shroud and said passage upstream of said body, the upstream surface of said body being gradually curved in the downstream direction whereby air leaving said slit attaches to said surface for deflection downstream in said shroud and for entrainment of gas in said shroud upstream of the body, an annular separating plate providing a separation orifice intermediate the ends of said shroud dividing the shroud into a mixing chamber upstream of a combustion chamber, means introducing fuel into said shroud downstream of said body and upstream of said plate for mixture with air flowing downstream around said body, means for igniting said mixture in said shroud to provide combustion in said combustion chamber and an opening in the downstream end of said housing at a point beyond the downstream end of said annular passage providing for the escape of exhaust gases following combustion while permitting recirculation of part of the products of combustion via said annular passage.

5. In combination in a fuel burner, a generally cylindrical housing, a generally cylindrical shroud fixedly secured within said housing providing an axially extending passage between said housing and said shroud, an axially extending open-ended tubular conduit introducing primary air under positive pressure axially into one end of said cylindrical shroud, means closing said one end of said housing around said conduit, a flow directing body in said shroud intermediate the ends thereof and immediately downstream of the open end of said conduit and combining therewith to provide an annular radially opening slit for the passage of air from the conduit in a direction radially outwardly adjacent said body, means providing an opening between the interior of said shroud and said passage upstream of said body, the upstream surface of said body being gradually curved in the downstream direction whereby air leaving said slit attaches to said surface for deflection downstream in said shroud and for entrainment of gas in said shroud upstream of the body, means introducing atomized liquid fuel into said shroud downstream of said body for mixture with air flowing downstream around said body, means for igniting said mixture in said shroud to provide combustion at the downstream end of said shroud and an opening in the downstream end of said housing providing for the escape of exhaust gases following combustion.

6. In combination in a fuel burner, a generally cylindrical housing, a generally cylindrical shroud fixedly secured concentrically within said housing and spaced therefrom providing an axially extending annular passage between said housing and said shroud, an axially extending open-ended tubular conduit introducing primary air under positive pressure axially into one end of said cylindrical shroud, means closing said one end of said housing around said conduit, a flow directing body in said shroud intermediate the ends thereof and immedaitely downstream of the open end of said conduit and combining with the open end of said conduit to provide an annular radially opening slit for the passage of air from the conduit in a direction radially outwardly adjacent said body, means providing an opening between the interior of said shroud and said passage upstream of said body, the upstream surface of said body being gradually curved in the downstream direction whereby air leaving said slit attaches to said surface for deflection downstream in said shroud and for entrainment of gas in said shroud upstream of the body, an annular separating plate providing a separation orifice intermediate the ends of said shroud dividing the shroud into a mixing chamber upstream of a combustion chamber, means introducing atomized liquid fuel into said shroud downstream of said body and upstream of said plate for mixture with air flowing downstream around said body, means for igniting said mixture in said shroud to provide combustion in said combustion chamber and an opening in the downstream end of said housing at a point beyond the downstream end of said annular passage providing for the escape of exhaust gases following combustion while permitting recirculation of part of the products of combustion via said annular passage.

7. In combination in a fuel burner providing blue-flame operation, a generally cylindrical housing, a generally cylindrical shroud fixedly secured concentrically within said housing and spaced therefrom providing an axially extending annular passage between said housing and said shroud, an axially extending open-ended tubular conduit introducing primary air under positive pressure axially into one end of said cylindrical shroud, means closing said one end of said housing around said conduit, a flow directing body in said shroud intermediate the ends thereof and immediately downstream of the open end of said conduit and combining with the open end of said conduit to provide an annular radially open slit for the passage of air from said conduit in a direction radially outwardly adjacent said body, said shroud being axially spaced from said means closing said one end of said housing to provide an annular opening between the interior of

said shroud and said passage at a point upstream of said body, the upstream surface of said body being gradually curved in a downstream direction whereby air leaving said slit attaches to said surface for deflection downstream in said shroud and for entrainment of gas in said shroud upstream of the body, an annular separating plate providing a separation orifice intermediate the ends of said shroud dividing the shroud into a mixing chamber upstream of a combustion chamber, means introducing atomized liquid fuel into said shroud downstream of said body and upstream of said plate for mixture with air flowing downstream around said body, means for igniting said mixture and said shroud to provide combustion in said combustion chamber, and an opening in the downstream end of said housing at a point beyond the downstream end of said annular passage providing for the escape of exhaust gases following combustion while permitting recirculation of part of the products of combustion via said annular passage.

8. In combination in a fuel burner providing blue-flame operation, a generally cylindrical housing, a generally cylindrical shroud fixedly secured concentrically within said housing and spaced therefrom providing an axially extending annular passage between said housing and said shroud, an axially extending open-ended tubular conduit introducing primary air under positive pressure axially into one end of said cylindrical shroud, means closing said one end of said housing around said conduit, a flow directing body in said shroud intermediate the ends thereof and immediately downstream of the open end of said conduit and combining with the open end of said

conduit to provide an annular radially open slit for the passage of air from said conduit in a direction radially outwardly adjacent said body, said shroud being axially spaced from said means closing said one end of said housing to provide an opening between the interior of said shroud and said passage at a point upstream of said body and providing an extension of said shroud a distance in excess of one inch upstream of said slit, the upstream surface of said body being gradually curved in a downstream direction whereby air leaving said slit attaches to said surface for deflection downstream in said shroud and for entrainment of gas in said shroud upstream of the body, means introducing atomized liquid fuel into said shroud downstream of said body, for mixture with air flowing around said body, means igniting said mixture, and an opening in the downstream end of the housing at a point beyond the downstream end of said annular passage providing for the escape of exhaust gases following combustion while permitting recirculation of part of the products of combustion via said annular passage.

References Cited by the Examiner

UNITED STATES PATENTS

2,056,531	10/1936	Morton	158—1
2,701,608	2/1955	Johnson	158—1
2,918,117	12/1959	Griffin	158—1
3,174,526	3/1965	Von Linde	158—1 X

FREDERICK L. MATTESON, Jr., *Primary Examiner.*

E. G. FAVORS, *Assistant Examiner.*