March 2, 1954 J. L. MacFARLANE 2,670,788

FUEL AND AIR MIXING UNIT FOR BURNER ASSEMBLIES

Filed Oct. 10, 1949 3 Sheets-Sheet 1

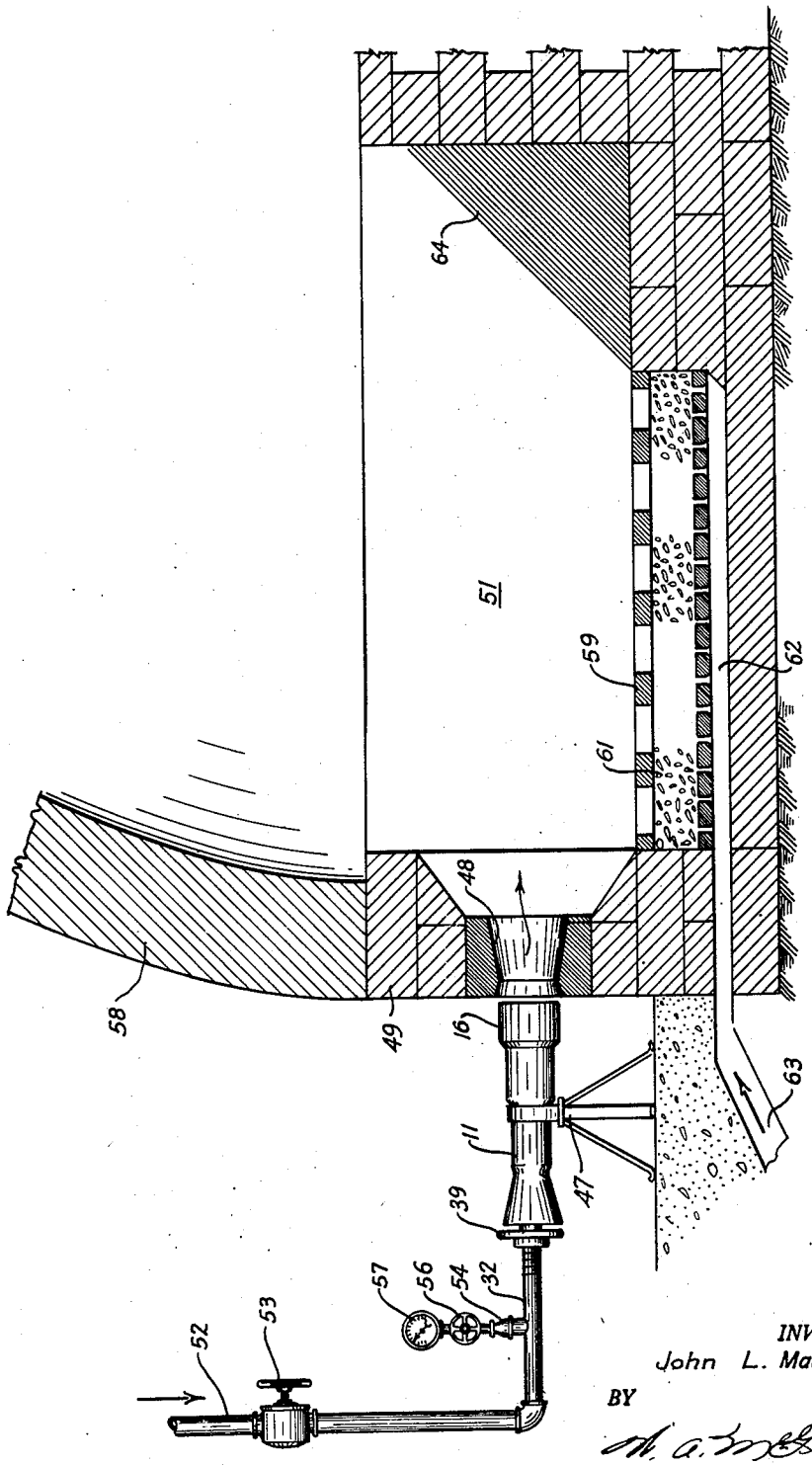


FIG.-1

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FUEL AND AIR MIXING UNIT FOR BURNER ASSEMBLIES

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3 Sheets-Sheet 2

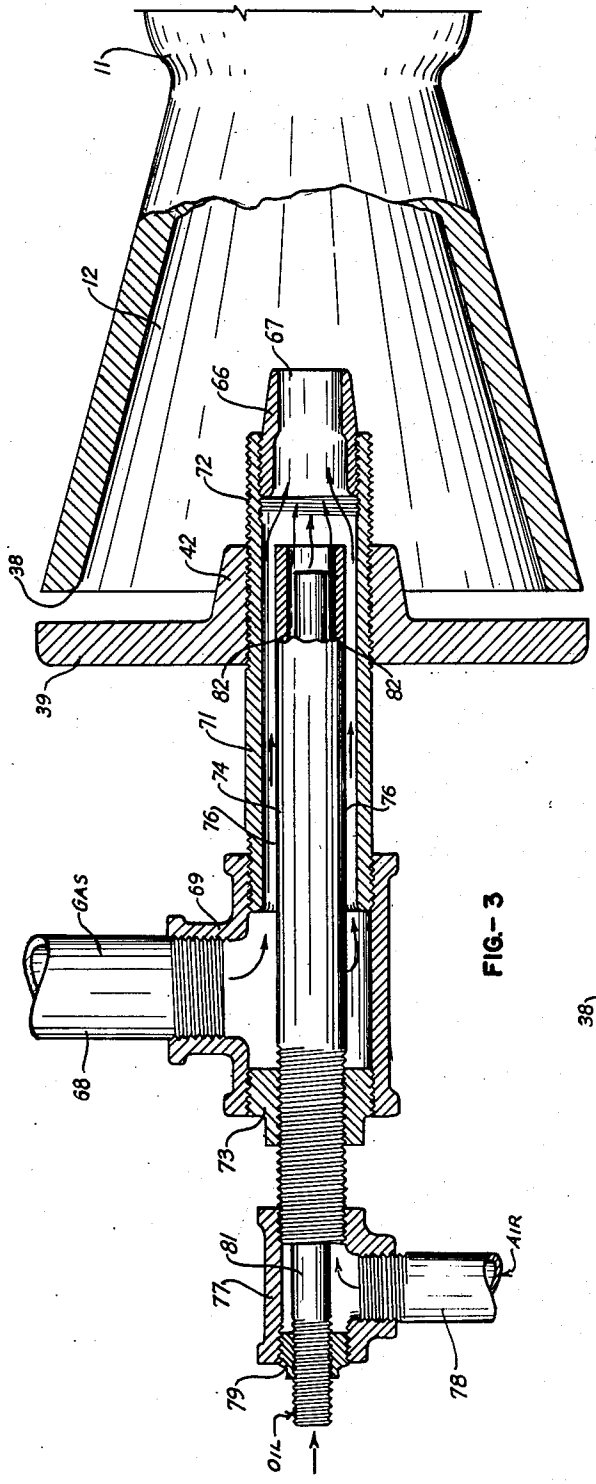


FIG.-3

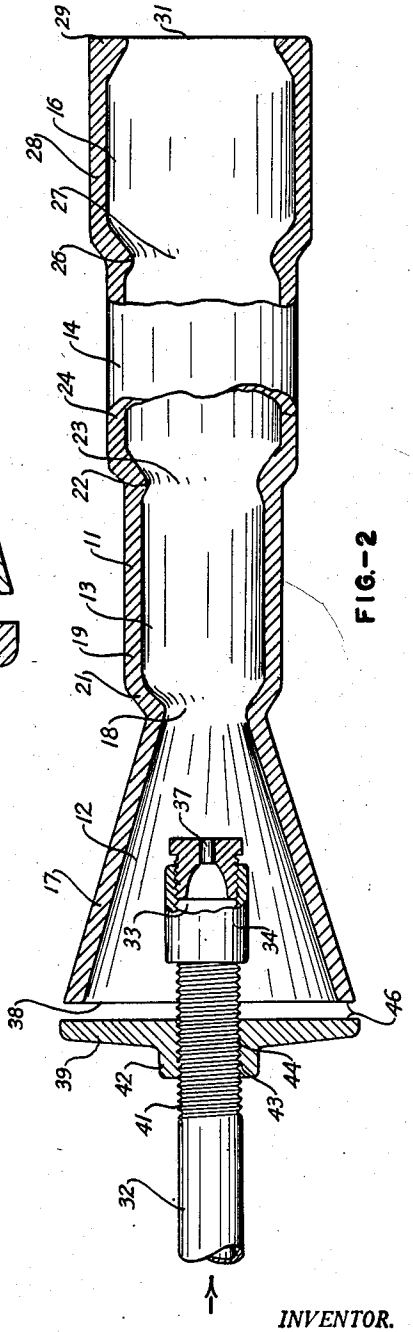


FIG.-2

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FUEL AND AIR MIXING UNIT FOR BURNER ASSEMBLIES

Filed Oct. 10, 1949

3 Sheets-Sheet 3

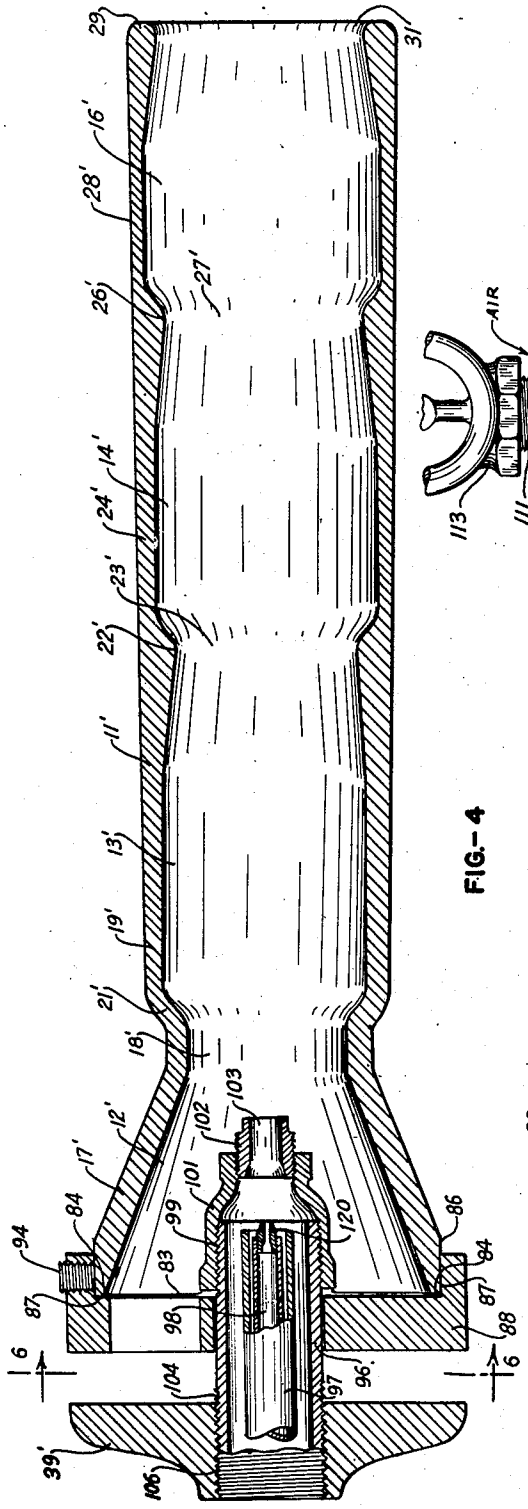


FIG.-4

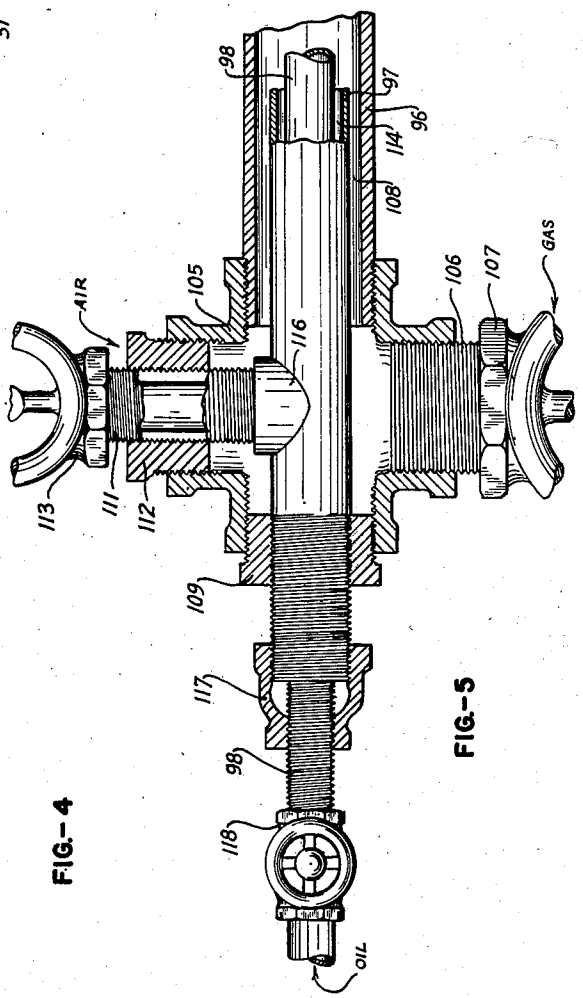


FIG.-5

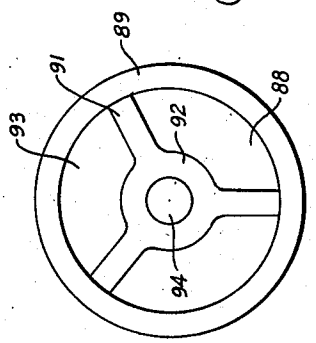


FIG.-6

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Patented Mar. 2, 1954

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UNITED STATES PATENT OFFICE

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FUEL AND AIR MIXING UNIT FOR BURNER ASSEMBLIES

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Application October 10, 1949, Serial No. 120,579

17 Claims. (Cl. 158—11)

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This invention relates to a fuel and air mixing unit for burner assemblies which is useful in obtaining a controlled heating pattern and efficient combustion.

Many different types of fuel and air mixing units or burners have previously been devised in attempts to increase the efficiency of combustion or to control the flame pattern. Generally most of the previous designs have been based on the theory that turbulence is essential for the complete intermixing of fuel and air and that a conical flame pattern is most desirable because the hot zones of the flame are then concentrated.

Certain disadvantages of fuel and air mixing units designed on the basis of the foregoing theory have become apparent. One disadvantage of flame patterns having hot zones is noted where the capacity of original installations has been increased. Such increases in capacity necessitate the burning of additional fuel which causes an elongation of the flame pattern tending to bring the hot zone of the flame into contact with parts of the fire box or furnace to the consequent damage of said parts. Accordingly burners that develop a hot zone have not been useful over a wide range of flow capacities unless the furnace or fire box was specially designed to accommodate such a burner.

Insofar as the mixing of the fuel and air is concerned, some of the previous designs have attempted by various means to increase the amount of turbulence within the mixing unit and outwardly into the flame pattern in the belief that such increased turbulence was necessary to assure the complete intermixing of fuel and air. As a result of the present inventor's studies, it would now seem that many previous devices for mixing fuel and air have actually created too much turbulence in the flow pattern to assure the complete intermixing of the combustion supporting products.

Primarily the complete intermixture of fuel and air is desired to increase the efficiency of combustion. Since maximum efficiency has not been obtained previously with prior types of mixing units or burners, it is evident that the intermixture of fuel and air has been incomplete or at least not in the proper proportions. These inefficiencies generally occur at all levels of operation, but in most installations an increase in the percent combustibles or in excess air is noted on either side of an optimum operation condition. Any type of burner which does not operate at near maximum efficiency over a wide range of operation levels does not thoroughly

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satisfy the requirements of modern furnace, kiln and other fire box installations.

In order to overcome the shortcomings of prior devices, the present inventor has devised a fuel and air mixing unit designed to satisfy the following objects:

To provide a fuel and air mixing unit which efficiently combines fuel and air in readily adjustable exact proportions to assure efficient combustion.

To provide a fuel and air mixing unit in which liquid or gaseous fuels may be efficiently intermixed with air or oxygen without creating excessive turbulence within or at the discharge of said mixing unit.

To provide a fuel and air mixing unit which is adapted to give a homogeneous flame pattern.

To provide a fuel and air mixing unit having a plurality of successive expansion chambers adapted to intermix the fuel and air products efficiently before discharging said products in a homogeneous flame pattern.

To provide a fuel and air mixing unit having successive chambers of increasing diameter adapted to efficiently intermix liquid and gaseous fuels with air introduced into said mixing unit by concentrically arranged conduits having flow and pressure controlling means associated therewith.

To provide a fuel burning arrangement inclusive of a mixing unit having expansion chambers of successively increasing diameter, conduit means for carrying fuel to said mixing unit at a predetermined rate of flow together with further means for controlling the amount of primary air introduced into said mixing unit and the amount of secondary air introduced into the fire box through a checker preheating system.

To provide a fuel and air mixing unit which is easily and economically manufactured and which incorporates simple control features easily operable by the personnel maintaining said mixing unit.

Further objects and advantages of the present invention will be apparent from the appended description and drawings in which:

Fig. 1 is an elevation in partial section showing the general use of the mixing unit of this invention in a brick kiln fire box installation inclusive of a secondary air preheating system;

Fig. 2 is an elevation in partial section showing the features of an embodiment of this invention in exact detail drawn to ½ scale;

Fig. 3 is an elevation in partial section showing the details of a fuel and air conduit arrangement

together with air control means for association with said mixing unit;

Fig. 4 is an elevation in partial section showing the features of a separate embodiment of this invention in exact detail drawn to ⅝ scale;

Fig. 5 is an elevation in partial section showing the details of a separate embodiment of the fuel and air conduits arrangement together with the control means thereof; and

Fig. 6 is an elevation on a reduced scale taken along the lines 6—6 of Fig. 4.

Briefly stated the present invention provides a fuel and air mixing unit inclusive of an entrance chamber having side walls which narrow or converge to provide an opening of minimum diameter consistent with the flow capacity of the mixing unit. Downstream from the said entrance chamber and the opening therein, a plurality of expansion chambers of successively increasing diameter in the downstream direction are provided. Each of the expansion chambers is substantially cylindrical in shape having the individual lengths thereof greater than the diameters of said chambers, but each of said chambers being of successively decreased length with respect to the next adjacent upstream chamber. The chambers themselves are separated one from another by a plurality of restrictions formed on the inner surfaces of said chambers which tend to narrow the passage therethrough to provide openings of diameter less than the diameter of the next adjacent upstream expansion chamber. Further these openings are of successively increasing diameter in the downstream direction. By means of the foregoing arrangement the inventor is able to establish a flame pattern which is homogeneous insofar as the dispersion of color is concerned. By use of separate means for controlling the amount of atmospheric air, fuel and air under pressure introduced into the mixing unit, the amount of fuel and air introduced can be controlled in exact proportion to maintain highly efficient combustion. Separate arrangements for controlling the amount of fuel and air introduced are provided in accordance with this invention together with means for controlling the distribution of the aforementioned homogeneous flame pattern within a fire box, furnace or the like.

In Fig. 2 the details of a first embodiment of this invention are shown. In this figure it will be noted that the inventor provides a fuel and air mixing unit 11 having in successive downstream arrangement an entrance chamber 12, a first expansion chamber 13, an intermediate expansion chamber 14 and a last expansion chamber 16. As shown, the entrance chamber is provided with converging side walls 17 of substantially frusto-conical shape. These side walls 17 converge or narrow in the downstream direction to an opening 18 of minimum diameter consistent with the desired maximum volumetric flow for the particular installation. Beyond the opening 18 a first expansion chamber 13 having walls 19 of substantially cylindrical shape is disposed, and interconnecting the cylindrical walls 19 of the first expansion chamber 13 and the converging side walls 17 of the entrance chamber 12 is a section 21 of expanding diameter to provide a transition member between the opening 18 and the cylindrical walls 19. The length of the first expansion chamber 13 and of the walls 19 thereof is approximately twice the inside diameter of the expansion chamber 13. At the terminal downstream end of the first expansion chamber

13, a constriction 22 disposed upon the inner surface of the walls 19 is provided. Preferably the constriction 22 narrows the passage through the first expansion chamber 13 to provide an opening 23 of diameter greater than the opening 18 and less than the diameter of the upstream expansion chamber 13. An intermediate expansion chamber likewise having walls 24 of substantially cylindrical cross section is disposed downstream from the opening 23 and is interconnected to the chamber 13 by a continuation of the restriction 22 and expands in diameter from minimum size at the opening 23 to maximum size coterminous with the diameter of the chamber 14. The diameter of the intermediate expansion chamber 14 is approximately 10 to 25 per cent greater than the diameter of the next adjacent upstream expansion chamber 13, and the length of the intermediate expansion chamber 14 is approximately one and one-half times the diameter.

At the downstream end of the intermediate expansion chambers another restriction 26 is likewise provided to narrow the passage through said intermediate chamber 14 to provide an opening 27 of diameter greater than the opening 23 and less than the diameter of the intermediate expansion chamber 14. A third or last expansion chamber 16 having cylindrical walls 28 is provided downstream from said opening 27 and a continuation of the restriction 26 of expanding diameter interconnects the intermediate chamber 14 and the walls 28 of the last chamber 16.

The diameter of the cylindrical expansion chamber 16 is approximately 1.2 times the diameter of the intermediate expansion chamber 14 and the length of the last chamber 16 is approximately 1.2 times the diameter. At the terminal end of the last expansion chamber 16 a circularly formed restriction 29 is provided which narrows the passage through said last expansion chamber to an opening 31. The diameter of the opening 31 is greater than the diameter of the upstream opening 27 but less than the diameter of the adjacent upstream expansion chamber 16.

Besides the ratios and proportions already set forth, it should be noted that the successive openings 18, 23, 27 and 31 are of successively increasing diameter in the downstream direction. The expansion chambers are of successively increasing diameter in a downstream direction from the entrance chamber 12 and of successively decreasing length. In all instances however, the sizes of the openings 18, 23, 27 and 31 are of smaller diameter than the next adjacent upstream chamber. While specific ratios and proportions have been set forth, it should be apparent that modification within certain limits is possible. Accordingly it should be realized that the dimensions and proportions set forth are given only to enable others to readily practice the present invention.

As further shown in Fig. 2 a mixing unit 11 is preferably used in conjunction with apparatus for delivering gaseous fuel into the mixing unit 11 where it is to be intermixed with air entering at atmospheric pressure. The associated apparatus shown is especially useful when it is desired to burn natural gas or similar gaseous fuel. When this type of installation is desired the inventor prefers to provide a pipe or conduit 32 having its end 33 disposed centrally in the entrance chamber 12. A coupling 34 and plug 36 or other similar closure members are provided on the end 33 of the pipe 32. Where a plug is used, an orifice

37 is drilled through the plug 36 so that the gaseous fuel being carried by the conduit 32 is delivered through the orifice 37 into the entrance section 12 of the mixing unit 11.

In order to regulate the amount of gas and air being introduced into the mixing unit so as to obtain the correct proportions necessary for efficient combustion, separate means such as valves or the like (not shown) are provided on the gaseous fuel introducing pipe 32 to control the flow and pressure of fuel through the pipe 32 and orifice 37. While other means may be used to accomplish the same result, the inventor prefers to mount a primary air control disk on the external surface of the pipe 32 for adjusted movement toward and away from the entrance opening 38 of the entrance chamber 12. To accomplish such adjusted positioning of the air control disk 39, the inventor in the embodiments shown provides threads 41 of extended length cut in the outer surface of the pipe 32. The air control disk 39 is preferably a member having a flat disk shape of size larger than the entrance opening 38 and a boss 42. The boss 42 and the central portion of the disk 39 is provided with an opening 43 having threads 44 therein for mating engagement with the threads 41 on the external surface of the pipe 32. It will be noted that as the air control disk 39 is rotated with respect to the pipe 32 it will be moved inwardly or outwardly with respect to the entrance opening 38. When the disk is moved away from the entrance opening 38 the opening 45 of cylindrical shape between the disk 39 and the entrance opening 38 will be increased to allow an increased amount of air to flow into the entrance section 12 of the mixing unit 11.

In Fig. 1 a typical installation which fully utilizes the advantages of a mixing unit similar to that shown in Fig. 2 is shown. In this figure it will be seen that the fuel and air mixing unit 11 is supported by a stand 47 so that the downstream opening 31 in the last expansion chamber 16 discharges through an opening 48 in the exterior wall 49 of a fire box 51. The conduit 32 is interconnected with a fuel supply pipe 52, and a valve 53 previously mentioned is provided to control the flow of fuel into and through the conduit 32. Beyond the valve 53 in a downstream direction the conduit 32 is provided with a tap 54, a valve 56 and a pressure gauge 57 useful in determining and controlling the delivery pressure of the gaseous fuel being used. As previously explained the air control disk 39 is mounted for adjusted movement along the conduit 32 to vary and control the amount of primary air introduced into the mixing unit 11. The fire box itself which is in this figure shown as being enclosed within a kiln 58 is provided with a grate 59 and a mass of broken fire brick 61 or other similar material which separates the fire box 51 from a secondary air entrance channel 62. The channel 62 is connected with a header 63 which is interconnected to a conventional type of blower (not shown) so that secondary air will be introduced into the fire box 51 through the header 63 and channel 62 and upwardly through the broken brick 61 and grate 59 to further control the placement of the flame pattern within the fire box 51 and to preheat the secondary air by means of its passage through the checker-like system provided by the broken brick 61. By means of this arrangement when the amount of fuel and air introduced through the mixing unit 11 is increased, the flame pattern emitting from

the discharge opening 31 can be controlled so that it will not impinge upon the fire wall 64 with such intensity as to destroy the fire wall. Since the flame pattern emitted by the mixing unit 11 is substantially homogeneous in character and since there are no marked hot zones in the flame pattern, this control of the placement of the flame pattern is possible without endangering any of the other parts, such as the roof (not shown) of the kiln. Likewise with this type of burner the placement of the flame pattern can be controlled in furnaces, ovens, open hearths, soaking pits and the like to prevent the destruction of parts within such units due to the concentration of heat.

The exact character of the flame pattern emitted by the mixing unit 11 should perhaps be more fully described. It has been written that this flame pattern is homogeneous. By this term the inventor intends to convey the impression that there are no marked physically apparent demarcations of flame pattern which might be characterized as oxidizing, reducing or as a hot zone. Instead the flame emitted from the discharge opening 31 is of elongated substantially cylindrical shape of slightly increasing diameter away from the discharge opening 31. Throughout the visible portion of the flame pattern the intermixture of colors such as the characteristic reds, blues, greens etc. is even, or in other words the flame pattern is homogeneous since the dispersion of such characteristic colors is complete.

While the complete dispersion of flame colors is not conclusive to prove that there is a complete intermixture of fuel and air, such results coupled with flue gas analysis results showing a maximum efficiency are conclusive to show that the intermixture accomplished by the inventor's type of mixing unit is complete and may be regulated in exact proportion to establish maximum combustion efficiency. In a brick kiln installation this type of mixing unit has made it possible to obtain consistent results showing not over $\frac{1}{10}$ of 1 per cent excess oxygen with no combustibles in the flue gas analysis. In the same installation mentioned when mixing units of the described type are installed, the saving in fuel was better than 40 per cent, and since a more intense heat was possible in a shorter period of time the production capacity of the plant was increased and the fuel cost per thousand bricks was effectively cut in half. While it is admitted that these results are perhaps unusual, they are evidence of the possibilities inherent in the inventor's type of design.

Besides the gaseous fuel and air installation as shown in Figs. 1 and 2 it has been found that the present type of mixing unit is adaptable to other fuel burning applications. Actually units of design similar to that described have been used to intermix gaseous, liquid and solid fuels with air under pressure and at atmospheric pressure. In all instances the results have shown that the fuel and air intermixture obtained is suitable for the attainment of maximum or near maximum combustion efficiencies.

An arrangement for the efficient intermixture of gaseous and liquid fuels with air under pressure and at atmospheric pressure is shown in Fig. 3. In this figure a mixing unit 11 is provided of form and shape substantially as shown in Fig. 2 having an entrance chamber 12 and an entrance opening 38 as previously described. Three separate concentric conduits are arranged within or adjacent to the entrance section of the

mixing unit 11 so that a gaseous fuel such as natural gas, a liquid fuel such as fuel oil and primary air under pressure will be conjointly introduced into the entrance section 12 on passing through a nozzle 66 having an orifice 67 therein. The actual arrangement of the conduits and associated members is fully shown in Fig. 3 where it will be noted that gas is introduced by means of a pipe 68 into a T fitting 69. A gas conveying conduit 71 interconnects with one opening of the T to form the outermost of the conduit members. The outer surface of this conduit 71 is provided with threads 72 for the reception of an air control disk 39 of shape, size and purpose corresponding to that previously described. As before, movement of the control disk 39 toward or away from the entrance opening 38 decreases or increases the amount of air introduced into the entrance chamber 12 at atmospheric pressure. A tapped plug 73 is provided in the third or remaining opening of the T fitting, and a conduit 74 having an outside diameter that is less than the inside diameter of the outer conduit 71 is connected through the tapped plug 73 and disposed concentrically within the outer conduit 71 so as to provide a passage 76 through which the gas introduced into the T by the pipe 68 may be conveyed toward the orifice opening 67. One opening of a second T 77 is interconnected to the outer end of the conduit 74 and an air delivery pipe 78 is interconnected into another opening of the T 77. A tapped plug 79 is disposed in a third opening of the second T 77 and an inner conduit 81 is connected through the tapped plug 79 and disposed within the conduit 74 to convey oil to the orifice 67 and into the entrance section 12. The outside diameter of the conduit 81 is substantially less than the inside diameter of the conduit 74 so that a passage 82 is provided between the conduits 81 and 74 through which air under pressure may be introduced for passage to and through the orifice 67 and into the entrance chamber 12. This particular arrangement of feed conduits is advantageous in installations where a more intense heat is desired or where the supply of one or the other types of fuel is not thoroughly dependable. Where a more intense heat is desired both the liquid and gaseous fuel will be introduced simultaneously with air under pressure and air at atmospheric pressure to provide a homogeneous mixture having a high heating value. It is significant that the intermixture of the separate types of fuel is so complete that the resulting flame pattern is still homogeneous and the flue gas analyses show corresponding efficiencies. By the use of valve members on the separate pipes 68, 78 and 81 the flow of any of the separate constituents may be closely controlled and accordingly whenever it is desired or necessary to cut off one particular type of fuel, adjustment may be readily made to maintain the efficient combustion. In instances where the primary type of fuel is cut off, the provision of a secondary fuel which may be efficiently burned to maintain a satisfactory heat is invaluable.

In Fig. 4 a modified form of mixing unit construction is shown. In this figure the mixing unit 11' is provided with an entrance chamber 12' and a plurality of expansion chambers 13', 14' and 16'. As in the previous arrangement the expansion chambers are successively of increasing diameter in the downstream direction. Further the side walls 17' of the entrance chamber 12' narrow to provide an opening 18' at the minimum diameter of said entrance section. The walls 19' of the first expansion chamber 13' are substantially cylindrical in shape and a section 21' of expanding diameter interconnects the opening 18' with the walls 19' of the first expansion chamber 13'. Adjacent the downstream terminal end of the expansion chamber 13' a restriction 22' is disposed to provide an opening 23' of diameter smaller than the diameter of the expansion chamber 13'. The actual form of the restriction 22' is different than that illustrated in Fig. 2 inasmuch as the modified form of restriction 22' provides for a gradual and even reduction in diameter from a maximum size equal to the diameter of the expansion chamber 13' to a minimum size equal to the diameter of the opening 23'. Downstream from the opening 23' the restriction 22' has an expanding or flared internal diameter adapted to provide a smooth but relatively sharp transition from the diameter of the opening 23' to the internal diameter of the walls 24' of the intermediate expansion chamber 14'.

A restriction 26' is likewise positioned adjacent the downstream terminal end of the intermediate expansion chamber 14'. The construction of the restriction 26' is similar to that of restriction 22' inasmuch as it provides for a gradual reduction in internal diameter from the diameter of the walls 24' to the diameter of an opening 27' separating the intermediate expansion chamber 14' from the last expansion chamber 16'. Downstream from the opening 27' the walls of the restriction 26' have an expanding diameter to effect a smooth but relatively sharp transition from the diameter of the opening 27' to the internal diameter of the walls 28' of the expansion chamber 16'. A further restriction 29' is disposed adjacent the downstream terminal end of the expansion chamber 16' to narrow the passage therethrough and to provide a discharge opening 31' of diameter less than the inside diameter of the walls 28'. Restriction 29' is formed similarly to the restrictions 22' and 26' inasmuch as its walls are adapted to provide a gradual transition between the diameters of the external walls 28' and the discharge opening 31'.

As in the previous embodiment the diameter of the expansion chamber 13' is greater than the diameter of the opening 18'. Further the expansion chambers 13', 14' and 16' are of successively increasing diameter in the downstream direction and the diameters of the openings 18', 23', 27' and 31' are likewise of successively increasing diameter in the downstream direction. Again each of the separate openings 18', 23', 27' and 31' are of less inside diameter than the next adjacent upstream chamber. Essentially the differences between the embodiments shown in Fig. 2 and Fig. 4 are concerned with providing transition shapes between the separate expansion chambers that more nearly conform to the shape of conventional type nozzles. These changes have been made inasmuch as the embodiment shown in Fig. 4 is designed for larger capacity than that shown in Fig. 2 and for the larger flow capacities the nozzle type restrictions give the proper intermixture without establishing excessive turbulence.

Figs. 5, 6 and a portion of Fig. 4 show the details and arrangement of a separate type of fuel and air feed and control. In Fig. 4 it will be noted that the entrance end 33 of the mixing unit 11' is provided with a flat face 34 and the side walls 17' of the entrance chamber 12' are turned to provide a cylindrical face 36. These machine faces are provided so that they may be

securely engaged in cooperative mating surfaces 87 of a spider member 88. As shown in Fig. 6 the spider 88 is provided with an outer ring 89 having the aforementioned mating surfaces 87 cut on the inner face thereof. Web members 91 interconnect a central hub 92 with the ring 89 so as to provide openings 93 communicating with the entrance chamber 12'. Set screws 94 in the ring 89 are adapted to secure the spider member 88 to the mixing unit 11' and the hub 92 provides an opening 94 in which the fuel and air feed conduits are received.

A separate arrangement for the fuel and air feed conduits is shown in Fig. 5 and in a portion of Fig. 4 where it will again be noted that the applicant provides a plurality of concentric conduits 96, 97 and 98 for introducing gas, air and oil respectively into the entrance chamber of the mixing unit 11'. The outermost of the conduits 96 is supported in concentric position within the entrance chamber 12' by the spider 88, and its inner end is provided with threads 99 to receive a reducer member 101, the outer end of which is partially closed by a plug 102 having an orifice opening 103 therein. As in the previous embodiment, adjusting threads 104 are provided on the outer surface of the conduit 96 for engagement by the threads 105 of the air control disk 39'. By means of this arrangement the air control disk 39' may be moved to adjusted position along the conduit 96 to increase or decrease the cross sectional area of flow past the air control disk 39' and the spider 88 and into the entrance chamber 12'. Accordingly a correspondingly accurate control of the amount of atmospheric air introduced into the mixing unit is likewise possible in this embodiment.

The outer end of the conduit 96 is secured in one opening of a cross 105. A gas supply pipe 106 having a valve 107 thereon for the control of gas through the pipe 106 is secured in a second opening of the cross 105 in such manner that the gas introduced through the pipe 106 will flow directly into the cross 105 and through a passage 108 between the conduits 96 and 97 into the entrance chamber 12'. Conduit 97 which is disposed concentrically within conduit 96 is held in such concentric position by a tapped plug 109 in a third opening of the cross 105. The air flowing through the conduit 97, however, is introduced through a pipe 111 passing through a tapped plug 112 disposed in the fourth opening of the cross. Pipe 111 is likewise provided with a valve 113 adapted to control the amount of air introduced through the pipe 111 and through a passage 114 between the conduits 97 and 98 into the entrance chamber 12'. In order to make this arrangement possible the pipe 111 is threaded into a T section 116 welded at right angles to the conduit 97. The outer end of the conduit 97 has a reducer 117 secured thereto, and conduit 98 is threaded for passage through the smaller end of the reducer 117. A valve 118 is provided on the conduit 98 to control the flow of oil through the conduit 98, through a metering orifice 120 disposed in the inner end of the conduit 98 and into the entrance chamber 12'.

By means of the fuel and air flow control arrangement last described, the inventor is able to control the exact proportions of fuel and air introduced into the mixing unit 11'. With such control and with the intermixing features of the mixing unit 11, the inventor is able to maintain highly efficient combustion having the advantages previously described.

The high level of efficiency possible with mixing units made according to the designs of the present invention is indicated by the following data of mixing units similar to those shown in Figs. 1 and 2 in a conventional silica fire brick baking operation. In one specific installation a brick kiln having an inside diameter of approximately 34 feet was provided with eight mixing units substantially as shown in Figs. 1 and 2. This down draft periodic type of kiln having a capacity of approximately 100,000 nine inch fire brick was charged to capacity and sealed. For the first ninety-six hours the mixing unit 11 was provided with an orifice 37 having an opening $\frac{5}{16}$ of an inch in diameter. During the first twenty-four hours the mixing units were operated with a 6 ounce pressure on the natural gas feed. With the air control disk 33 adjusted to give efficient combustion approximately 75,000 cubic feet of gas were used and a temperature of 600° F. was attained at the end of the twenty-four hour hour period. For the next twenty-four hours 12 ounces of gas pressure was used and corresponding changes were made in the positioning of the air control disk to assure complete combustion of the greater amount of fuel. During this second twenty-four hour period approximately 123,000 cubic feet of gas were used and a temperature of 1320° F. was obtained.

During the third twenty-four hour period 20 ounces of pressure was used on the gas supply and the amount of primary air was increased to give efficient combustion. During this third twenty-four hour period approximately 163,000 cubic feet of gas was burned and a temperature of approximately 2,000° F. was obtained. During the fourth twenty-four hour period, four pounds, four ounces gas pressure was utilized to burn approximately 317,000 cubic feet of gas bringing the kiln to a temperature of approximately 2400° F.

After ninety-six hours elapsed time the orifice 37 was changed to provide an opening $\frac{7}{16}$ of an inch in diameter. With this orifice size, two pounds, four ounces of gas pressure was used for the next twenty-four hours to burn approximately 443,500 cubic feet of gas and to obtain a temperature of approximately 2650° F. After a total elapsed time of 120 hours the gas pressure was increased to three pounds per square inch for a period of twenty-four hours during which time approximately 511,000 cubic feet of gas was burned. At the end of this last twenty-four hour period a temperature of 2750° F. had been obtained within the kiln. As soon as this temperature was obtained the gas supply was cut off and the bricks were left in the kiln without additional heat for fourteen days.

During the entire heating cycle a total of approximately 1,632,000 cubic feet of gas was burned. In connection with these total figures it should be noted that the kiln installation mentioned was located at an altitude of aproximately 5,000 feet and the heating value of the natural gas used was necessarily reduced by such conditions.

From the foregoing figures when taken together with results previously mentioned it should be apparent that the present device fully satisfies the objects enumerated. While separate embodiments of this invention have been shown and described, it is readily apparent that the invention is adaptable to modifications and changes. All such modifications and changes as are within the scope of the hereunto appended claims are deemed to be a part of this invention.

What is claimed is:

1. A mixing unit for burner assemblies comprising an elongated open-ended body having an entrance chamber inclusive of side walls forming a narrowing passage arranged to receive streams of air and fuel, means for injecting streams of air and fuel into said entrance chamber at its open end, said body including a plurality of expansion chambers of successively increased cross-section downstream from said entrance chamber, and a plurality of constriction members between said chambers having surfaces arranged to narrow the passage therebetween to a cross section less than the cross sectional dimension of the next adjacent upstream chamber so as to mix said streams in their travel through said chambers.

2. A mixing unit for burner assemblies comprising an elongated open-ended body, an entrance chamber on said body inclusive of side walls forming a narrowing passage arranged to receive streams of air and fuel, means for injecting streams of air and fuel into said entrance chamber at its open end, said body including a plurality of substantially cylindrical expansion chambers of successively increased diameter downstream from said entrance chamber, and a plurality of restrictions acting as division members between said chambers having surfaces arranged to narrow the passage therebetween to a diameter less than the diameter of the next adjacent upstream chamber so as to mix said streams in their travel through said chambers.

3. A mixing unit for burner assemblies comprising an elongated open-ended body having imperforate side walls, an entrance section on said body arranged to receive streams of air and fuel, means for injecting streams of air and fuel into said entrance section at its open end, and said body including a plurality of expansion chambers disposed in open ended relation lengthwise of said body downstream from said entrance section, each of said chambers being defined by restrictions acting as division members at the ends thereof, each said expansion chamber being of shorter length than the next adjacent upstream expansion chamber so as to mix said streams in their travel through said chambers.

4. A mixing unit for burner assemblies comprising an elongated open-ended body of circular cross section, an entrance section on said body arranged to receive streams of air and fuel, means for injecting streams of air and fuel into said entrance section at its open end, and said body including a plurality of expansion chambers disposed in open ended relation lengthwise of said body downstream from said entrance section, said chambers being separated from each other by a restriction therebetween, each said expansion chamber being of greater diameter and shorter length than the next adjacent upstream expansion chamber so as to mix said streams in their travel through said chambers.

5. A fuel and air mixing unit for burner assemblies comprising an elongated open-ended body having an entrance section inclusive of side walls forming a narrowing passage, said body including a plurality of expansion chambers of successively increasing diameter and decreasing length downstream from said entrance section disposed in open ended relation lengthwise of said body, said chambers being separated by restrictions therebetween, a conduit for conveying fuel having a discharge outlet disposed within said entrance section at the open end, an orifice member mounted at said outlet in heat conductive connection with said conduit, an air control disk mounted on said conduit at the upstream end of said entrance section for selective movement along said conduit to vary the quantity of air introduced into said entrance section, and valve means on said conduit for controlling the amount of fuel introduced through said conduit into said entrance section.

6. A fuel and air mixing unit for burner assemblies comprising an elongated open-ended body having an entrance section inclusive of side walls forming a narrowing passage, said body including a plurality of expansion chambers of successively increasing diameter downstream from said entrance section disposed in open ended relation lengthwise of said body, a first conduit having a discharge outlet disposed in the entrance section for discharging gaseous fuel into the upstream end of said mixing unit, a concentric intermediate conduit disposed within said first conduit and having its discharge outlet within said first conduit, an inner conduit disposed concentrically within said intermediate conduit having its discharge outlet within said intermediate conduit, said inner and intermediate conduits providing a passage for the introduction of air, a regulating member having an orifice opening therein for engagement with the discharge outlet of said first conduit for regulating the flow of fuel and air into said mixing unit, and valve members on each of said conduits for regulating the flow and pressure of the fuel or air in the respective conduits.

7. A fuel and air mixing unit for burner assemblies comprising an elongated open-ended body, an entrance section on said body inclusive of side walls forming a narrowing passage, said body including a plurality of expansion chambers of successively increasing diameter downstream from said entrance section disposed in open ended relation lengthwise of said body, concentric external, intermediate and inner conduits of selected diameters arranged to provide a passage between said external and intermediate conduits and a second passage between said intermediate and inner conduits, with a third passage internally of said inner conduit, said conduits having their discharge ends disposed in spaced relation to the downstream end of the entrance section of the mixing unit to convey liquid fuel, gaseous fuel and air under pressure into said mixing unit, an air control member for selective positioning to vary the amount of atmospheric air introduced into said entrance section, and means for separately varying the pressure head on said liquid fuel, gaseous fuel and compressed air to maintain a regulated flow of said fuels and air as necessary to obtain efficient combustion.

8. A fuel and air mixing unit for burner assemblies comprising an elongated open-ended body, an entrance section on said body inclusive of side walls forming a narrowing passage, said body including a plurality of expansion chambers of successively increasing diameter downstream from said entrance section disposed in open ended relation lengthwise of said body, concentric external, intermediate and inner conduits of selected diameters arranged to provide a passage between said external and intermediate conduits for gaseous fuels and a passage between said intermediate and inner conduits for air under pressure with a third passage internally of said inner conduit for the flow of liquid fuel, said conduits having their discharge ends disposed

in spaced relation to the downstream end of the entrance section to convey fuels and air into said unit, a nozzle in the end of said external conduit for controlling the flow of said fuels and air, external threads on the outer surface of said external conduit, an air control disk mounted on said threads for selective positioning on said conduit to vary the amount of atmospheric air introduced into said entrance section, and means for separately varying the pressure head on said liquid fuel, gaseous fuel and compressed air to maintain a regulated flow of said fuels and air as necessary to obtain efficient combustion.

9. A fuel and air mixing unit for burner assemblies comprising an elongated open-ended body, an entrance section on said body inclusive of side walls forming a narrowing passage and an opening of minimum diameter consistent with the flow requirements of the mixing unit, means for injecting streams of air and fuel into said entrance chamber at its open end, said body forming a plurality of expansion chambers, including a first expansion chamber disposed downstream from said entrance section of substantially cylindrical shape, a second expansion chamber downstream from said first chamber of substantially cylindrical shape having an internal diameter greater than the internal diameter of said first expansion chamber, a third expansion chamber downstream from said second expansion chamber of substantially cylindrical shape having an internal diameter greater than the internal diameter of said second expansion chamber, constriction members between said chambers having surfaces arranged to form passages between said chambers having a diameter less than the diameter of the next adjacent upstream chamber, and a constriction at the discharge end of the last of said chambers providing a discharge opening of diameter less than the diameter of said last chamber and greater than the diameter of the passage through the next adjacent upstream constriction member.

10. A fuel and air mixing unit for burner assemblies, comprising an elongated open-ended body having an entrance chamber open to the atmosphere, said body including a plurality of expansion chambers of successively increased cross sectional area downstream from said entrance chamber, a plurality of constriction members between said chambers having surfaces arranged to form passages between said chambers having a cross section less than the cross section of the next adjacent upstream chamber, and a conduit means for delivering fuel into said entrance chamber for subsequent mixing during travel through the mixing unit.

11. A fuel and air mixing unit for burner assemblies, comprising an elongated open-ended body having an entrance chamber, said body including a plurality of expansion chambers disposed in open ended relation lengthwise of said body of successively decreasing length downstream from said entrance chamber, said chambers being separated by a constriction therebetween, and a conduit for delivering fuel and air to a point of discharge into the entrance chamber of said mixing unit.

12. A fuel and air mixing unit for burner assemblies, comprising an elongated open-ended body having an entrance chamber open to the atmosphere, said body including a plurality of expansion chambers of successively increased cross sectional area and decreased length downstream from said entrance chamber, a plurality of constriction members between said chambers having surfaces arranged to form passages between said chambers having a cross sectional area less than the cross sectional area of the next adjacent upstream chamber, and a conduit for delivering air and fuel into the first upstream chamber of said mixing unit.

13. A mixing unit for burner assemblies comprising an elongated open body having imperforate side walls, an entrance section on said body arranged to receive streams of air and fuel, means for injecting streams of air and fuel into said entrance section at its open end, said body forming a plurality of expansion chambers, including, a first expansion chamber downstream from said entrance section, a second expansion chamber downstream from said first expansion chamber of greater internal cross section than said first chamber, a third expansion chamber downstream from said second expansion chamber of greater cross section dimension than the internal cross section of said second chamber, and restrictions acting as division members between said chambers having surfaces arranged to form passages therebetween having a cross section less than the cross section of the next adjacent upstream chamber so as to mix said streams in their travel through said chambers.

14. A mixing unit for burner assemblies comprising an elongated open-ended body of circular cross section having an entrance section inclusive of side walls forming a narrowing passage arranged to receive streams of fuel and air, means for injecting streams of air and fuel into said entrance section at its open end, said body including a plurality of expansion chambers of successively increased diameter downstream from said entrance section, and a plurality of restrictions acting as division members between said chambers having a diameter less than the diameter of the next adjacent upstream chamber, said passages being of successively increasing diameter downstream from said entrance section so as to mix said streams in their travel through said chambers.

15. A mixing unit for burner assemblies comprising an elongated open-ended body having an entrance section inclusive of side walls forming a narrowing passage arranged to receive streams of fuel and air, means for injecting streams of air and fuel into said entrance section at its open end, said body including a plurality of expansion chambers downstream from said entrance section, and a plurality of restrictions acting as division members between said chambers having surfaces arranged to form passages between said chambers having a cross section less than the cross section of the next adjacent upstream chamber, said passages being of successively increasing cross section downstream from said entrance section so as to mix said streams in their travel through said chambers.

16. A mixing unit for burner assemblies comprising an open-ended body of circular cross section, an entrance section on said body inclusive of side walls forming a narrowing passage arranged to receive streams of fuel and air, means for injecting streams of air and fuel into said entrance section at its open end, said body including a plurality of expansion chambers downstream from said entrance section of successively increased diameter, restrictions acting as division members between said chambers having surfaces arranged to form passages between the chambers having a diameter less than the diameter of

the next adjacent upstream chamber, and a constriction at the discharge end of the last of said chambers providing a discharge opening of diameter less than the diameter of said last chamber and greater than the diameter of the passage through the next adjacent upstream restriction so as to mix said streams in their travel through said chambers.

17. A fuel mixing unit for burner assemblies comprising an elongated open-ended body having an entrance chamber arranged to receive streams of air and fuel, means for injecting streams of air and fuel into said entrance chamber to its open end, said body including a plurality of expansion chambers of successively increased cross section downstream from said entrance chamber, said chambers being of substantially equal volume, and a plurality of constriction members between said chambers whereby said streams are mixed in their travel through said chambers.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
700,020	Dennis	May 13, 1902
1,170,765	Lindemann et al.	Feb. 8, 1916
1,217,551	Armor	Feb. 27, 1917
1,241,135	Mastenbrook	Sept. 25, 1917
1,428,400	Schroeder	Sept. 5, 1922
1,476,232	Zander	Dec. 4, 1923
1,711,982	Argo et al.	May 7, 1929
1,862,673	Foster	June 14, 1932
1,909,298	Methudy	May 16, 1933
2,368,370	Maxon, Jr.	Jan. 30, 1945
2,383,641	Focke et al.	Aug. 28, 1945
2,393,887	Clements	Jan. 29, 1946

FOREIGN PATENTS

Number	Country	Date
1,108	Great Britain	of 1876
113,393	Germany	Sept. 24, 1900
30,005	Great Britain	of 1909
770,478	France	July 2, 1934