March 6, 1934. L. WILSON 1,950,044

METHOD OF AND APPARATUS FOR PRODUCING STABLE LUMINOUS FLAME COMBUSTION

Filed May 18, 1931 2 Sheets-Sheet 1

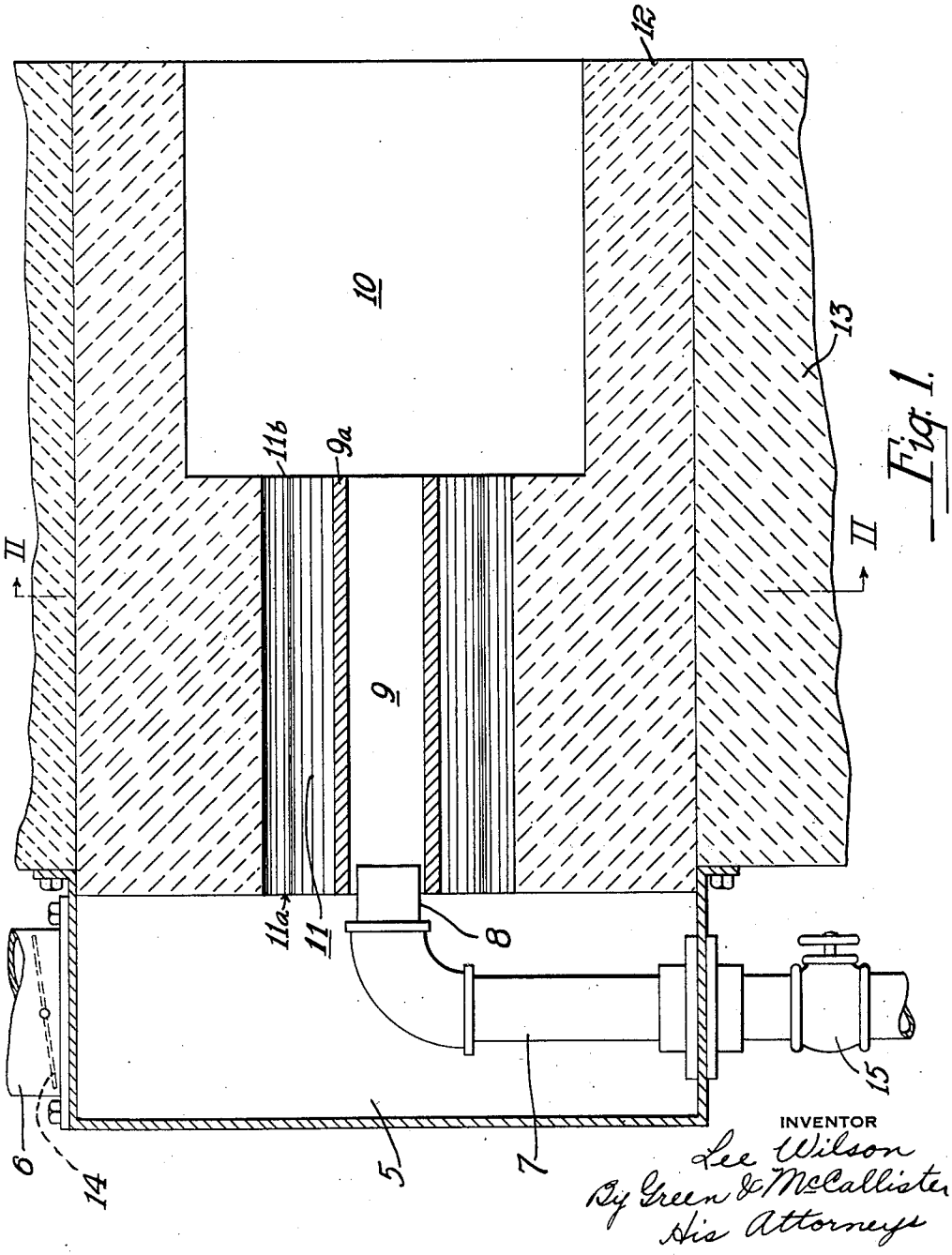


Fig. 1.

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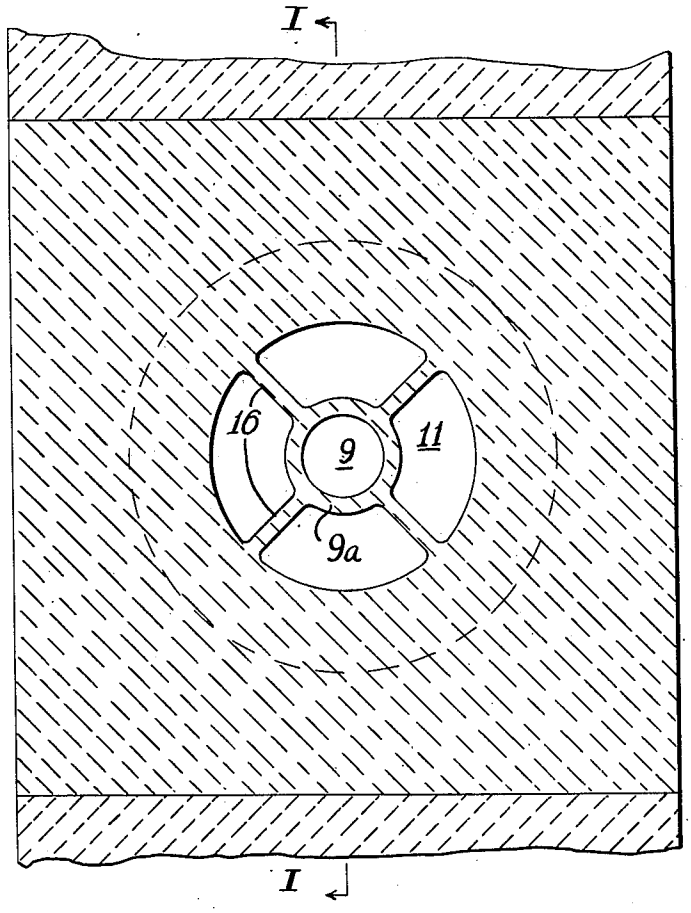


Fig. 2.

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UNITED STATES PATENT OFFICE

1,950,044

METHOD OF AND APPARATUS FOR PRODUCING STABLE LUMINOUS FLAME COMBUSTION

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Application May 18, 1931, Serial No. 538,067

7 Claims. (Cl. 158—110)

This invention relates broadly to combustion control for the production of a luminous flame, and particularly to the burning of gas in the production of a luminous flame.

In the industrial arts the application of heat forms an important part of many manufacturing processes. It is frequently desirable to heat the material subjected to the manufacturing processes in the presence of the heating flame, and it frequently happens that the character of the atmosphere in which the material is heated is of material importance. For example, it is desirable, and often necessary to anneal steel during the manufacturing processes to which it is subjected. This consists in raising the steel to a determined temperature and then cooling it under conditions which experience has demonstrated will produce the desired physical characteristics in the steel. The character of the atmosphere in which the steel is heated plays an important part. For example, if the heating takes place in an oxidizing atmosphere, scale will be formed on the steel, and in a great many cases this scale must be removed before the manufacturing processes can be carried forward.

It is my theory that many of the detrimental effects resulting from the heating of material during manufacturing processes, are occasioned by the presence of oxygen in the nascent state, or in any event by the presence of oxygen in such a state that its affinity for the material being heated is somewhat increased. It is also my theory that oxygen in this highly active state may result from combustion, or at least is a component of the products of combustion unless the combustion is carefully controlled. This is borne out by my understanding that scaling is more likely to take place in the annealing of steel, if the heating of the material under treatment is accomplished in the presence of the flame, or within the chamber where the combustion is taking place. This it appears, results from the fact that it is more difficult to control the atmosphere to which the steel or other material is subjected during the heat treatment, where the heating is accomplished in the presence of the flame or in the same chamber in which the heat producing combustion is taking place.

It is well known that heat is ordinarily more effectively transmitted by radiation than by convection, and because of this it is often highly desirable to locate the material being heated within the combustion chamber, since under such circumstances it is not necessary to raise the temperature of the interior of the chamber walls to an effective heat radiating temperature by heat externally applied to those walls. It follows, that even where the heating of the material treated is accomplished within the combustion chamber, there is an advantage in employing a heat radiating flame, i. e., a luminous flame, even though we do not consider the fact that the character of the atmosphere may be more easily controlled where such a flame is utilized. This fact, when taken in connection with the further fact that the products of combustion resulting from luminous flame combustion are usually free from nascent oxygen or oxygen in highly active state, discloses the advantages to be derived from luminous flame combustion.

Experience has shown that it is difficult to obtain the desired degree of heat, and at the same time maintain luminous flame combustion, and that this is particularly true where a gaseous fuel is employed. The flame breaks out of control under ordinary operating conditions. That is to say, where a gaseous fuel is employed, a luminous flame may be produced, and may be maintained with expert and careful handling, but under ordinary operating conditions, i. e., conditions which contemplate fortuitous variations in gas or air delivery pressures, the flame is unstable, in that it may break into a dead flame, i. e. a smoke producing flame, or it may break into a hard intense flame, i. e., a clear or partially clear flame, where there is some or considerable turbulence in the mixing of the gas and air, unless the combustion is constantly under the control of an expert and skilled operator. In the event the flame does break out of control detrimental effects are almost certain to result, even though the undesired conditions subsist for a short time only.

An object of my invention is to produce a method of promoting combustion of gaseous fuels which will result in the production of a luminous flame which will remain stable under the ordinary variations in operating conditions encountered in the operation of gas-fired furnaces.

A further object is to produce apparatus in the form of a gas burner for carrying forward the steps of my improved method of burning gaseous fuel.

In the drawings accompanying and forming a part hereof I have more or less diagrammatically illustrated such a burner. Figure 1 is a longitudinal sectional view along the line I—I of Fig. 2; and Fig. 2 is a transverse sectional view along the line II—II of Fig. 1.

I will first describe my improved method as

employed by me in connection with natural gas, such as is employed commercially in the western part of Pennsylvania and throughout West Virginia, but it will be understood that the invention may be carried forward in connection with any gaseous fuel. I deliver the gas and air under pressure, but I am careful to keep the pressures of both fluids substantially equal, as far as this can be done under ordinary operating conditions. The gas is delivered to the furnace in a well-defined consolidated stream totally surrounded by an envelope of air moving at substantially the same velocity as the gas stream. The gas is delivered at a pressure which occasions the desired rate of flow, i. e., the desired volume at the desired velocity. The gas is partially expanded to convert at least a portion of the pressure thereof into kinetic energy in the form of fluid velocity but the expansion is so accomplished as to avoid turbulence and so as to produce the gas flow in a well defined stream in which all portions of the stream are moving at the desired velocity along well-defined parallel lines toward and into the furnace enclosure. I have used the term "consolidated" in connection with this stream to mean a compact homogeneous stream. That is to say, the stream is preferably substantially circular in cross section at all points along its length, and is homogeneous in that there are no eddy currents and no turbulence either during or after the conversion from pressure to flow velocity. The air is also delivered at a pressure which will occasion the desired rate of flow at the desired velocity, but in this connection it will be understood that the velocity of gas flow determines, within narrow limits, the permissible velocity of air flow, and that with natural gas, for example, where the proportions of air to gas should be about 10 to 1, the variation in the rate of air flow must be taken into consideration in determining upon the cross sectional dimensions of the air stream. In addition, the conversion from pressure to kinetic energy in the form of fluid velocity must be so accomplished that the streams of air and gas will unite to form a consolidated jet within the confines of the furnace. By consolidated jet I mean a compact homogeneous jet, in which the velocity of flow at all points at any cross section of the jet is the same. In this connection it should, however, be noted that a well-defined stratification between the air and the gas is maintained in the jet so that the jet is, as before implied, a well-defined consolidated stream of gas surrounded by an envelope of air moving at the same velocity as the gas stream.

For the reasons above stated the gas stream is preferably annular, and the conversion from pressure to kinetic energy in the form of fluid velocity is preferably accomplished in a passage or passages surrounding the region or passage in which the gas stream is initiated. With the air, as with the gas, the initiation of the flow directs the air in the direction of the flow of the consolidated jet, and is accomplished without turbulence and without setting up disturbing or eddy currents, so that the union between the two streams will take place without turbulence.

Both streams of gas and air are initiated under such conditions as to ensure substantially equal velocities of the two streams. This is accomplished in the present embodiment of the invention by so forming the passages in which the conversion from pressure to kinetic energy in the form of fluid velocity is accomplished, that they are in effect open ended tubes, one surrounding the other and with a means of communication at their inlet ends. With this arrangement the pressures in the two tubes will be maintained substantially equal even under varying conditions of gas or air pressure and as a result the fluid velocities set up in the two streams will be substantially equal.

Another feature of this invention is the fact that combustion takes place at the surface of union between the gas and air streams forming the consolidated jet and takes place under such conditions that the sensible heat of the combustion occasions a "cracking down" of the hydrocarbons in the gas into fixed carbon particles which are heated to incandescence by the heat of combustion, but are surrounded by an atmosphere incapable of occasioning their immediate and complete combustion. This renders the flame luminous and the flow conditions are such that each such incandescent carbon particle moves in the general direction of the jet until it enters an atmosphere containing sufficient oxygen to complete its combustion.

In this connection it should also be pointed out that the combustion is carried forward under such conditions that the gaseous products of the combustion taking place at the surface of the gas stream contaminate the air stream and in effect produce a strata of contaminated air around the gas stream in which the percentage of oxygen is relatively low but increases outwardly from the gas stream. This contaminated air moves with the jet at substantially the velocity of the jet and delays the complete combustion of the incandescent particles but establishes a condition such that as the particles progress with the jet, they move through an atmosphere in which the oxygen content gradually increases, with the result that each particle takes up sufficient oxygen to maintain it in an incandescent state. This slow rate of combustion is maintained until the particles are completely consumed.

This contaminated air envelope around the gas stream also results in slow or delayed combustion of the gas which, as has been noted, contributes to the luminosity of the flame by the "cracking down" process above mentioned.

By practicing the process herein outlined I am able to produce a stable luminous flame and to maintain that flame under the varying conditions encountered in commercial heating operations. I am able also to vary, within relatively wide limits, the volume of gas or the volume of air delivered to the combined jet without upsetting the stability of the flame. I have also been able to project flames of various lengths and to vary the effective heat within the furnace throughout a relatively wide range.

The burner illustrated constitutes apparatus capable of being employed in carrying forward the method described, and includes a chamber 5 to which air under pressure is admitted through a piping 6. In the burner illustrated a gas supply pipe 7 in effect projects into the chamber 5 and is provided with a discharge nozzle 8, which extends beyond the chamber and into a conduit 9, which, at its inlet end, is open to the chamber except for the interpositioning of the nozzle 8. The conduit 9 is tubular, that is to say, the passage therethrough is cylindrical and its outlet end opens into a passage 10. A substantially annular conduit 11 surrounds the conduit 9, and its inlet end 11a is in open communication with the chamber 5 and its outlet end 11b is in open com-

munication with the passage 10. The conduits 9 and 11 and the passage 10 may be conveniently formed in a refractory block or body 12. The passage 10 opens into the interior of the furnace with which the burner is associated. A fragmentary portion only of the furnace wall 13 is shown.

As shown, the air delivery piping 6 is provided with a control valve 14 which, for convenience of illustration, is shown as a butterfly or damper valve. The piping 7 is shown as extending through a side wall of the chamber 5, as having an elbow near its outlet end for properly positioning the nozzle 8 with relation to the conduit 9, and a valve 15 for controlling the flow of gas to the nozzle.

As shown in Fig. 2 the tubular enclosing wall 9a of the conduit 9 is supported from the cylindrical wall of the annular conduit 11 by means of webs 16. These webs are preferably radially disposed with relation to the conduits 9 and 11 and each web is straight throughout its entire length and in effect forms a flow directing partition in the conduit 11. I have found that it is desirable to employ an even number of such webs spaced so as to divide the interior of the conduit into an equal number of exactly similar passages. It will be noted that all these sub-passages are not only parallel to each other, but are also parallel to the passage within the conduit 9. As a matter of fact, I have found it convenient to call these passages straightener passages, since they initiate and direct the flow of fluid traversing them and are of sufficient length and volume to establish a quiescent flow of the fluid in stream lines parallel to the walls of the passages. That is to say, the conversion from pressure to kinetic energy in the form of fluid velocity takes place within the passages and under such conditions as to produce a non-turbulent flow in the direction of flame propagation. I have also found that it is highly desirable to provide the passages with smooth walls so as to avoid occasioning a disturbance in the flow of fluid through them.

Where the burner is to be employed in connection with natural gas, the aggregate cross sectional area of the combined conduit 11 should be about ten times that of the cross sectional area of the conduit 9, and it is also desirable to so proportion the conduit 9 with relation to the nozzle 8 that it is not only somewhat larger than the external diameter of the nozzle, but is also sufficiently large to provide a pressure equalizing passage around the nozzle 8 and between the chamber 5 and the interior of the conduit 9.

The air is delivered to the chamber 5 under pressure and at a pressure substantially equal to the delivery pressure of the gas through the nozzle 8. It will, of course, be understood that the flow of both gas and air may be controlled by the valves to which reference has been made, but it is desirable to maintain the delivery pressures of the two fluids as nearly equal as is possible under ordinary commercial operating conditions such as are encountered in various factories, where the gas pressure and even the air pressure may vary somewhat throughout the period of the working day.

It should also be said that the conduits 9 and 11 are proportioned to obtain equal velocities of the fluids traversing them and particularly at the outlet ends thereof. That is to say, if it is desired to burn 100 feet of natural gas per hour and to maintain a velocity of 15 feet per second of the gas as it issues from the conduit 9, then the air passages going to make up the annular conduit 11, must be so proportioned as to deliver approximately 1,000 feet of air per hour at the pressure determined upon to give substantially 15 feet per second exit velocity to the air. From the foregoing it will be understood that the absolute pressures of the gas and air as delivered to the nozzle 8 and the chamber 5 are not essential so long as they are maintained substantially equal and are sufficient to produce the volume of flow desired.

In operation the gas is delivered at the desired pressure and volume through the nozzle 8 and into the conduit 9. It will be apparent that the nozzle 8 directs the gas axially of the conduit 9 and it will also be apparent that the gas on leaving the nozzle 8 expands somewhat because of the increased cross sectional area of the conduit, and that the conduit because of its length and because of its smooth straight walls establishes a well defined stream line flow in the gas stream prior to its delivery from the conduit into the passage 10. As has been said, the air is delivered at the desired volume to the chamber 5, and at such a pressure that the pressure in the annular conduit 11 will be substantially equal to the pressure in the conduit 9 and so that the velocity of the air issuing into the passage 10 will be substantially equal to the velocity of the gas as it issues into that passage. Here again the conditions are such that the sub-divisions of the conduit 11 establish a quiescent stream line flow of the air which is parallel to the stream line flow of the gas; and the locational relation of the conduits 9 and 11 is such that the streams of air and gas unite to form a consolidated jet which is preferably circular in cross section and in which there is a well defined stratification between the air and the gas.

It will also be noted that the stream of gas is a consolidated stream, both while traversing the conduit 9 and after delivery from that conduit in that it is circular in cross section and of substantially uniform velocity at all points of any cross section along its length. It will, of course, be apparent that no matter how smooth the walls of the conduits 9 and 11, they will occasion some friction which will to some extent retard the flow of fluid immediately adjacent to them, but the intent is to provide as nearly uniform conditions of flow at all points throughout any cross section of both conduits as can be obtained.

It will also be noted that the jet, formed by the union of the two streams in the passage 10, is in effect a composite jet in that the stratification is maintained after the issuance from the conduits 9 and 11 and the gas stream is totally enclosed within the envelope or annular sheath of air which is moving at substantially the same velocity as the gas stream. Every precaution is taken to prevent turbulence in either stream and inasmuch as combustion is a chemical reaction between gas and oxygen, combustion will take place at the surface of union between the two streams, that is to say, around the outside of the gas stream. The combustion taking place under the conditions described may, however, be termed delayed combustion. The effect of this will be the propagation of a luminous flame. At all points along the central stream of gas the surface of the gas will be subjected to an oxygen bearing atmosphere with the result that combustion will take place at the surface of the gas stream, but will not spread into the gas stream, due to the lack of oxygen. The gas will, however, be subjected to the sensible heat of the combus-

tion and the hydrocarbons contained therein will be "cracked down" into fixed carbon particles which, by reason of the heat to which they are exposed, will glow and render the flame luminous. As previously described, these particles will not be immediately or rapidly consumed because of the lack of sufficient oxygen to complete their combustion. Each luminous particle, however, will be eventually moved into an atmosphere or medium containing sufficient oxygen to complete its combustion, with the result that complete combustion of the gas will eventually be accomplished, but under such conditions that the flame is at all times a luminous flame, but at the same time not a smoky flame.

The burner illustrated produces a non-turbulent flow of the stratified components of combustion and the combustion of the gas is accomplished in a long luminous slow burning flame as distinguished from a rapid burning violent flame such as is produced where an intimate mixture of gas and air is accomplished by reason of turbulence in the separate streams or by reason of a more or less intimate mixture of the gas and air in the burner chambers or even beyond the burner. It will also be apparent that the passage 10 is what may be termed a directing passage. There may be some expansion of the gas and air streams as they leave the conduits 9 and 11, but the passage 10 has a confining and directing effect on the combined jet and tends to maintain the flow of the two streams in the direction of flow initiated by conduits 9 and 11. As illustrated, the passage 10 is circular in cross section and is concentric with the conduit 9.

Where the gas or the air is delivered under such conditions as to tend to produce a difference in the pressures within the conduits 9 and 11, these pressures are equalized or maintained equal by reason of the fact that both passages are open to the chamber 5. With such an arrangement it will be apparent that if the volume and pressure of the gas issuing from the nozzle 8 is such as to tend to maintain a pressure at the inlet end of conduit 9 below that within the chamber 5, then sufficient air will enter the conduit 9 to equalize the pressure conditions in the two conduits 9 and 11.

It will be apparent that the air is delivered in an annular stream around the gas flow from the nozzle 8 and that the admission of this air to the conduit 9 is not such an admission as would be caused by the entraining force of the gas flow, but is rather a flow which is occasioned by whatever difference in pressure may exist between the inlet end of the conduit 9 and the chamber 5. That is to say, such flow of air as enters the conduit 9 is a non-turbulent quiescent flow and is in the form of an envelope surrounding the gas flow issuing from the nozzle 8 and in effect fills out the gas stream within the conduit 9 to such an extent that the flow and pressure conditions in it are substantially equal to those in the air conduit 11. If for any reason the pressure of the gas delivered through the nozzle 8 exceeds that of the air pressure within the chamber 5 the condition will be reversed from that just above described, and the open end of the conduit 9 will effect an equalization of pressures and flow conditions.

It will, of course, be apparent that even if the temperature conditions are sufficient to occasion combustion in the conduit 9, the combustion will take place under the conditions above described, due to the stratified conditions of the gas and air, and will be a delayed or slow combustion, such as previously described.

It is my belief that such gas as may enter the conduit 11 by reason of the effectiveness of the pressure equalizing arrangement described, will be of such minute quantities that it will hardly more than contaminate the air entering along the inner wall of the conduit 11 and will therefore not be in sufficient quantity to result in combustion unless the temperatures encountered are quite high. Then too, it is apparent that any gas entering the conduit 11 will necessarily enter around the inner peripheral wall of the conduit, and will either move through the conduit as a thin annular sheath of gas or will merely contaminate a thin annular sheath of air, and this because of the non-turbulent character of the flow through the conduits. In any event, such combustion as may take place in the conduit 11 cannot be of sufficient extent to disturb the quiescent stream line flow heretofore described. This is also true of such combustion as may take place within the conduit 9, but here uncontaminated air is delivered into the conduit 9 by reason of whatever variation in pressure may exist between the chamber 5 and the inlet end of that conduit, and this air is delivered in the form of an annular sheath, but in such small quantities that even if it mixes with the gas it can do hardly more than contaminate the gas at the surface of the stream forming and formed within the conduit 9.

Under ordinary operating conditions the valves 14 and 15 may be manipulated to vary the quantity of air and gas admitted to the conduits 9 and 11 and I have found that considerable variation may be made without upsetting the stability of the flame.

A condition may be encountered where, due to infiltration of air in the combustion chamber or furnace, more air is delivered than is desirable. Under such conditions, either the air valve 14 may be manipulated to decrease the air flow or the gas valve 15 may be manipulated to increase the gas flow and in either event the flow conditions in the jet will be so maintained as to ensure the stratification and the quiescent flow above described. It will, of course, be understood that if it is desired to either increase or decrease the amount of gas burned within the furnace, both of the valves 14 and 15 may be manipulated to produce the change desired.

While I have described what I now consider to be the preferred procedure in carrying out my method of producing luminous flame combustion and while I have also illustrated a form of burner which may be employed in connection with this method it will be understood that some changes, either in the steps of the method described and certainly in the structure of the burner illustrated, may be made without departing from the spirit and scope of my invention as set forth by the appended claims.

What I claim is:

1. In combination in a gas burner, a chamber, means for delivering a fluid under pressure thereto, a conduit circular in cross-section communicating with said chamber, a nozzle of less external diameter than the interior diameter of said conduit, projecting from said chamber into the end of said conduit, and axially aligned therewith, an annular conduit surrounding said first mentioned conduit, axially aligned therewith and communicating with said chamber, a plurality of radially extending partitions sub-dividing the interior of said annular conduit into straight pas-

sages, each similar to the other and each parallel to said first mentioned conduit, and means for delivering gas under pressure to said nozzle.

2. In a device of the character described, a refractory body, two straight concentric conduits extending through said body, radial webs extending from the outer surface of the inner conduit to the outer conduit, and means for passing non-turbulent gas and air streams through said inner and outer conduits, respectively, at substantially the same velocity, the cross-sectional area of said outer conduit being of the order of ten times the cross-sectional area of said inner conduit.

3. In a device of the character described, a refractory body, two straight concentric conduits extending through said body, radial webs extending from the outer surface of the inner conduit to the outer conduit, and means for passing non-turbulent gas and air streams through said inner and outer conduits, respectively, at substantially the same velocity, the cross-sectional area of said outer conduit being of the order of ten times the cross-sectional area of said inner conduit, and the construction, arrangement and velocity being such that a non-turbulent composite jet is projected from said conduits wherein the central gas stream is sheathed in an annular air stream, delayed combustion occurring at the contacting surfaces of the two streams in accordance with the rate at which the gas stream is eventually furnished with sufficient oxygen for combustion.

4. In a device of the character described, a refractory body, two straight concentric conduits extending through said body, radial webs extending from the outer surface of the inner conduit to the outer conduit, and means for passing non-turbulent gas and air streams through said inner and outer conduits, respectively, at substantially the same velocity, the cross-sectional area of said outer conduit being of the order of ten times the cross-sectional area of said inner conduit, and the construction, arrangement and velocity being such that a non-turbulent composite jet is projected from said conduits wherein the central gas stream is sheathed in an annular air stream, in the proportions imposed by the cross-sectional areas of said conduits, delayed combustion occurring at the contacting surfaces of the two streams in accordance with the rate at which the gas stream is eventually furnished with sufficient oxygen for combustion.

5. A method of promoting luminous flame combustion, which consists in maintaining separate bodies of gaseous fuel and air, establishing communication therebetween to substantially equalize the pressure thereof, setting up a flow of the gaseous fuel, continuing such fuel flow and confining it to establish a well defined consolidated stream moving at a substantially uniform velocity, simultaneously establishing from said body of air, a flow of air around said fuel stream and continuing and confining such flow to establish a well defined annular stream of air surrounding but separated from said fuel stream and moving in substantially the same axial direction and at substantially the same velocity as said fuel stream, combining said streams to form a consolidated stream while maintaining a well defined stratification between such streams, confining and directing the combined stream while promoting combustion at the surface of union between the two streams of fuel and air, constituting components thereof, projecting the combined stream as a substantially unconfined jet and in the direction of its confined travel and continuing such combustion along such projected jet.

6. In combination in a gas burner, a chamber having an air inlet port, two concentric conduits communicating with said chamber, means extending into said chamber and projecting into the central conduit for delivering gaseous fuel thereto, and an open ended directing passage of greater diameter than the external conduit and communicating with both conduits.

7. In combination in a gas burner, a chamber having an air inlet port, contiguous conduits communicating with said chamber, means extending into said chamber and communicating with one of said conduits for delivering gaseous fuel thereto, and a directing passage of greater cross-sectional area than the combined area of said conduits communicating with the outlet ends thereof.

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