

[54] **INFRARED BURNER AND APPARATUS FOR PRODUCING SAME**

1,677,811 7/1928 Bowen 431/353
 3,231,202 1/1966 Milligan 239/557

[75] Inventor: **Walter Dorwin Teague, Jr.**, Nyack, N.Y.

FOREIGN PATENTS OR APPLICATIONS

[73] Assignee: **Columbia Gas System Service Corporation**, Wilmington, Del.

1,241,828 8/1960 France 431/328
 600,022 10/1925 France 431/328
 600,198 7/1934 Germany 431/328

[22] Filed: **Dec. 26, 1972**

Primary Examiner—Carroll B. Dority, Jr.
Attorney, Agent, or Firm—Curtis, Morris & Safford

[21] Appl. No.: **318,043**

Related U.S. Application Data

[63] Continuation of Ser. No. 78,549, Oct. 6, 1970, abandoned, Continuation-in-part of Ser. No. 775,978, Oct. 2, 1968, abandoned.

[57] **ABSTRACT**

An infrared burner having a plurality of orifices therethrough to pass a stoichiometric mixture of air and gas which is ignited in a combustion zone adjacent one side of the burner. The orifices are constructed in such a fashion as to increase the velocity of the gas-air mixture passing therethrough.

[52] U.S. Cl. **431/328**

[51] Int. Cl. **F23d 13/12**

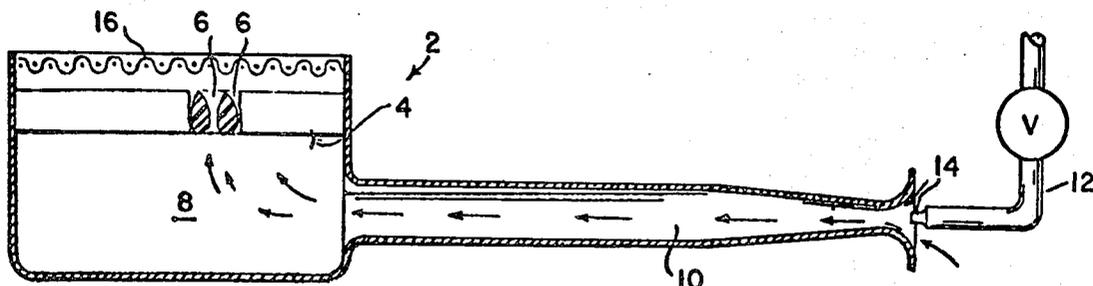
[58] Field of Search 431/328, 329

[56] **References Cited**

UNITED STATES PATENTS

1,308,364 7/1919 Lucke 431/328

6 Claims, 8 Drawing Figures



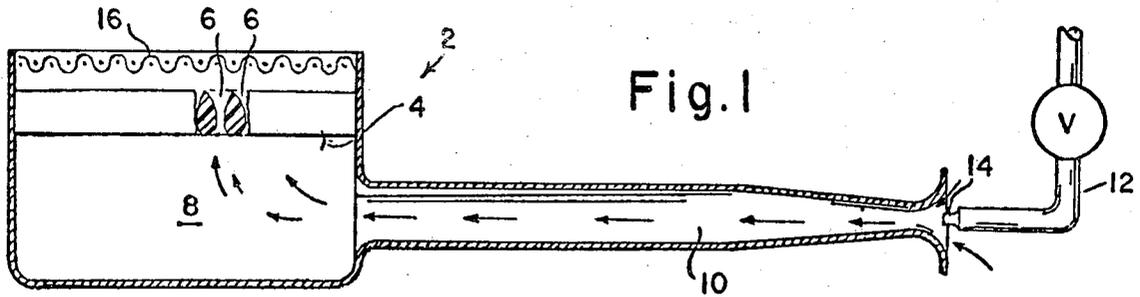


Fig. 1

Fig. 2

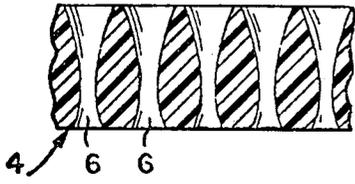


Fig. 4

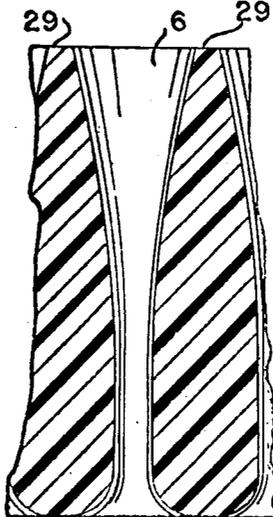


Fig. 3

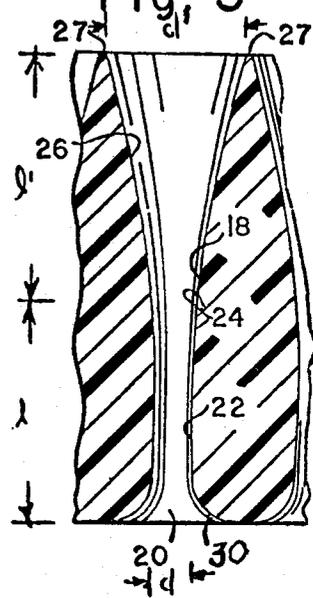


Fig. 5

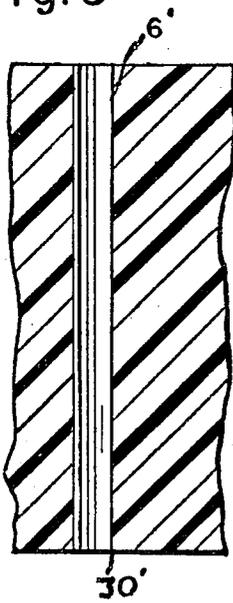


Fig. 6

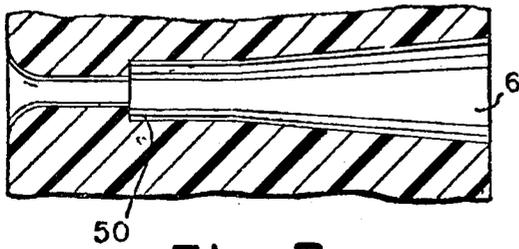
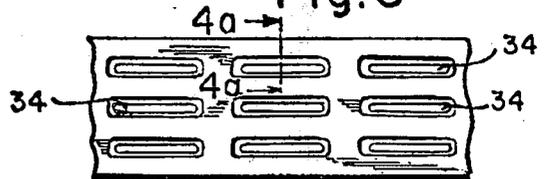


Fig. 7

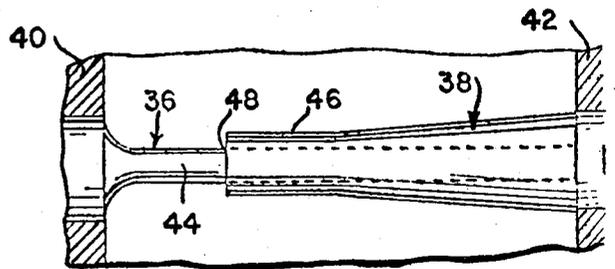


Fig. 8

INFRARED BURNER AND APPARATUS FOR PRODUCING SAME

Application Ser. No. 78,549, filed Oct. 6, 1970 is a continuation-in-part of copending U.S. Pat. application, Ser. No. 775,978, filed Oct. 2, 1968, and now abandoned the disclosure of which is incorporated herein by reference.

This invention relates to gas burners, and more in particular to the configuration of the orifices in infrared burners through which the air and gas mixture passes immediately before it reaches the zone at which it is ignited, and also relates to the method and apparatus for making the burners.

In infrared gas burners of the type of the present invention, the mixture of air and inflammable gas passes from a receiving chamber through a plurality of orifices to the space in which combustion takes place. Unlike conventional gas burners of the non-infrared type which depend on secondary air for their operation, the infrared type of burner normally uses no secondary air and consequently the aspirator must draw in all of the air required for combustion. Consequently in the infrared burner, the gas/air mixture in the chamber under the orifice plate is approximately stoichiometric and hence highly inflammable. It is essential that the velocity of the air and gas mixture moving through each of the orifices be greater than the speed at which the flame moves through the mixture. If this is not true, the flame in the combustion zone will spread through the orifices and into the plenum chamber, thus causing "flashback" and preventing the proper operation of the burner. At the same time, it is desirable that the infrared burner be operative to employ a so-called natural aspirating, or self-aspirating system, in which the air is supplied at atmospheric pressure and mixed with the pressurized gas. Self-aspirating systems present the advantage of simplicity, both in construction and operation, but they are not always capable of keeping the air-gas mixture at a high enough pressure to maintain an adequate velocity through the orifices. This problem becomes particularly acute when it is necessary that the rate of flow be adjustable over a considerable range so as to provide for modulation or adjustment of the heat produced by the burner. Using conventional orifice configurations, the greatest ratio that a self-aspirating burner can produce between the maximum and minimum rates is about two to one.

An object of this invention is to provide an orifice configuration that will enable a self-aspirating burner to operate over a wide range or ranges of gas flow without danger of flashback.

A further object of this invention is to provide such a configuration that will cause the flame to burn solely within the desired zone at the orifice plate, regardless of the rate at which gas is supplied to the burner.

A further object is to provide such a configuration that will permit heat to be radiated from almost the entire surface of the orifice plate in which said orifices are formed.

A still further object of the invention is to provide simple and inexpensive methods and apparatus for producing an orifice plate.

These and other objects will be in part obvious and in part pointed out below.

In the drawing:

FIG. 1 is a somewhat schematic vertical section of an embodiment of the present invention;

FIG. 2 is an enlarged sectional view of a group of the orifices shown in FIG. 1;

FIG. 3 is a greatly enlarged cross-section of one of the orifices shown in FIG. 2;

FIGS. 4 and 7 are views similar to FIG. 3 but showing other embodiments of the invention;

FIG. 5 is a view similar to FIG. 3 showing a conventional orifice configuration;

FIG. 6 is a plan view of another embodiment of the invention; and,

FIG. 8 is an elevational view partially in cross-section of a portion of the mold which forms one of the orifices of the embodiment shown in FIG. 7.

Referring to FIGS. 1 and 2, an infrared burner 2 includes a ceramic orifice plate 4 containing a plurality of orifices 6 through which the mixture of fuel gas and air passes before being ignited. Orifice plate 4 forms the upper wall of an enclosed chamber 8. The mixture of air and gas enters chamber 8 through a cylindrical tube 10. Gas under pressure from a supply pipe 12 passes through a nozzle 14 located in the flared open end of tube 10. The annular zone or space between nozzle 14 and tube 10 permits atmospheric air to be drawn into tube 10 by the motion of the stream of gas (see arrows).

The nozzle 14 is designed and constructed so that sufficient atmospheric air is drawn into the nozzle providing an air-gas mixture which is stoichiometric and, hence, can support complete combustion without necessitating the introduction of a secondary air supply in the combustion chamber. The gas and the air drawn into tube 10 are mixed as they enter chamber 8. The mixture then passes through orifices 6 and is ignited adjacent the upper surface of orifice plate 4. A screen 16, may be located a short distance above orifice plate 4 and absorbs heat from the flame and incandescens thereby increasing the amount of radiated heat.

Each of the orifices 6 has the shape of a venturi nozzle, and the horizontal cross-section of each of them is circular throughout its length. Instead of being cylindrical, however, each of the orifices has the vertical cross-section shown in FIG. 3. The orifice wall 18 curves inwardly from the lower end of the orifice 20 to a central throat portion 22, forming a slightly convex intermediate portion 24. Above the contracted throat portion 22, the orifice begins to grow larger, forming a generally conical expanding section 26 having an included angle of approximately 13°. Typically, the length 1 of throat portion 22 is approximately the same as the length 1' of conical section 26 while the diameter of conical section 26 is approximately two and one-half that of the throat portion. In one specific embodiment, the lengths 1 and 1' are 0.325 inches and 0.300 inches respectively, and the diameters d and d' are 0.046 inches and .118 inches respectively.

As the gas mixture passing through the orifice approaches throat portion 22, the reduction in the size of the orifices increases its velocity, so that the mixture moves at a high velocity through the throat portion.

The increase in the gas velocity is a result of two factors. The first factor effecting the increased velocity is the rounded entrance port 30 (see FIGS. 3 and 4), which, in contradistinction to the standard sharp-cornered entrance port 30' (see FIG. 5) common in prior art orifices, allows approximately 35 per cent

greater velocity with the same gas pressure. This results from an improvement in the orifice coefficient from approximately 0.60 for an orifice as shown in FIG. 5 to 0.95 for an orifice as shown in FIG. 3. Hence, as flow rate is directly proportional to the orifice coefficient the velocity is increased by the same factor, i.e. 35 per cent.

The second factor effecting the increase in velocity is the diverging section 26 which, because of its pressure recovery ability, allows much greater flow of gas with the same pressure differential, e.g. with the orifice of FIG. 5 and a given gas pressure and the orifice of FIG. 3 and the same gas pressure, a greater volume of gas will result with the orifice construction shown in FIG. 3. The combination of these two velocity increasing factors results in a velocity in the throat portion of the orifice which is approximately $3\frac{1}{2}$ to 4 times greater than the velocity of the gas flow in a cylindrical orifice as shown in FIG. 5. Thus, an orifice having the construction as shown in FIG. 3 will pass approximately $3\frac{1}{2}$ to 4 times as much gas and air through it as an orifice having the configuration shown in FIG. 5 for the same throat cross-sectional area.

In addition, the rounded entrance area 30 has the beneficial effect of preventing the formation of eddy currents or disturbances in the gas stream and, unlike the conventional cylindrical gas port shown in FIG. 5, does not produce disturbances in the gas flow along the wall of the port resulting in a slow moving portion of the gas stream which increases the possibility that the flame will burn its way back through the nozzle and cause flashback into the chamber.

The swift, uniform flow of the gas and air mixture through the throat portion 22 of the present invention avoids flashback from the burner flame to chamber 8. The advance of the flame upstream of the flowing gas and air is always less than the minimum rate of flow through the throat. Hence, the flame may move down toward the throat but never through it.

The increase in the rate of flow of the gas as a result of the contour of the orifices is particularly significant with a self-aspirating system, such as the one shown, because such systems supply the air and gas mixture at relatively low pressures. Because of this increase, the present invention permits the safe and dependable operation of the burner at much lower pressures than conventional radiant burners. For this reason, it is possible to adjust burners employing the present invention over a much greater range of rates of flow than has been possible in self-aspirating burners employing conventional ports.

A further difficulty created by the conventional cylindrical port is that if the velocity of the gas flow is too great, the flame may be raised from or "lifted off" the orifice plate instead of maintaining a position immediately adjacent it. The expanding section 26 of the present invention solves this problem because of the great reduction in the velocity of the gas mixture that takes place as the diameter of the orifice increases approaching the upper surface of orifice plate 4. Because of the great drop in the velocity of the gas mixture in expanding section 26, the point where the gas speed and the flame speed reach equilibrium will be located within it. It is this point of equilibrium that determines the location of the flame.

It should also be pointed out that when orifices constructed in accordance with the present invention are

used in burner plates only $\frac{1}{8}$ to $\frac{1}{4}$ the number of orifices need to be used to provide the same BTU output as a burner using conventional cylindrical orifices having the same minimum diameter. Thus, in one embodiment of the invention a burner plate having only 62 orifices per square inch will produce the same BTU output as a plate having 3 or 4 times as many cylindrical orifices since the percentage of the upper surface area which is occupied by the ports is much greater than with a conventional burner. This is, of course, due to the greatly expanded area at the upper end of the port. Whereas the number of ports are reduced by a factor of 4, the outlet area of each port is increased by a factor of approximately 10. Therefore, the percentage of the top surface which is occupied by open holes is greater thus increasing the BTU output for each orifice. This factor is extremely important since the tendency of the upper surface to incandesce is greatly increased by reducing the amount of ceramic area and increasing the amount of open area. Other infrared burners in the prior art attempt to achieve greater incandescence by making artificial ridges, points, etc., on the surface to increase the ceramic area adjacent the burner area in order to have more ceramic material adjacent the flame area for greater incandescence. Burner plates constructed in accordance with the present invention will increase the incandescence in a much more refined manner by reducing the amount of ceramic material between all adjacent holes and such burner plates are more economical to manufacture. Even greater incandescence can be achieved by shaping the exit port so that it has a hexagonal section in the expanded portion of the orifice so that the ridges between the holes become even thinner in cross-section than with the circular cross-section expanded portion. This will present a plan view which will look very much like the wax walls of a bee's honeycomb and, will produce a greater incandescence effect, if such is desired.

It is anticipated that most embodiments of the invention will require a large number of orifices 6. The number of the orifices to be used and the geometrical arrangement of them in orifice plate 4 depends upon the purpose for which the burner is designed. In many cases, it is desirable that the upper or outlet openings of expanding sections 26 of the orifices should occupy almost the entire surface area of the orifice plate. For this purpose, circular orifices are arranged in a "honeycomb" fashion. The orifices shown in FIG. 3 are separated only by narrow flattened ridges 27. In other cases, it may be desirable that the upper openings of the orifices occupy substantially less than the entire surface area of the orifice plate. In the embodiment shown in FIG. 4, for example, orifices 6 are separated by flattened ridges 29, which are considerably larger than those of the embodiment shown in FIG. 3.

FIG. 6 illustrates an embodiment of the invention employing a series of elongated orifices 34. The cross-section of one of these orifices along the line 4a-4a is identical to the cross-section shown in FIG. 4 of the circular orifice. The end portions 34 of the elongated orifices are semi-circular. Each of the semi-circular end portions is of the same configuration as half one of the circular orifices 6 of the embodiment shown in FIG. 3. This embodiment offers the advantage of requiring fewer orifices than burners employing circular orifices.

In burners of the type described, orifice plate 4 is normally made of a ceramic material with a low heat

transfer coefficient. The orifice plate is molded in a die having a number of pins equal to the desired number of orifices. As the mold is opened, the pins are withdrawn, leaving the orifices. Since the orifices of the present invention are narrowest at throat portion 22 and grow larger in both directions, a single pin cannot be used to mold each of the orifices and then withdrawn from it in the usual manner. FIGS. 7 and 8 illustrate the manner in which the orifices of the general type of FIGS. 1 to 4 of the present invention may be formed. Rigidly mounted on the bottom wall of the lower mold section (a segment of which is represented in FIG. 8 at 40) is a group of pins 36 corresponding in number to the orifices to be formed in the burner. Pins 36 are shaped and positioned to form the lower portions of the orifices. Similarly mounted on the top wall of the top mold section 42 is a similar group of pins 38 which mate with pins 36 and form the upper portions of the orifices. Each of pins 38 has a center bore which snugly receives a projecting extension of its mating pin 36. Hence, when the mold sections are moved together the extension of each pin 36 projects into the bore in its mating pin 38 and insures exact alignment of the pins.

The cylindrical portion of each pin 44 forms the throat portion 22 of the orifice, and it flares out adjacent the wall of the lower mold section 40 to form the convex intermediate orifice portion 24. The main portion of pin 38 has the general shape of a truncated cone and forms the expanding section 26 of the orifice. Pin 38 has a cylindrical extension 46 with a flat end 48 that is somewhat larger than pin 36. The difference in the sizes between the end of pin 38 and pin 36 produces a slight step or shoulder 50 in the shape of the orifice. Shoulder 50 may produce a disturbance in the flow of the air-gas mixture through the orifice, but since any such disturbance would occur after the mixture has passed through the throat portion 22 and away from the outlet, it would not cause difficulties.

During operation the flame front may move generally in the direction of the axes of the orifices within the general zone of the flame front, or outlet side of the orifice plate. When the maximum amount of the air-gas mixture is being supplied to the burner the flame front moves up to the outlet ends of the orifices and may in fact move above that general plane. However, the orifice restricts the flow rate such that the flame does not "lift off," i.e., move upwardly away from the top surface of the orifice plate. As the amount of the air-gas mixture is reduced so as to reduce the amount of heat being produced by the burner, the reduced rate of flow at the outlet ends of the orifices becomes less than the rate at which the flame advances along the air-gas stream. Accordingly, the flame front moves into the outlet end of each orifice. However, due to the converging side walls and resultant reduced cross-section, the rate of flow gradually increases from the outlet end of each orifice in the direction toward the orifice throat. Hence, with a gradual reduction in the rate at which the air-gas mixture is supplied to the burner, there is a correspondingly gradual movement of the flame front downwardly into the orifices. The rate of flow within each orifice is at its maximum in the throat, and the minimum rate of flow in the throat is greater than the rate at which the flame front advances along a stream of the air-gas mixture for which the burner is to be used. Hence, when the burner is turned down to

reduce the heat, the flame front moves down into the orifices but it does not move into the orifice throats.

The shape of the orifices is such as to provide an efficient and dependable modulation of the heat without resorting to the use of air under pressure in the air-gas mixture. The orifice construction insures optimum operation for various infrared burner arrangements.

What is claimed is:

1. In a burner construction for an air-gas mixture, an orifice plate formed of a ceramic material having approximately 60 orifices per square inch of surface area formed therein defining parallel flow paths for the air-gas mixture between the upstream side of the plate and the flame front side of the plate, each of said orifices having parallelly extending side walls defining a throat portion having the minimum cross-sectional area of the orifice and having a maximum dimension of the order of 0.046 inches and extending from the upstream side of the plate towards the center of the plate, each orifice also having a diverging portion extending from said throat portion towards said flame front side in the direction of flow of said air-gas mixture, said diverging portion defining an included angle of the order of 13° and having a smooth surface throughout its entire extent, said diverging portion also having a length of the order of 0.033 inches and a cross-sectional area at the flame front side of the plate which is at least twice the area of said throat portion and having a maximum dimension of the order of 0.118 inches, said throat portion having a minimum cross-sectional area of the orifice along substantially its entire length whereby the rate of flow of said air-gas mixture is maximum in said throat and is decreased in said diverging portion of said orifices, said maximum flow rate being greater than the rate of advance of flame in the air-gas mixture.

2. Apparatus as defined in claim 1 wherein said orifice has a generally circular cross-section.

3. Apparatus as defined in claim 2 which includes means for forming a flow chamber adjacent the upstream side of said plate from which the air-gas mixture flows into said orifices, and means to supply the air-gas mixture to said chamber comprising a gas injector and an air aspirator unit.

4. Apparatus as described in claim 1 wherein each of said orifices has rounded inlets for the air-gas mixture and wherein the outlet ends of said orifices comprise substantially the entire area of said flame front side of said orifice plate.

5. Apparatus as in claim 1 wherein each of said orifices has a rounded inlet and wherein there is a substantially flat surface on said flame front side of said plate between each orifice and the next adjacent orifices.

6. In a burner construction for an air-gas mixture, an orifice plate having approximately 60 orifices per square inch of surface area formed therein defining parallel flow paths for the air-gas mixture between the upstream side of the plate and the flame front side of the plate, each of said orifices having a generally elongated cylindrical throat portion having parallelly extending side walls defining a minimum cross-sectional area of the orifice and extending from the upstream side of the plate towards the center of the plate, each orifice also having a diverging frusto-conical portion extending from said throat portion towards said flame front side in the direction of flow of said air-gas mixture, said diverging portion defining an included angle of the order of 13° having a smooth surface throughout

7

8

its entire extent, having approximately the same length as said throat portion; the ratio of the diameter of said diverging portion of the orifice at the flame front side of said plate with respect to the diameter of said throat portion being on the order of 2.5, said throat portion having a minimum cross-sectional area of the orifice

along substantially its entire length whereby the rate of flow of said air-gas mixture is maximum in said throat and is decreased in said diverging portion of said orifices, said maximum flow rate being greater than the rate of advance of a flame in the air-gas mixture.

* * * * *

10

15

20

25

30

35

40

45

50

55

60

65