March 23, 1965 R. L. JONES ETAL 3,174,474

RADIANT HEATING UNITS

Filed Oct. 4, 1963 2 Sheets-Sheet 1

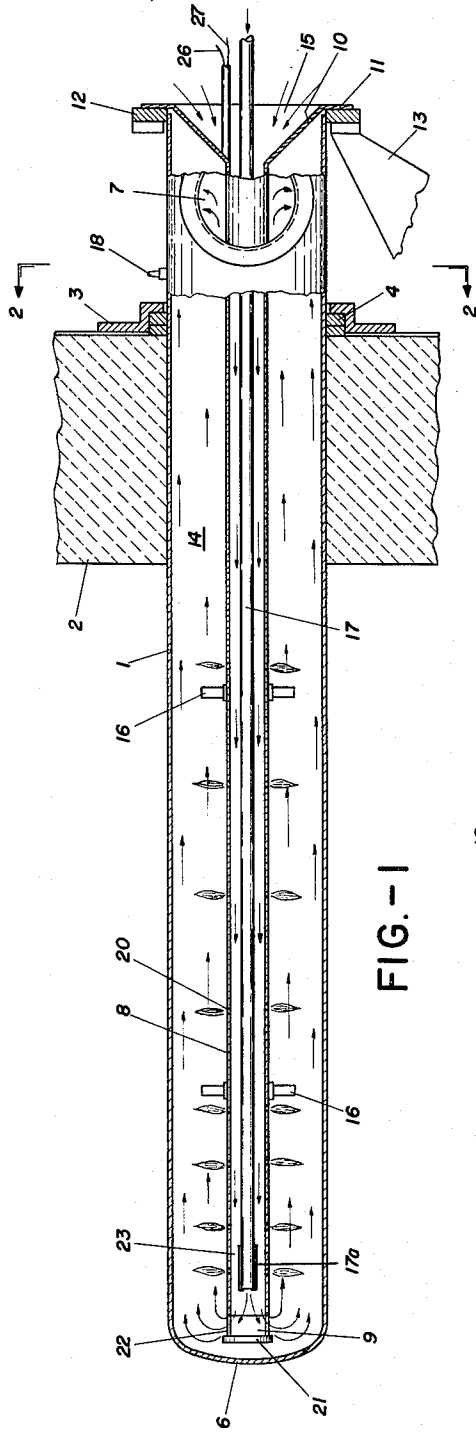

FIG. - 1

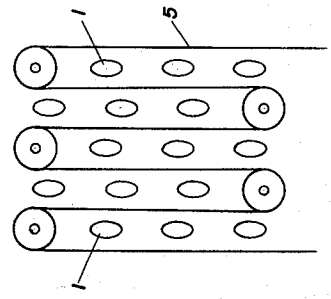

FIG. - 4

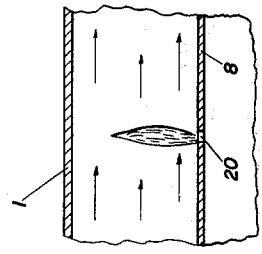

FIG. - 3

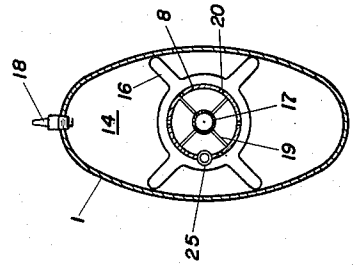

FIG. - 2

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RADIANT HEATING UNITS

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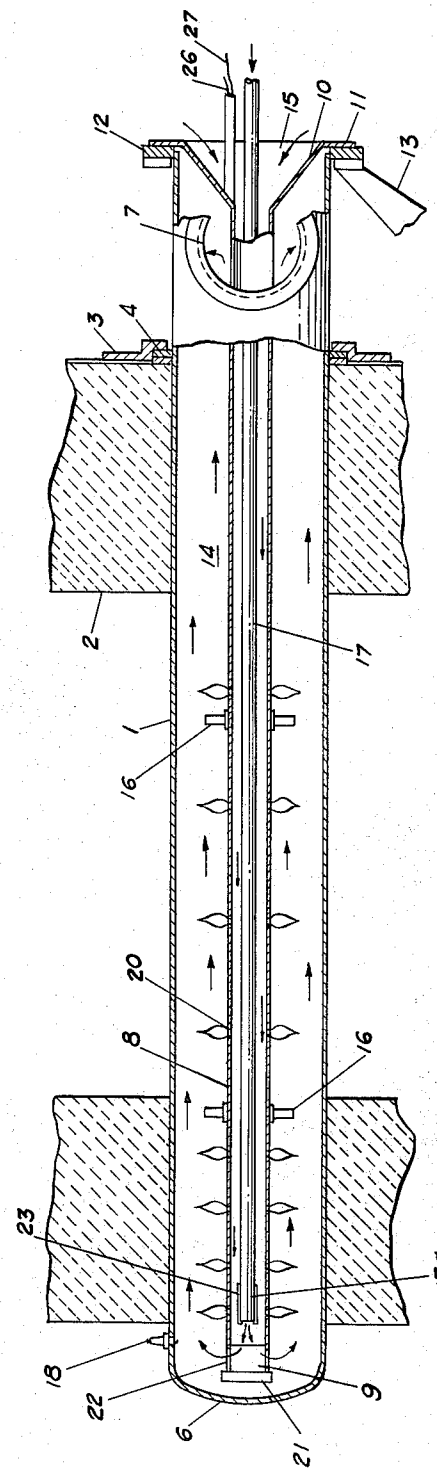

FIG. 5

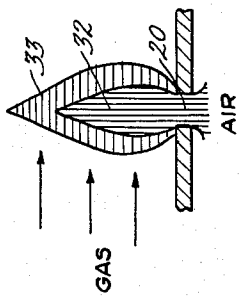

FIG. 7

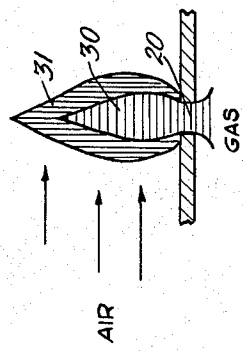

FIG. 6

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RADIANT HEATING UNITS

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This invention relates to new and useful improvements in radiant heating units, more particularly to a self-contained gaseous fuel combustion unit in which the combustion chamber is the space between a metal housing and a combustion air tube disposed within said housing and fuel is supplied by a pipe extending centrally through said combustion air tube; the heat generated being radiated from the housing wall to the articles or chamber being heated without any products of combustion escaping to the heating chamber. The present application is a continuation-in-part of an application serially numbered 122,591, filed July 7, 1961, which application has been abandoned.

It is among the objects of this invention to provide a radiant heater unit having a closed housing portion of tubular elliptical or other shape mounted on and extending from a wall or between spaced walls of a heating chamber, one or both ends of the housing extending outside said walls and having a combustion air tube projecting substantially the full length into the housing and in which one end of said tube may be secured to the outer end of the housing to form a closure therefor.

It is still a further object of the invention to provide a method of firing radiant heating units in which a mixture of gaseous fuel and preheated air is directed to the end of a combustion chamber and caused to reverse its direction of flow while burning in said chamber and by adding air preheated to combustion temperatures at intervals into the path of flow of said burning mixture combustion is maintained throughout the length of the combustion chamber.

Heretofore radiant heating units utilized a primary burner at the closed end of the tube to which a combustible mixture of fuel and air was continually supplied and in some instances supplemental air was delivered to the combustion chamber surrounding the air tube to control or regulate combustion along the length of the tube.

In accordance with the present invention, pre-mixed air and fuel are caused to flow through an annular combustion chamber and pre-heated air from a series of perforations or air ports in an air tube pierces the flow of the combustible gases causing a jet-like flame that completely burns the adjacent combustible mixture which is inspirated into the air stream and any excess combustible mixture by-passes the flame and goes to the next perforation to be consumed in the presence of the secondary air from the air tube orifice. These burner flames are the reverse of an ordinary Bunsen burner flame because there is no primary combustion as in conventional tube heaters.

The invention will become more apparent from a consideration of the accompanying drawings constituting a part hereof in which like reference characters designate like parts and in which:

FIGURE 1 is a vertical section taken longitudinally of a radiant burner unit embodying the principles of this invention;

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

FIGURE 3 is a view diagrammatically illustrating the flame characteristic of the hot pre-mixed air and gases burning in the combustion chamber;

FIGURE 4 is a diagrammatic illustration of an annealing chamber utilizing the radiant heating units for the annealing of sheet steel or strip that continuously passes through said chamber;

FIGURE 5 is a vertical section taken longitudinally of

a radiant burner unit as in FIGURE 1, in which the tube is disposed between the spaced wall of a heating chamber; and

FIGURES 6 and 7 are diagrammatic views of air and gas inspirated flames, respectively.

In the drawing, the numeral 1 is a housing supported in a furnace wall 2 by means of a clamping ring 3 and a sealing material 4. The housing 1 is not supported at its extended end that projects into the furnace chamber such as an annealing chamber for annealing steel sheets or strip, designated by the numeral 5 in FIGURE 4 of the drawing, the numeral 1 designating a plurality of the radiant heating units of FIGURE 1 as they are arranged for continuous annealing of the strip shown in FIGURE 4.

The housing 1 has a closed end 6 and is provided with a waste gas exit passage 7. An inner tube, or what may be termed a combustion air tube 8, is disposed within the housing 1 and is open at 9 and provided with a flared end 10 at its other end. The end 10 is provided with a flange 11 that seats against a sealing material 12 carried by a mounting bracket 13.

In the construction so far shown, it will be evident that if the waste gas passage 7 is connected to a fan, the combustion chamber between the housing 1 and tube 8 that is designated by the numeral 14 may be exhausted or evacuated. However, when a fan is so applied, air will be drawn in through the funnel-shaped opening designated by the numeral 15, and drawn from the mouth 9 of the inner tube into the chamber surrounding that tube, which is the chamber 14.

The inner tube 8 is held in position by spacer lugs 16, of which there are four shown in FIGURE 2 of the drawing, the lugs being spaced longitudinally within the housing, as shown in FIGURE 1.

Disposed within the combustion air tube 8 is a tube 17 connected to a source of fuel gas. The tube runs to substantially the end of the combustion air tube 8 and delivers fuel gas to mingle with the air drawn into the opening 15 when both the fuel and air reach the end of the tube 8. This combustible mixture may be ignited in any suitable manner as by a spark plug 18 located at the exhaust end of the combustion housing, FIGURE 1, or at the closed end shown in FIGURE 5. The fuel gas tube 17 is provided with spacers 19 to center the tube with the combustion air tube 8, as shown in FIGURE 2. The combustion air tube 8 is provided with a series of perforations 20 that are spaced longitudinally of the combustion air tube 8, as shown in FIGURE 1. These perforations may be supplied in any number and spaced in any manner, they being shown in angularly spaced relation in FIGURE 2. It is apparent, however, that they may be spaced in a helical path for reasons to be hereinafter explained.

As shown in FIGURE 2, the housing 1 is of elliptical shape, while the combustion air tube 8 is of cylindrical shape, as is also the gaseous fuel tube 17. The spacers 16 and 19 maintain the combustion air and fuel tubes in proper spaced relation to each other and with the outer housing 1.

Fuel gas is supplied through the tube 17 to the end of the fuel tube, which is adjacent the end of the combustion air tube 8, as shown in FIGURE 1. There is a small deflector plate 21 secured to the end of the combustion air tube 8 by spaced lugs 22. Also a small tubular portion 17*a* is mounted in spaced relation with the gaseous fuel tube 17 near the end of said tube to draw the combustion air from the space 23 between the combustion air tube 8 and fuel gas tube 17 into the mixing end or chamber 9 of the tubes to form a mixture of air and gaseous fuel that will burn in the presence of secondary air, said secondary air is metered into the above mixture through the perforations 20 as it flows toward the exhaust end of the combustion chamber 14. The

combustible mixture, in the combustion chamber **14**, is ignited by the spark plug **18**. The regulation of the exhaust controls the rate of circulation for flow of the gas air mixture and the products of combustion resulting therefrom. The perforations **20** along the path of flow of this mixture supplies preheated air to the mixture to support secondary combustion and the outer housing **1** becomes substantially uniformly heated over the area exposed to the work.

The preheated fuel gas with air preheated to substantially combustion temperature is delivered at the closed end **6** of the housing and flows counter to the air and gas flow through the annular combustion space **14** to the outlet **7**, as shown by the arrows in FIGURE 1 of the drawing, and as the pre-mixed fuel and air passes through the annular chamber **14**, it is pierced by high velocity streams of preheated air at each of the perforations **20**. The resulting flame may be termed a reverse flame because the air cone is inside and the fuel and air pre-mix is on the outside of the flame. The flame at each perforation **20** consumes the available fuel and any excess fuel by-passes the flame and goes to the next perforation to be consumed in the presence of the secondary air from the adjacent orifice **20**. There is no mixing of the air and fuel at the orifices **20** because they merely supply air and there is a complete fire at each orifice point.

Conventional gaseous fuel burners are of the Bunsen burner type, as shown in FIGURE 6 of the drawing. In this case, the flame exists in a media of secondary air and the gas velocity through the port must inspirate enough of this secondary air to complete combustion of all of the gas passing through the port **20**. The volume of secondary air required usually exceeds the volume of the gas by several hundred percent, depending upon the percentage of combustibles in the gaseous fuel. In FIGURE 6, the reference numeral **30** designates an area of combustible gas in the form of a burner flame and the flame-shaped area **31** designates the inspirated air enveloping the gaseous mixture to complete combustion of the gas passing through the port **20**. In other words, the flame-shaped fuel area **30** is projected into a normal atmosphere to ignite in the presence of the oxygen in the air. When this type of flame is employed in a tight closure, the products of combustion from the flame contaminate the secondary air media reducing the oxygen content. It does not take very much of a reduction of this oxygen content to upset the characteristic of the flame and with a little more contamination of the media, the flame goes out, assuming there are a series of such flames in the path of travel of the secondary air media.

In FIGURE 7, the flame is shown as a flame-shaped cone **32** of preheated air; namely, air preheated to substantially combustion temperature surrounded by a flame-shaped area **33** of a combustible gaseous mixture. In other words, the flame-shaped areas of preheated air are projected into a combustible gaseous atmosphere which is the reverse of the Bunsen type burner flame shown in FIGURE 6. Contrary to the contamination of the air that sustains combustion of the flame in FIGURE 6 of the drawing, the products of combustion surrounding the flame in FIGURE 7 only reduce the B.t.u. content or the percentages of combustibles in the fuel gas media into which the preheated air is injected, as shown in FIGURE 7. This percentage of combustibles has to drop quite low before the velocity of the air stream cannot inspirate enough fuel to satisfy the oxygen of the air piercing the gaseous media above the port **20**, FIGURE 7. The remainder is unsatisfied oxygen and not unburnt fuel, hence no contamination of the secondary air media as occurs in the Bunsen burner type of combustion.

It is thus evident that with a slight excess of air occurring when the flames exhaust in a very low percentage of combustibles, practically all of the fuel in the media can be burned in a tight enclosure such as in a radiant tube heater with the character of the flame remaining substantially constant.

Other advantages of the type of flame of FIGURE 7 are that the velocity of the air passing through port **20** can be fairly high before any blow-off of the flame occurs, whereas in the flame of FIGURE 6 where fuel gas passes through the port **20**, blow-off occurs at a much lower velocity and the type of flame shown in FIGURE 7 has a much higher radiation characteristic than the Bunsen burner type flame of FIGURE 6. In the type of flame produced as shown in FIGURE 7, the air is separated from the products of combustion and each jet of air inspirates sufficient fuel to combine with all the oxygen in the jet of air from port **20**. Products of combustion dilute the remaining unburnt fuel but the continuing piercing of the gas stream with multiple jets of air results in complete combustion of the gaseous mixture passing across the burner flames.

Each row of holes completely burns the adjacent fuel which is inspirated into the air stream until the oxygen in the individual air stream is exhausted. Fuel passing around this cone of combustion mixes with the products of combustion from this particular flame and passes on to be pierced by the next row of holes. Each cone is sharp and distinct and combustion at the last rows of orifices at the exit end of the tube takes place in a very low B.t.u. gas content, but the temperature of this gas is high enough for combustion at this point.

This glowing radiant heat is transmitted to the continuous strip or steel sheet passing over the guide rolls of FIGURE 4 in the annealing chamber, which is enclosed within the walls **2** and **2***a* of the furnace. If the perforations **20** are spaced to form a helix in the wall of the combustion air tube **8**, the gaseous fuel mixture and products of combustion will be directed to flow angularly in the combustion chamber **14**. This would give the fuel mixture and products of combustion a longer path of travel in its passage through the combustion chamber.

The return or exhaust of the fan can be regulated by placing a thermostat **25** in the wall of the combustion air tube, as shown in FIGURE 2, and the thermostat may be connected by conductors **26** and **27**, FIGURE 1, to an electric control circuit for regulating the fan or blower speed.

It is, of course, evident that instead of an exhaust fan connected to the waste gas exit **7**, the open mouth or inlet passage **15** may be connected to a blower and air forced under pressure through the combustion air tube **8** to the end of the tube and thence into the combustion chamber **14** from which it exits from the passage **7**. Whether the air supply is under pressure or by suction is immaterial to the operation of the device, as it will function the same either way.

It is evident that the injection of the air preheated to combustion temperatures into the hot pre-mixed air and gas, produces an intense heating flame in the combustion chamber adjacent the point of injection. This is plainly visible on the outside of the housing **1**, which is more intensely heated adjacent the air holes or perforations than in other areas of the housing.

As shown in FIGURES 1 and 5, the ignition means such as the spark plug **18** may be located at any portion of the combustion tube, it being shown at the exhaust end in FIGURE 1 for convenience so that it is outside of the heating chamber where it would not be exposed to the heat of the chamber. Similarly, in FIGURE 5 the spark plug **18** is shown outside of the chamber but at the closed end of the tube. It could also be located at the center or any other part of the tube for the reason that the separate flames will be propagated successively from the point of ignition because of the separate jets of air that support combustion. As previously explained, the pre-mixed, preheated air and fuel is not a combustible mixture, per se,

as combustion takes place only at the air jets where sufficient oxygen is available to burn the pre-mixed air and fuel. Hence there can be no explosion resulting from ignition.

Although one embodiment of the invention has been herein illustrated and described, it will be evident to those skilled in the art that various modifications may be made in the shape of the housing, the relative size of housing and combustion air tube, the number and kind of spacing lugs and in the arrangement and number of air holes in the combustion air tube and other details of construction without departing from the principles herein set forth.

We claim:

1. In a radiant heating unit a housing forming a combustion chamber closed at one end and having an exhaust passage for the products of combustion at the other end thereof, a tubular member having a perforated wall extending into said housing in spaced relation with the inner and end walls of said housing, said tubular member being open at its extended end adjacent the closed end of the combustion chamber housing to conduct a gaseous medium into the space between the tubular member and the closed end of the combustion chamber housing and through the perforations in the wall thereof, a second tubular member disposed in said first tubular member in spaced relation therewith having an open end adjacent and axially spaced from the open end of said first tubular member, said second tubular member being adapted to conduct a gaseous medium to the open end of said first-named tubular member to mix with the gaseous medium in said first-named tubular member and cause the same to flow around from the closed end of the combustion chamber through the annular space between the first-named tubular member and the combustion chamber wall to the exhaust passage of the combustion chamber, and ignition means at the exhaust end of the combustion for igniting the gaseous mixture beginning at the perforations in the first-named tubular member nearest the exhaust passage of the combustion chamber.

2. A radiant heating unit as set forth in claim 1 in which the first-named tubular member is an air tube and the second-named tubular member a tube for supplying a gaseous fuel whereby the air from the perforations pierce the gas mixture flowing through the space between the first tubular member and the combustion chamber wall to form ignition points at each perforation.

3. A radiant heating unit as set forth in claim 2 in which the ignition means at the exhaust end of the combustion chamber ignites the air and gas mixture at the perforation nearest the ignition point.

4. The steps in the method of firing a radiant heating unit having a housing forming a combustion chamber with an exhaust passage at one end, an air tube for delivering air with perforations opening into the combustion chamber and open at the closed end of the combustion chamber and a fuel line in said air tube for delivering gaseous fuel to the open end of the air tube which comprises;

(*a*) delivering air under pressure through the air tube to the open end of the air tube and through the perforations in the wall thereof,

(*b*) delivering fuel under pressure to the open end of the air tube to form a gas mixture passing through the combustion chamber to the end opposite the entrance of the gas and air mixture by reversing the flow of the gaseous mixture on the outside of the air tube,

(*c*) piercing the gas mixture flowing through the combustion chamber by the air escaping from the perforations of the air tube, and

(*d*) igniting the gas mixture at the exhaust end of the combustion chamber to initially fire the gas mixture developed at the perforation of the air tube nearest the exhaust passage whereby the gaseous mixtures resulting from the air escaping from the perforations are progressively ignited along the length of the air tube.

5. The steps in the method of firing a radiant heating unit having a housing forming a combustion chamber closed at one end with an exhaust passage at the other end and a perforated air tube and a fuel line disposed therein having openings adjacent the closed end of the combustion chamber which comprises:

(*a*) delivering air through the perforations of the air tube at a velocity to form air jets extending into the combustion chamber,

(*b*) delivering fuel under pressure to the open ends of the air tube and fuel line to form a gas mixture at the closed end of the combustion chamber to pass through the combustion chamber across the air jets to the exhaust passage opposite the entrance of the gas and air mixture, and,

(*c*) igniting the gas mixture when combined with the air from the jets to propagate burner flames in the combustion chamber at the perforations along the length of the air tube.

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