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Williams

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[54] **BURNER AND HEAT EXCHANGER**

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[52] **U.S. Cl.** ..... **122/235 R,** 110/1 J, 431/10

[51] **Int. Cl.** **F22b 21/22**

[58] **Field of Search** ..... 110/1 J, 28 R; 122/235; 431/10

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[57] **ABSTRACT**

A combination burner and heat exchanger has a first combustion zone for hot gaseous flow adjacent the burner, a first stage of heat exchanger in and terminating this zone and adapted to cool the flow to a temperature too low to support formation of certain undesired components therein but sufficiently high to support combustion of other undesired components, a second combustion zone, longer than the first, wherein the flow is maintained at a temperature sufficiently high to support such combustion, and a second stage of heat exchanger wherein the flow exiting the second combustion stage is cooled below the combustion temperature.

5 Claims, 5 Drawing Figures

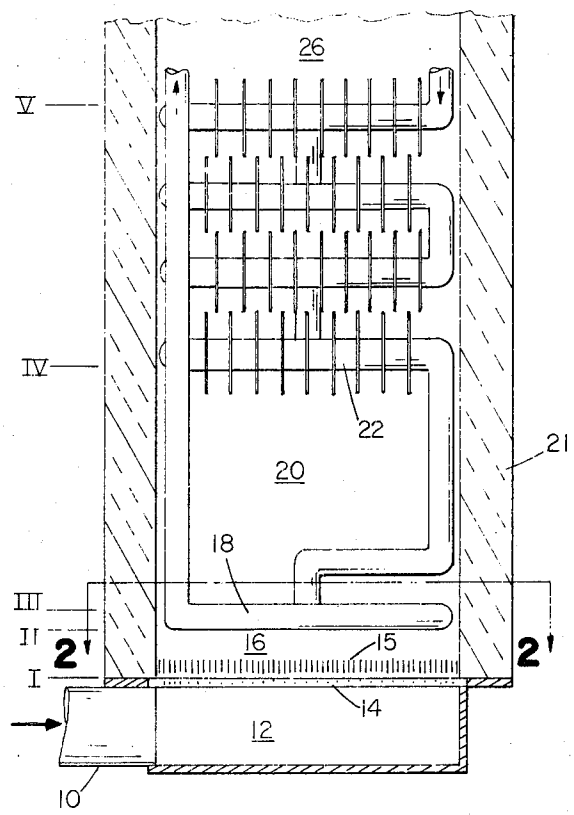


FIG 1

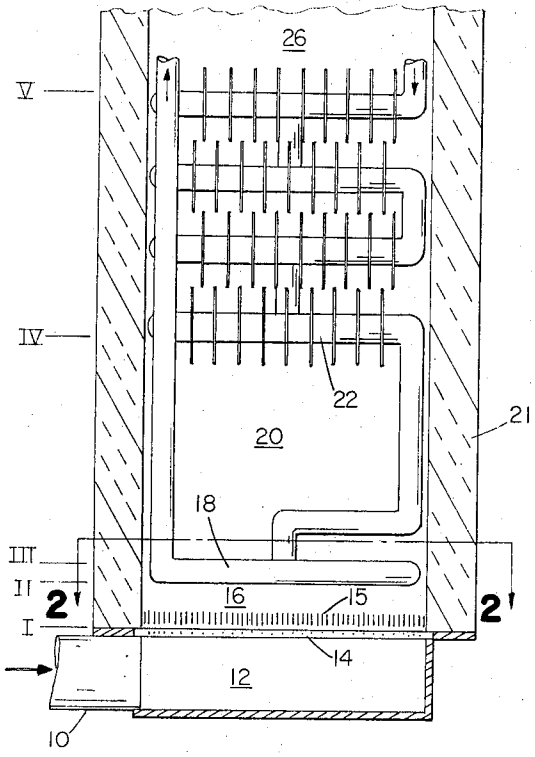
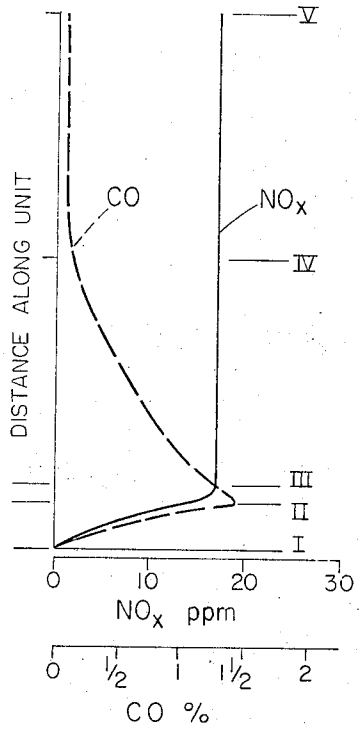


FIG 4



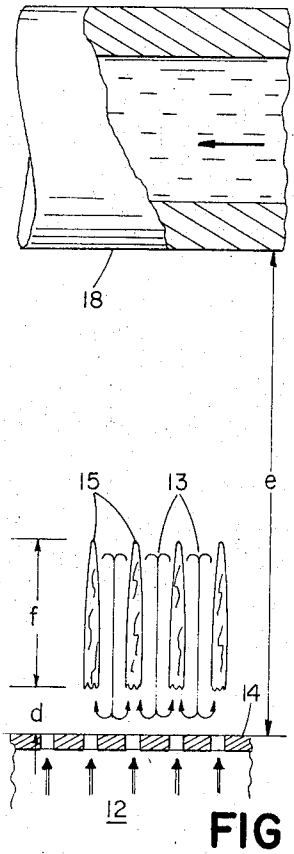
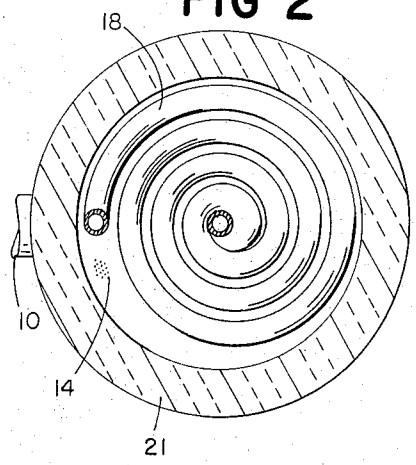


FIG 3

FIG 2



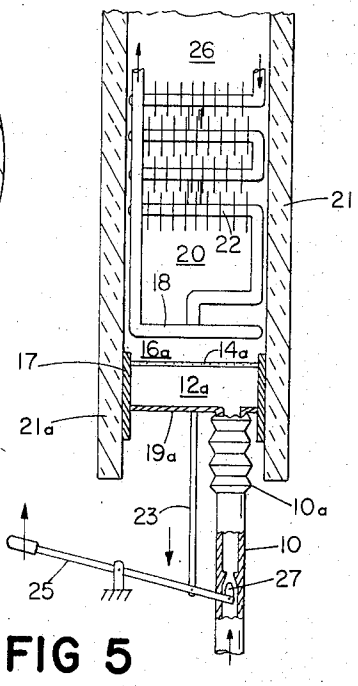


FIG 5

BURNER AND HEAT EXCHANGER

This invention relates to a combination burner and heat exchange unit with particular relevance to units of the high intensity type, usually for producing a heated fluid such as water or vapor.

The object of the invention is to provide units which have lower levels of pollutants in the exhaust emissions, in particular lower levels of various oxides of nitrogen (NO_x) as well as acceptable levels of carbon monoxide and hydrocarbons, and which are suitable for a wide range of applications, particularly for powering external combustion engines in conveyances and for heating domestic hot water and the like.

Units of the type particularly concerned are characterized by the use of a large number of small flames fed at high velocity (e.g. 200 or more flames per square inch of perforated feed plate with cold gas flow rates through the apertures of 10 to 40 feet per second), and heat outputs on the order of 1 million BTU/ cubic foot of the burner-heat exchanger unit per hour. While the residence times of gases in such units are short, it has been found that significant quantities of nitrogen oxides are formed in the region beyond the flame.

In such units the levels of the various pollutants in the exhaust emissions have been a matter of compromise. The longer the gaseous combustion products are held at high temperature, the more thorough the removal of carbon monoxide and hydrocarbons, burning to carbon dioxide, but the greater the quantities of nitrogen oxides, and vice versa. It is desirable to improve the performance of such units to obtain a low value for each of these pollutants.

The present invention utilizes, following the initial combustion zone, a first stage of heat exchanger constructed to reduce the temperature of the combustion gases only partly, maintaining the temperature above that which supports combustion of certain undesired components, but below a higher temperature at which formation of certain other undesired components is supported. In particular, in the case of providing for burn-out of carbon monoxides and hydrocarbons and of suppressing the production of nitrogen oxides, the first stage is constructed to cool to the range of about 1,600–1,800°K.

There follows a secondary combustion zone between this first stage and a further heat exchanger stage. At the further heat exchanger stage the gases are cooled to a level not supporting combustion of the first mentioned undesired components, e.g. carbon monoxides and hydrocarbons. The physical length of the secondary combustion zone is typically longer than the first combustion zone, the particular length of each depending upon the velocity of the gases and the characteristic duration required for burn-out of the undesired component, e.g. for CO and hydrocarbons the time is in the range of about 6 to 20 milliseconds under normal circumstances.

In its particular aspect the invention is based upon the fact that the production of nitrogen oxides is very heat-sensitive and the discovery that a first stage of heat exchanger cooling the gases only a limited degree can abruptly stop nitrogen oxides production, while by postponing the removal of most of the heat to a later stage burn-out of residual carbon monoxide and hydrocarbons can occur. In preferred embodiments of this aspect the length of the first combustion chamber is less than 3 inches, preferably about 1 inch and the residence time of the gas in the second combustion zone is at least several times its residence in the first combustion zone.

In the drawings, FIG. 1 is a diagrammatic view of a combination burner and heat exchange unit according to the invention;

FIG. 2 is a horizontal cross-section taken on line 2-2 of FIG. 1;

FIG. 3 is a diagrammatic view on a larger scale of the embodiment of FIG. 1 showing the relation of the flames and the first stage of heat exchanger;

FIG. 4 is a graph illustrating the effect of the invention upon the pollutants; and

FIG. 5 is a diagrammatic view similar to FIG. 1 adapted to adjust for operation at various firing rates.

Referring to FIG. 1 a fuel/air mixture with gaseous or finely atomized fuel is introduced through gas passage **10** to a manifold **12** behind perforated feed-plate **14**, through which the mixture enters the combustion zone **16**, forming a multiplicity of little flames **15**. Despite high velocity of the mixture the flames **15** remain in stable position because of local recirculation of hot burned gases (arrows **13**, FIG. 2) which sustains ignition of the entering gas mixture.

Using the example of a propane-air mixture with 25 percent excess air, the temperature attained in the flame region **16** is in the range of about 2,000–2,200°K.

Immediately beyond the flame region is a first heat transfer stage **18** which reduces the gas temperature to the range of about 1,600–1,800°K. The efficiency of this stage is intentionally limited, therefore a coiled tube without heat transfer fins is employed. The production of nitrogen oxides is immediately quenched. The reason why this occurs is not well understood. It is theorized that in high intensity burners hydrogen atoms and hydroxyl radicals are generated in a temperature-critical reaction, and the presence of hydroxyl radicals facilitates the formation of nitrogen oxides at a rapid rate in the post-flame region while the presence of hydrogen atoms retards the oxidation of carbon monoxide. Reduction of the gas temperature only a few hundred degrees Kelvin below flame temperature by contact with the surface of the first stage of heat exchanger is believed to reduce the concentration of hydroxyl radicals so low as to cause stoppage of the rapid growth of nitrogen oxides; similarly the concentration of hydrogen atoms is reduced.

Following heat transfer stage **18** is a secondary combustion or "burn-out" zone **20** for holding the gases at burn-out temperature for a duration in the range of about 6 to 20 milliseconds. It is in this region that the residual carbon monoxide and hydrocarbons can burn out in the presence of the excess air and a reduced concentration of hydrogen atoms. Following zone **20** are heat transfer stages **22** which quench the burn-out and reduce the gases to the desired discharge temperature at **26**, with low pressure drop in the total gas path.

Thus, to summarize, and referring to FIGS. 1 and 4:

Between:

I–II Fuel & Air $\rightarrow CO_2+H_2O+HC+CO+NO_x+O_2+N_2$

II–III NO_x Formation stopped

III–IV CO + HC Burn out

IV–V Complete heat exchange

Depending upon the need for compactness some degree of heat exchange is permissible between III and IV so long as an adequate burn-out temperature is maintained until the desired level of carbon monoxide and hydrocarbons is reached.

It is important that the first stage **18** of the heat exchanger be spaced beyond the flame region, to avoid quenching the flame, but close thereto to minimize NO_x. In a domestic hot water system in which there are fixed feed rate, fuel properties and flow velocity, the flame will have a constant length and the distance to heat exchanger stage **18** can be permanently set. In a steam auto engine, however, regulation of power output is achieved by varying the feed rate, hence the gas velocity and flame length. In such case the distance between feed plate and heat exchanger may be fixed on the basis of the maximum feed rate and flame length (which also corresponds to the maximum discharge of exhaust products).

In other instances the distance between feed plate and first stage of heat exchanger (and as well between first stage **18** and further stages **22**) may be adjustable, lengthening these spacings with increase in feed rate and vice versa, as through mechanical linkage with the throttle, or by use of the inlet pressure of the fuel/air mixture or with other suitable mechanisms. Such a system is illustrated schematically in FIG. **5** where like numbers refer to like elements in FIG. **1.** Here the perforated burner plate **14a** and the rear wall **19***a* forming manifold **12***a* are mounted permanently within sleeve **17** which forms a slidable telescopic seal with extensions **21***a* of wall **21.** The burner unit (combination of elements **14***a*, **19***a* and **17**) is positioned by rod **23** which is diagrammatically shown to be actuated by throttle **25** which also throttles the inlet gas at **27.** Flexible conduit **10a** connects conduit **10** to the movable burner unit. It will be seen that increase in feed rate by movement of the throttle in the direction of the arrow moves the burner unit away from heat exchanger stage **18** thus accommodating the resultant longer flames, lengthening the first combustion zone. Preferably in this embodiment the distance between burner plate **14** and stage **18** is less than 3 inches at maximum.

Referring again to FIGS. **1–3** in a specific example of a fixed plate system for e.g. domestic hot water, the feed plate **14** comprises a 6 inch diameter stainless steel plate, 0.030 inch thick, perforated in a regular pattern with 0.033 inch diameter holes with a density of 225 holes/square inch, corresponding to an open area of 20 percent. On the basis of a propane-air mixture with cold gas velocities in the range of about 10 feet per second and flame velocities on the order of 1 foot per second, the flame length is on the order of 10 times the diameter of the feed holes plus an added correction *d* of less than 30 percent for the fact (see FIG. **3**) that the flames **15** do not commence until a distance *d* from the plate due to the method of ignition by recirculation.

The first stage **18** of the heat exchanger is spaced a distance e approximately 1 inch from the feed plate **14,** and the duration of stay of the gases in the first combustion zone **16** is on the order of 3 to 5 milliseconds. Stage **18** is of limited cooling capacity for reducing the gases from flame temperature on the order of 2,000°K to 1,600–1,800°K, below the critical temperature for NO_x production. Typically stage **18** comprises stainless steel tubing of one half inch outer diameter formed in a flat coil, parallel with and opposed to the feed plate **14,** see FIG. **2.**

The secondary combustion zone **20** simply comprises an unobstructed gas passage surrounded by insulation **21** to maintain the temperature high enough to support the combustion of CO and hydrocarbons. The residence time in this zone may be on the order of 6 to 20 milliseconds. Then a series of flat coils of the tubing as used in the first stage but with fins for improving heat transfer define the later stages of the heat exchanger **22.** These quench the burn-out of CO and hydrocarbons (if incomplete) and extract the bulk of the useful heat from the gaseous combustion products. These coils are similarly parallel with and opposed to the feed plate **14.**

Through the use of this embodiment outputs on the order of 300,000 BTU/hour can be obtained with favorable levels of pollutants, for instance nitrogen oxides of less than 20 ppm, while carbon monoxide and hydrocarbons are similarly reduced to acceptable levels.

Various conical configurations (i.e. burner plate and heat exchanger stages in form of a series of superposed, spaced cones) and design compromise can be effected while taking advantage of the basic principle of this invention.

It is to be noted that the invention provides a burner-heat exchanger combination which can produce a low level of pollutants using only the gases and heat of the original combustion (that is, without the necessity of introducing either secondary air or fuel) within a compact size and with few structural parts.

What is claimed is:

1. In a combination high intensity burner and heat exchanger unit, the burner connected to a supply for a mixture of vaporous or vaporizable fuel and excess air of a quantity to sustain complete combustion while attaining temperatures of the order of 2,000°K and wherein the burner is arranged to provide a hot gaseous flow including combustion products at an elevated temperature above a first temperature which supports combustion of certain undesired components and above a second higher temperature which supports formation of nitrogen oxides, and the heat exchanger is arranged in the gaseous flow to extract heat therefrom, the improvement which includes:

means defining a first combustion zone for said gaseous flow adjacent said burner;

a first stage of heat exchanger disposed in and terminating said first combustion zone and adapted to cool the gaseous flow to a temperature in the range of about 1,600–1,800°K, below said second temperature but above said first temperature;

means defining a second combustion zone for said gaseous flow immediately following and longer than said first combustion zone and adapted to maintain said gaseous flow above said first temperature;

and a further stage of heat exchanger disposed in the path of gaseous flow terminating said second combustion zone and adapted to cool the gaseous flow below said first temperature, the only entry for combustion air being said supply.

2. The unit of claim **1** wherein the residence time of the gas in said second combustion zone is at least several times its residence time in said first combustion zone.

3. The unit of claim 1 wherein said burner includes a perforated wall member and means to feed a fuel-air mixture through said wall member to form flames, and the spacing of said first stage of heat exchanger from said wall member is less than 3 inches.

4. The unit of claim 3 wherein said spacing is about 1 inch.

5. In a combination burner and heat exchanger unit wherein the burner is arranged to provide a hot gaseous flow including combustion products at an elevated temperature above a first temperature which supports combustion of certain undesired components and above a second higher temperature which supports formation of other undesired components, and the heat exchanger is arranged in the gaseous flow to extract heat therefrom, the improvement which includes:

means defining a first combustion zone for said gaseous flow adjacent said burner;

a first stage of heat exchanger disposed in and terminating said first combustion zone and adapted to cool the gaseous flow to a temperature below said second temperature but above said first temperature;

means defining a second combustion zone for said gaseous flow immediately following and longer than said first combustion zone and adapted to maintain said gaseous flow above said first temperature;

and a further stage of heat exchanger disposed in the path of gaseous flow terminating said second combustion zone and adapted to cool the gaseous flow below said first temperature and which includes means for adjustably changing the length of said first combustion zone.

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