The present invention relates to a novel method for suppressing the formation of nitrogen oxides formed in the combustion of gaseous fuels with air and a novel burner for practicing said method. Said burner comprises a combustion chamber having a converged nozzle portion formed at one end thereof and a draft tube having an upwardly expanding vertical cross-section and spaced ahead of said nozzle portion for guiding the combustion gases exhausted from said combustion chamber.
FIG. 1

FIG. 2

FIG. 3
This invention relates to a method for gas used in boilers, various industrial heating furnaces, dryers, ovens, etc., whereby the amount of nitrogen oxides contained in combustion gases are minimized; and a burner apparatus for practicing said method.

As the major factors which have influence on the amounts of nitrogen oxides contained in the combustion gases, there are generally considered flame temperature, excess air ratio and cooling velocity of flame. In this regard, various methods have been employed in conventional fixed-type combustion apparatus for suppressing the generation of nitrogen oxides, which are broadly classified into the following two types: Namely, in one type, the combustion gases are recirculated to lower the flame temperature, and in the other type the amount of air required for the combustion is fed slowly so as to control the combustion rate. However, the former method has disadvantages in that the stability of the flame is low, means must be provided for recycling the combustion gases and thermal efficiency is low. On the other hand, the latter method has the disadvantage that, since the mixing ratio of fuel gas and air tends to be inconsistent, the excess air ratio must be made slightly greater than with the ordinary combustion method, with the result that the formation of nitrogen oxides is further promoted. It has further disadvantages in that means must be provided for supplying the secondary air and in that the combustion flame becomes undesirably long.

The present invention has been achieved based on an entirely novel concept of suppressing the formation of nitrogen oxides in the oxidation of fuels such as hydrocarbons, e.g., natural gas, etc., with air, which as used here, includes air containing more or less than the usual amount of oxygen. According to the invention, the disadvantages of the conventional combustion methods can be completely eliminated and the thermal efficiency can be markedly enhanced.

The present invention will be described in detail hereinafter with reference to the accompanying drawing which illustrate an embodiment of the invention. In the drawings:

FIG. 1 is a vertical cross-sectional view illustrating an embodiment of the burner apparatus according to the present invention;

FIG. 2 is an enlarged-sectional view illustrating another embodiment of the nozzle portion; and

FIG. 3 is a diagram graphically showing the combustion characteristic of the burner apparatus with respect to the amounts of nitrogen oxides generated during combustion.

In FIG. 1, reference numeral 1 designates a combustion chamber having a converging nozzle portion 2. The cross-sectional area of the combustion chamber 1 is 5 - 20 times the cross-sectional area of the nozzle portion 2. Reference numeral 3 designates a secondary air passageway formed around the combustion chamber 1. One end of the secondary air passageway 3 is provided secondary air passage holes 4 and the other end thereof is open or closed in the vicinity of the nozzle portion 2. With reference to FIG. 2, in case the secondary air passage 3 is closed in the vicinity of the nozzle portion 2, the secondary air passage holes 11 are formed in chamber 1. In such a case, the cooling air stream 12 is formed on the side of the nozzle portion 2 which cools the nozzle portion 2 made from a metallic material. The quantity of the secondary air passing through the secondary air passageway 3 is 10 - 40 percent of the theoretical air requirement and determined by the secondary air passage holes 4. Reference numeral 5 designates a draft tube for drawing the combustion gas in the furnace by the jetting combustion gases stream. The draft tube 5 has an upwardly expanding vertical cross-section so as to enhance the drawing effect of the combustion gases in the furnace, and is suitably spaced ahead of the nozzle portion 2. The combustion chamber 1, the secondary air passageway 3 and the draft tube 5 are respectively made from a metallic or refractory material. Reference numeral 6 designates an air flow equalizing plate having a large number of primary air passage holes 7 formed therein and connected integrally with a gas feed pipe 8, and 9 designates a pilot burner concentrically mounted in said gas feed pipe 8.

With the construction described above, air required for combustion is supplied through an air inlet port 10 and part of the air, i.e., a quantity of air 60 - 90 percent of the theoretical air requirement, is introduced into the combustion chamber 1 through the primary air passage holes 7 formed in the air flow equalizing plate 6. The remaining part of the air enters the air passageway 3 through the secondary air passage holes 4 and reaches the end extremity of the nozzle portion 2 after passing through said air passageway 3. A fuel gas is fed into the combustion chamber 1 from the fuel gas feed pipe 8, and intensely mixed with the primary air and burned therein. Since the combustion chamber 1 has the convergent nozzle portion 2 as stated above, the load in the combustion chamber reaches as high as about 5,000 - 10,000 × 10^3 Kcal/m^2 hr. The combustion gases contain some amount of unburned fuel gas because only the primary air is introduced into the combustion chamber 1, and is exhausted from the nozzle portion 2 to the outside of the combustion chamber 1, while undergoing secondary combustion. When the combustion gases are mixed with the secondary air supply and are burned, a negative pressure is created around the nozzle portion 2 in accordance with the energy of jetting combustion gases and the combustion gases within the furnace are drawn under the effect of said negative pressure as indicated by the arrows. The jetting combustion gases and the combustion gases in the furnace are mixed so quickly that the high temperature, high velocity combustion gases, containing some amount of unburned fuel gas, are increasingly exhausted and cooled, and the unburned fuel gas contained therein is completely burned. In this case, since the amount of the jetting combustion gases is as large as 10 - 200 times that of the accompanying gases within the furnace, though variable, depending upon the flow...
resistance in the furnace, an extremely large amount of combustion gas circulates in the furnace.

Characteristic curve A in the chart of FIG. 3 represents the result of combustion obtained by the method and apparatus of the instant invention. It will be apparent from this characteristic curve that according to the invention, that the amounts of nitrogen oxides can be substantially decreased as compared with the conventional burner apparatus, the characteristic of which is represented by a curve E.

Although in the embodiment described above, the secondary air passageway 3 is formed around the combustion chamber 1 and the draft tube 5 is provided ahead of the nozzle portion 2, the amounts of nitrogen oxides formed can be substantially decreased as compared with the conventional burner E, by employing the combustion chamber 1 only of the construction described without providing said secondary air passageway 3 and said draft tube 5. In this case, the theoretical quantity of air for combustion is introduced into the combustion chamber 1 in its entirety but the cross-sectional area ratio between the nozzle portion 2 and the combustion chamber 1 must be made smaller and the flow rate of air into the combustion chamber 1 must be made smaller than in the case of providing the secondary air passageway 3, so that the combustion may not be completed within said combustion chamber. The combustion gases containing some amount of unburned fuel gas are exhausted from the nozzle portion 2 at a high velocity. The combustion gases jetting from the nozzle portion 2 suck and are mixed with the combustion gases within the furnace, whereby the amount thereof is increased and the temperature thereof is lowered, and the unburned fuel gas contained therein is consumed in the secondary combustion. In such case, the amount of the gases sucked from the furnace is somewhat smaller than in the preceding case because the air is not fed stepwise and the draft tube 5 is not provided. However, as will be obvious from a curve D in FIG. 3, the amounts of nitrogen oxides formed are very much smaller than in case of the conventional burner E. Curve B in FIG. 3 represents the combustion characteristics of a burner apparatus in which the draft tube 5 is provided ahead of the combustion chamber 1 but the secondary air passageway 3 is not provided, similar to the preceding case. In this case, the secondary air is not supplied but, since the amount of the gases withdrawn from the combustion chamber 1 is increased by the existence of the draft tube 5, the effect of suppressing the formation of nitrogen oxides is greater than in the case of the burner apparatus comprising only the combustion chamber 1. Curve C in FIG. 3 represents the combustion characteristics of a burner apparatus in which the secondary air passageway 3 is provided around the combustion chamber 1 but the draft tube 5 is not provided. In this case, the amount of the combustion gases withdrawn from the furnace is smaller than in case of the first-mentioned case but, since the secondary air supply is through the secondary air passageway 3 and is used for the secondary combustion, the amounts of nitrogen oxides formed can be substantially decreased.

It will be understood, after all, that the present invention achieves a remarkable effect in suppressing the formation of nitrogen oxides, due to a combination of factors including the fact that the primary combustion is a fuel-rich combustion, that the combustion is effected stepwise by the primary and secondary combustions, that the secondary combustion reaction is carried out while the temperature of the fuel gas is being lowered by combustion of the gases in the furnace, that the residence time of the combustion gases within the furnace is long, and that the length of the flame is short. Further, as will be understood from FIG. 2, while in the conventional burner apparatus the amounts of nitrogen oxides formed corresponding to the load factor (the amounts of nitrogen oxide per unit quantity of heat) are substantially constant, in the burner apparatus of the instant invention an increasing load factor results in an increasing velocity of the combustion gases jetting from the nozzle portion 2 and hence in an increasing amount of the gases being withdrawn from the combustion chamber, so that the rate of formation of nitrogen oxides is lowered.

According to the invention, as described above, it is possible not only to substantially decrease the amounts of nitrogen oxides formed, but also to improve the heat transmission rate by making the temperature distribution within the furnace uniform without providing any special means, and to reduce the size of or eliminate the combustion chamber of a furnace. Thus, by practicing the invention, the general heating apparatus can be simplified.

What is claimed is:

1. A combustion method for suppressing the formation of nitrogen oxides issuing from gas burners, comprising introducing the theoretical quantity of air for combustion into a combustion chamber in its entirety, said combustion chamber being formed with a nozzle portion and said combustion chamber having a cross-sectional area 5–20 times that of said nozzle portion, burning 60–90 percent of a fuel gas in said combustion chamber, exhausting the combustion gases containing unburned fuel gas at a high velocity through said nozzle portion and burning the unburned fuel gas completely outside the burner apparatus by providing means cooperating with said nozzle portion for drawing the combustion gases in the furnace therefrom by said combustion gases jetting from said nozzle portion.

2. A combustion method for suppressing the formation of nitrogen oxides issuing from gas burners, according to claim 1, wherein a secondary air supply in a quantity of 10–40 percent of the theoretical quantity of air for combustion is passed along the outer wall of said combustion chamber and the unburned fuel gas contained in the combustion gases jetting from said nozzle port is completely burned by said secondary air outside the burner apparatus.

3. A burner apparatus so designed as to suppress the formation of nitrogen oxides, comprising a combustion chamber having a converged nozzle portion formed at one end thereof, said combustion chamber having a cross-sectional area 5–20 times that of said nozzle portion and a draft tube having an upwardly expanding vertical cross-section and spaced ahead of said nozzle portion for guiding the combustion gases exhausted from said combustion chamber.

4. A burner apparatus so designed as to suppress the formation of nitrogen oxides, according to claim 3,
wherein a secondary air passageway is formed around said combustion chamber with one end thereof open in the vicinity of said nozzle portion.

5. A burner apparatus so designed as to suppress the formation of nitrogen oxides, according to claim 4, wherein one end of the secondary air passage is closed in the vicinity of the nozzle portion and the secondary air passage holes are formed in the combustion chamber in the vicinity of said nozzle portion.

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