May 14, 1968 D. BIENSTOCK ET AL 3,382,822

METHOD OF BURNING COAL

Filed Feb. 24, 1967 2 Sheets-Sheet 1

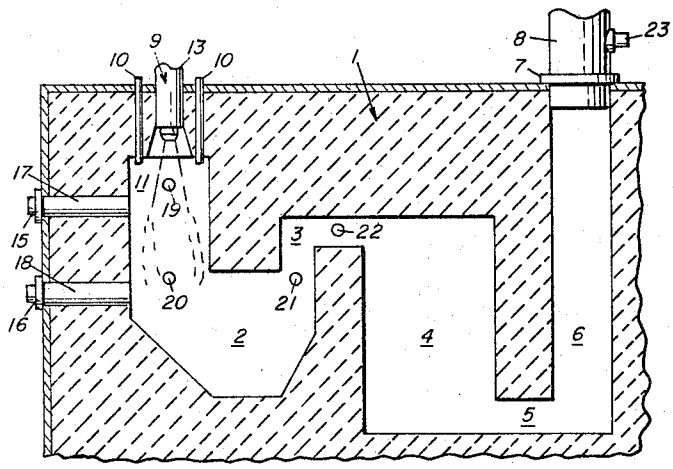


FIG. 1

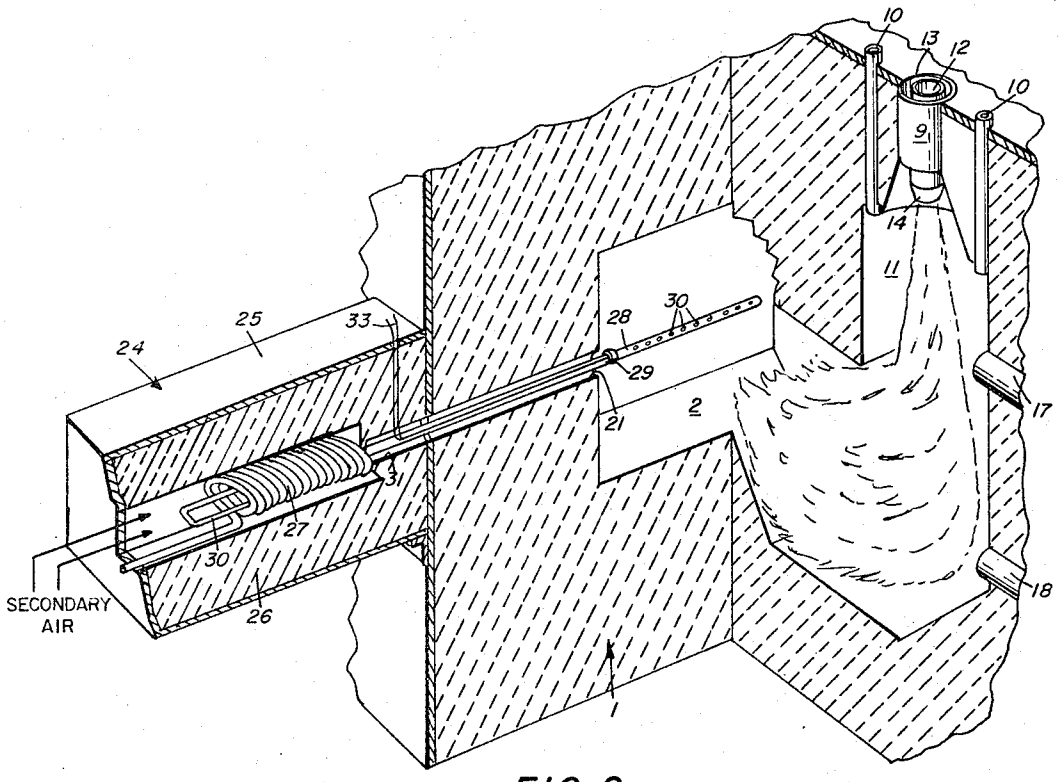


FIG. 2

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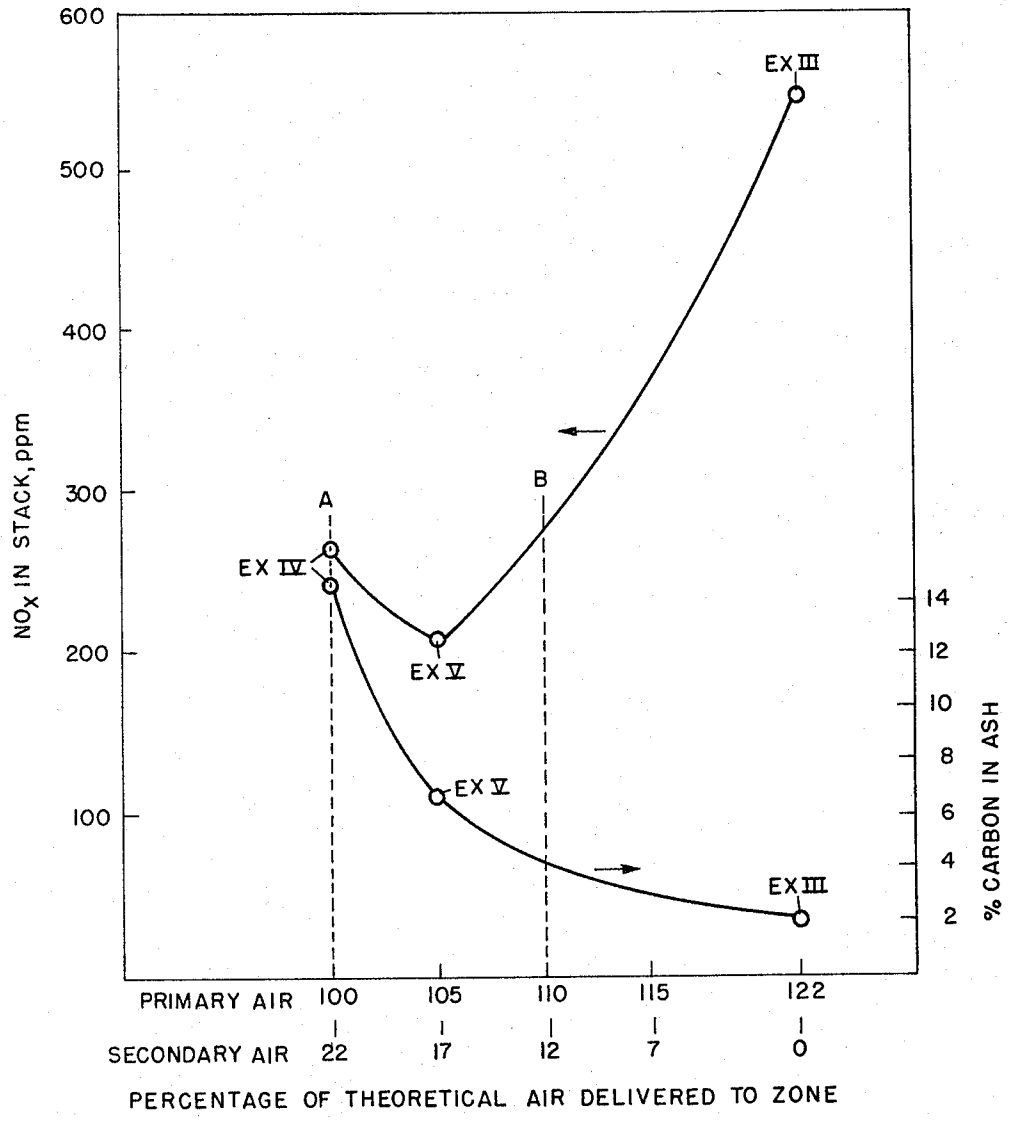


FIG. 3

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United States Patent Office 3,382,822 Patented May 14, 1968

3,382,822

METHOD OF BURNING COAL

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Filed Feb. 24, 1967, Ser. No. 619,522
6 Claims. (Cl. 110—28)

ABSTRACT OF THE DISCLOSURE

A method of burning pulverized coal comprising combusting said coal with from about 100–110% stoichiometric air in a first combustion zone and subsequently with about 10–25% stoichiometric air in a 2nd combustion zone. The total air supplied to the coal is from 120–125% stoichiometric.

BACKGROUND OF INVENTION

Field of invention.—This invention relates to the burning of pulverized coal and more particularly to a method of burning pulverized coal whereby the formation of nitrogen oxides is greatly reduced. Nitrogen oxides have been shown to be atmospheric pollutants [1] and precursors of smog.[2, 3] Consequently, any method designed to reduce the input of nitrogen oxides into the atmosphere is from the standpoint of health very desirable. The present invention is such a method.

Description of prior art.—U.S. Patent 3,048,131 to Hardgrove discloses a two-stage fuel combustion method for reducing the nitrogen oxide content of stack gases. This method comprises burning fuel with 80 to 95% of stoichiometric air in a first combustion zone, allowing the gases to cool and then adding the remainder of stoichiometric air with as much as 7% excess air to a second combustion zone.

Barnhard and Diehl [4] have shown that such a two-stage combustion resulted in a reduction of nitrogen oxide content in the stack gases of 27%.

While the process of Hardgrove finds great applicability to gas and oil combustions, it has not proven successful for coal combustions. In particular, it has been found that the process of Hardgrove as applied to coal does not result in a process of acceptable efficiency having a low nitrogen oxide content. The present invention solves these problems for the combustion of pulverized coal.

SUMMARY

Briefly, the present invention comprises a method of burning pulverized coal wherein the coal is first burned with 100–110% of stoichiometric air in a first combustion zone and subsequently burned with an additional 10–20% air in a second combustion zone such that the total air supplied to the coal is from 120–125% stoichiometric.

It has been found that by using such a two-staged combustion with the amounts of air as indicated, the nitrogen oxide formation content in the stack gases can greatly be reduced.

Accordingly, it is an object of this invention to provide an improved process for burning coal.

[1] Report of the Surgeon General to the U.S. Congress. Motor Vehicles, Air Pollution, and Health, 87th Con., 2nd Sess., House Document No. 489,427 (1962).

[2] Haagen-Smit et al., "Ozone Formation in Photochemical Oxidation of Organic Substances," Ind. Eng. Chem., vol. 45, pp. 2086–2089 (1953).

[3] Stephens et al., "Reactions of Nitrogen Dioxide and Organic Compounds in Air," Ind. Eng. Chem., vol. 48, pp. 1498–1504 (1956).

[4] D. H. Barnhart and E. K. Diehl, "Control of Nitrogen Oxides in Boiler Flue Gases by Two-Stage Combustion," J. Air Poll. Control Assoc., 10 : 397–406 (1960).

Still another object of this invention is to provide an improved coal combustion that results in a minimum of nitrogen oxide formation.

Still other objects and advantages of this invention will become apparent from the following detailed description.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 represents a cross-section of a furnace adapted to burn coal according to the present invention.

FIG. 2 is an isometric view partly cut away showing the primary and secondary combustion zones of the furnace.

FIG. 3 is a graph showing the nitrogen oxide content in the stack gas and percent carbon in the ash as a function of air distribution for the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present method is applicable to a wide variety of industrial coal-fired furnaces and heater units. Most of these units can easily be modified to practice the present invention. The invention, however, will be described with reference to a small pulverized coal furnace, the design and operation of which has previously been described in the literature.[5]

FIG. 1 shows a cross-section of this furnace. In that figure, **1** represents the body portion of the furnace which consists of three layers of refractory brick within a steel shell. Within the body portion of the furnace there is provided a primary combustion chamber **2**, as arched passage **3**, a secondary combustion chamber **4**, passage **5**, and breech **6**. The latter leads out of the furnace and attaches by way of connection **7** to a stack **8**. A downwardly projecting burner **9** and auxiliary air supplies **10** lead into the furnace and communicate with the upper portion **11** of primary combustion chamber **2**. Burner **9** is shown in more detail in FIG. 2. There it is seen that the burner consists of an inner annular ring **12**, a concentric outer annular ring **13**, and a nozzle **14**. Returning now to FIG. 1, inspection ports **15** and **16** are shown communicating with portion **11** of chamber **2** via passages **17** and **18**, respectively. In a similar manner sampling ports are provided at **19**, **20**, **21**, **22** and **23**, so that the temperature and composition of the combustion gases can be determined at any time during a combustion.

FIG. 2 shows the furnace of FIG. 1 modified to provide a secondary combustion. In that figure, a preheater air injection unit **24** is shown attached to the body **1** of the furnace adjacent to and aligned with sampling port **21**. The preheater air injection unit comprises a casing **25**, insulation **26**, heating coil **27**, an air inlet (not shown), an air distribution pipe **28**, and a thermocouple **29**. The air inlet (not shown) leads to the hollow heating coil **27**, which has a silicon carbide heating element **30**, and which is positioned within insulating material **26**. Communicating with the heating element by way of an air-tight passage **31** is distribution pipe **28** which then extends through sampling passage **21** and across chamber **2**. Positioned at spaced intervals along that portion of pipe **28** which extends across chamber **2** are openings **30**. Also running from the preheater unit **24** into chamber **2** along with pipe **28** is thermocouple **29** whose leads **33** extend through casing **25** to a recording device (not shown).

After start-up, which may be accomplished through the use of a conventional preheat burner, a mixture of pulverized coal and air is fed to inner annular ring **12**, and air is fed through both outer annular ring **13** and auxiliary air inlets **10**. It has been found desirable to introduce roughly one-fourth of the air through inner annular ring **12** with the coal, one-fourth through outer annular ring

[5] Kurtzrock et al., "A Laboratory-Scale Furnace Fired With Pulverized Coal," Journal of the Institute of Fuel, vol. XXXVI, No. 265, p. 55 (1963).

13 and the remainder through auxiliary air inlets **10**. It has also been found desirable to direct the streams of air coming through passages **13** and **10** in a spiral configuration relative to the central longitudinal axis of the flame, thus creating a swirling effect.

We have found that the total amount of air entering into the upper portion **11** of the primary combustion chamber **2** through the combination of passages **10**, **12** and **13** should be within the range of 100–110% of the stoichiometric or theoretical amount required to combust the entering coal. Such a combustion will produce a temperature in the range of from about 2300°–2800° F. at sampling port **19**, which is within the flame, about 2000°–2500° F. at port **20**, which is at the edge of the flame front, and about 1800°–2300° F. at port **21**, which is beyond the flame front.

Simultaneous with the burning of the coal as above described in the upper portion **11** of the primary combustion chamber **2**, an additional 10–25% stoichiometric air is added through distribution pipe **28** at the locus of sampling port 3. This air should be heated to a temperature great enough to sustain the combustion, which will depend in part upon the amount of air added at this point and the temperature of the gas. The total amount of air used in both combustion zones should be in the range of 120–125% stoichiometric.

TABLE 1

Ex.	Excess Air, percent	Port No. 1			Port No. 2			Port No. 3			Port No. 4			Stack			Carbon in Ash, percent
		NO_x, p.p.m.	Temp. ° F.	O_2, percent	NO_x, p.p.m.	Temp. ° F.	O_2, percent	NO_x, p.p.m.	Temp. ° F.	O_2, percent	NO_x, p.p.m.	Temp. ° F.	O_2, percent	NO_x, p.p.m.	Temp. ° F.	O_2, percent	
1	0	630	2,480	1.2	320	2,190	0.4	265	2,120	0.4	255	1,850	-------	105	800	0.2	42.3
2	5	600	2,375	0.7	440	2,275	0.4	340	2,070	2.2	300	1,990	1.9	210	975	1.1	13.8
3	22	690	2,335	3.5	780	2,440	2.0	590	2,090	4.3	590	1,950	4.0	550	975	4.0	2.0

Example 4

The same amount and quality coal as in Example 1 was burned in a furnace of the type shown in FIG. 2 with 100% stoichiometric air in a primary combustion zone, however, in this run, an air delivery pipe at the locus of sampling port **21**, as shown in figure, fed an additional 22% air. The results are shown in Table 2.

Example 5

Two pounds per hour of the type coal used in Example 1 was burned in a furnace having two combustion zones with 105% stoichiometric air supplied to the primary combustion zone and an additional 17% air supplied through air delivery pipe **26** at the locus of sampling port **21**. The results are shown in Table 2.

Example 6

Two pounds per hour of the type coal used in the previous examples was burned in a furnace having two combustion zones with 105% stoichiometric air supplied to the primary combustion zone and with 17% stoichiometric air supplied through pipe **26** at the locus of sampling port **20**. The results of this test are shown in Table 2.

TABLE 2

Ex.	Excess Air, percent	Port No. 1			Port No. 2			Port No. 3			Port No. 4			Stack			Carbon in Ash, percent
		NO_x, p.p.m.	Temp. ° F.	O_2, percent	NO_x, p.p.m.	Temp. ° F.	O_2, percent	NO_x, p.p.m.	Temp. ° F.	O_2, percent	NO_x, p.p.m.	Temp. ° F.	O_2, percent	NO_x, p.p.m.	Temp. ° F.	O_2, percent	
4	0	610	2,510	0.9	405	2,270	1.4	(1)	(1)	(1)	285	1,800	3.8	265	870	4.0	14.6
5	5	670	2,510	1.8	420	2,185	1.4	(2)	(2)	(2)	270	1,840	5.0	210	930	3.9	6.6
6	5	610	2,400	1.4	(2)	(2)	(2)	395	2,040	5.3	385	1,870	4.7	320	840	3.9	7.3

[1] 22% air injection. [2] 17% air injection.

When pulverized coal is burned according to the above method, a satisfactorily complete combustion is accomplished and a minimum amount of nitrogen oxides are formed.

The present method for burning coal and the effects of changes in air percentages and distributions are illustrated in the following examples.

Example 1

Two pounds per hour of a high-volatile B bituminous coal ground so that 95% would pass through a 325-mesh screen was burned in the upper portion **11** of a primary chamber **2** of the furnace shown in FIG. 1. The total air supplied was 100%. There was no secondary combustion. The results are shown in Table 1.

Example 2

The same amount and type of coal as in Example 1 was burned with 105% stoichiometric air. All the air was fed to the primary combustion. There was no secondary combustion. The results are shown in Table 1.

Example 3

The same amount and type of coal as in Example 1 was burned with 122% stoichiometric air, all of which was supplied to a single combustion. There was no secondary combustion. The results are shown in Table 1.

From the results of Table 1 it is seen that a single stage combustion operating at 100% stoichiometric air (Example 1) is too inefficient (42.3% carbon in ash) for practical use. When the amount of air is increased to 105%, the efficiency of the combustion increases (13.8% carbon in the ash) to a value which represents an acceptable combustion efficiency and the nitrogen oxide content of the stack gas increases twofold to 210 p.p.m., which is also an acceptable amount. When a single stage combustion is operated at 122% (Example 3), stoichiometric air, the nitrogen oxide content rises sharply to 550 p.p.m. which represents an unacceptable amount of pollutants.

Table 2 shows the results when the furnace is operated in a two-stage combustion. When 100% stoichiometric is supplied to a primary combustion zone and 22% to a secondary zone located beyond the flame front, the results show a nitrogen oxide content in the stack gas of 265 p.p.m. which is considered acceptable and a carbon content in the ash of 14.6% which is acceptable but high.

When 105% stoichiometric is supplied to the primary combustion zone and 17% to a secondary combustion zone beyond the flame front (Example 5), an expected increase occurs in the efficiency of combustion (6.6% car-

bon in ash) but there is an unexpected drop in nitrogen oxide formation. Nitrogen oxide content is reduced to 210 p.p.m. or the same as exhibited in Example 2, while the efficiency of the process is more than that of Example 2.

The results for Example 6 show that if the air for the secondary combustion is not added beyond the flame front from the first combustion, both the nitrogen oxide content of the stack gases and the carbon content in the ash will increase.

As mentioned above, our discovery is that there is a range of air distributions in a two-stage combustion of pulverized coal which will result in minimum nitrogen oxide formation and an acceptable combustion efficiency. This phenomena is most aptly shown by FIG. 3 which shows in graphical form the relationships between air distribution and nitrogen oxide formation and carbon content in the ash. The results of Examples 3, 4 and 5 are plotted to illustrate the relationships.

The range of air distributions which our method contemplates for a system using 122% total air is enclosed by the dotted vertical lines labeled A and B.

As previously noted, total air of 120–125% may be used and thus the amount of air delivered to the primary combustion zone may vary from 100% to 110% and the air delivered to the secondary combustion zone will vary from 10% to 25%.

While we have described our inventive method with reference to a particular size and type and size of coal and a particular form of apparatus, the use of our method is not limited thereto but rather it is useful for all types and sizes of coal and any form of combustion apparatus which is capable of carrying out our method.

Accordingly, many of the various adaptations and modifications which are within the spirit and scope of our invention will become apparent to those of ordinary skill in the art.

What is claimed is:

1. A process for the combustion of pulverized coal comprising burning said coal with 100–110% stoichiometric air in a first combustion zone thereby producing a flame front, and subsequently burning said coal with 10–25% stoichiometric air in a second combustion zone located at a distance beyond said flame front said combution being controlled so that the total amount of air supplied to the coal in said first and second zones is in range of from about 120–125% stoichiometric.

2. The process of claim **1** wherein said coal is burned with about 105% stoichiometric air in the first zone and with about 17% stoichiometric air in the second zone.

3. The process of claim **1** wherein the pulverized coal is brought to said first combustion zone in a stream of air.

4. The method of claim **3** wherein said stream of air comprises less than half the total air supplied to said first combustion zone.

5. The method of claim **4** wherein at least a portion of the remainder of the air supplied to said first combustion zone is supplied in a swirling flow.

6. The method of claim **1** wherein said coal is a bituminous coal.

References Cited

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