Aug. 13, 1968 R. A. PAUL ETAL 3,397,256
COMBUSTION PROCESS AND APPARATUS TO INCREASE
A FLAME TEMPERATURE
Filed July 1, 1966 2 Sheets-Sheet 1

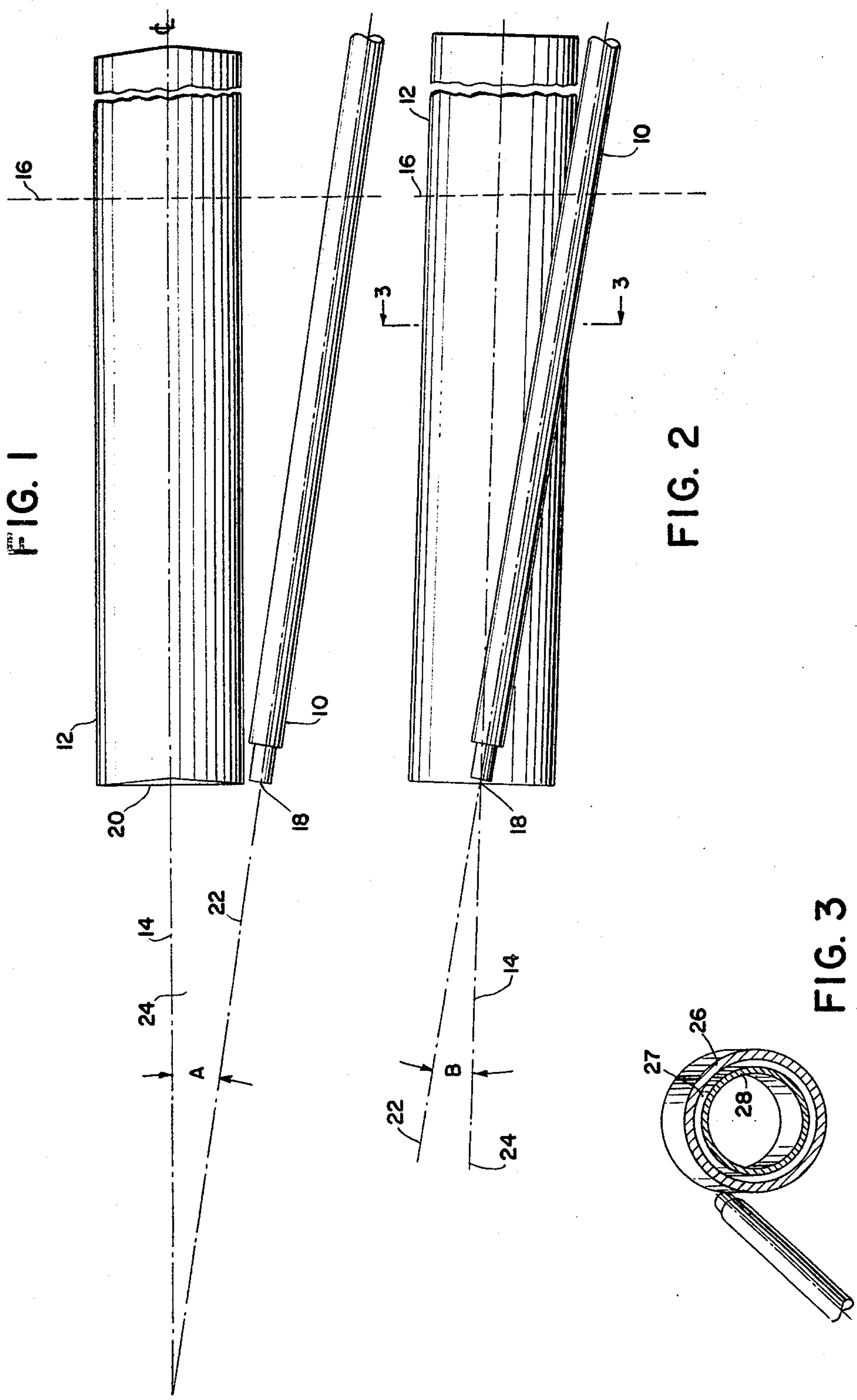

FIG. 1

FIG. 2

FIG. 3

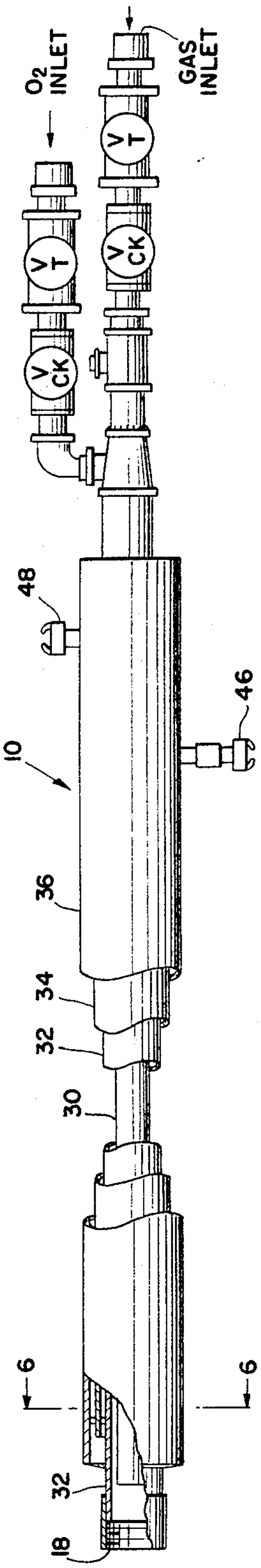

FIG. 5

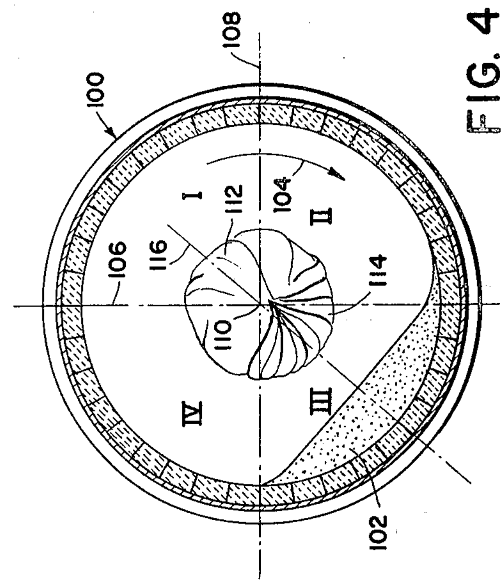

FIG. 4

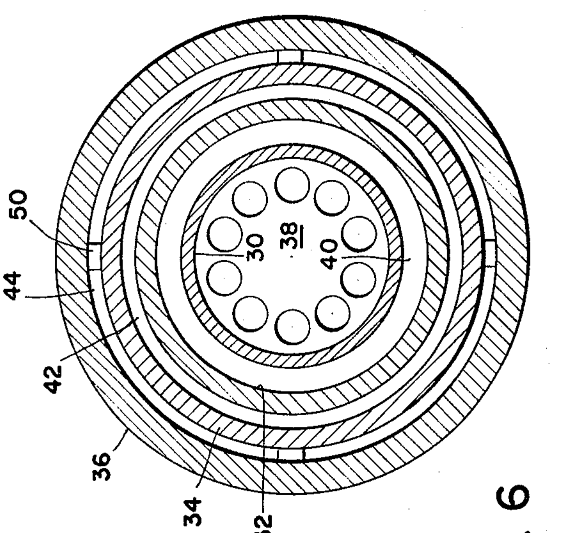

FIG. 6

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COMBUSTION PROCESS AND APPARATUS TO INCREASE A FLAME TEMPERATURE

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19 Claims. (Cl. 263—52)

ABSTRACT OF THE DISCLOSURE

A method for combustion heating in which a fuel-oxygen flame is impinged on a fuel-air flame, which supplies the major portion of the heating, thereby increasing the temperature of the fuel-air flame at the area of impingement relative to the remainder of the fuel-air flame. An apparatus to carry out said method comprising a first burner, adapted to burn said fuel and air and to supply the major heat requirement, and a second burner whose flame is positioned to impinge on the first burner flame at an acute angle to the axis of the first burner flame.

The present invention is directed to an improved combustion apparatus and the processes made possible by its use. More particularly, the present invention is directed to processes and apparatus for heating material in a rotary kiln in such a way as to achieve higher temperatures than were heretofore possible.

It is known in other arts to use oxygen in place of air to obtain a significant production improvement. Attempts in the cement industry to utilize oxygen as a direct substitute for air in supporting the combustion of a primary fuel were largely unsuccessful because of overheating of the kilns. It is also known in the cement art that production improvement may be obtained by injecting oxygen alone into the load quadrant of the flame in the kiln. By injecting pure oxygen into the load quadrant, the refractory is shielded from the hottest part of the flame by the load in that quadrant, and by the mirror effect and insulation shield effect of the main body of the flame in the other three quadrants. The temperature in the burning zone of a cement kiln varies between about 2500 to 3000° F. which is considerably lower than that of kilns used for other purposes, such as dead burning dolomite. The problems encountered at the lower temperatures are different in kind from those encountered at the higher temperatures. Attempts made to apply the teaching of the cement burning art to other arts, particularly the dead burned dolomite art were unsuccessful, and it became necessary to develop particular processes and techniques for the peculiar problems of the other arts.

It is an object of this invention to provide an improved combustion apparatus capable of producing higher rotary kiln temperatures.

It is a further object of the present invention to improve the product rate and product quality of air-fuel fired furnaces or kilns by the use of an auxiliary oxygen-fuel burner to increase the temperature of a portion of an air-fuel flame.

Other features and objects will be apparent to those skilled in the art from reading the following description taken in conjunction with the drawings in which:

FIGURE 1 is a view showing the angular relationship in one plane between the gas-oxygen burner and the coal-air burner in the practice of this invention;

FIGURE 2 is a view taken substantially at right angles to the view of FIGURE 1 showing the angular relationship between a gas-oxygen burner and a coal-air burner in the practice of this invention;

FIGURE 3 is a sectional view taken generally along lines **3—3** of FIGURE 2;

FIGURE 4 is a sectional view through a rotary kiln showing the flame pattern produced by the method and apparatus of the present invention;

FIGURE 5 is a detail view of a gas-oxygen burner useful in the practice of this invention; and

FIGURE 6 is a cross-sectional view taken generally along lines **6—6** of FIGURE 5.

This invention relates to a method of increasing the temperature of an air-fuel stream by impinging a high temperature oxygen-fuel flame, or stream of combustion products therefrom, upon it. The mechanism is not fully understood but it is believed that the effect of an enthalpy increase within the main fuel-air stream is to cause an increase in the reaction rate of the mixture which, together with the sensible heat released by the auxiliary flame, causes a large increase in the air-fuel flame temperature with a corresponding increase in the usable energy level of the flame system. This, in turn, causes increased heat transfer to the furnace contents with the attendant benefits therefrom. Basically this invention describes a method of obtaining a synergistic interaction between air-fuel and oxygen-fuel flames with resultant unexpectedly large increase in temperature. The present invention is accordingly distinguishable from conventional methods of raising air-fuel flame temperatures which involve either means for increasing the oxygen content of combustion mixtures, as in undershot oxygen usage for open-hearth furnaces, or preheating the combustion air.

A principal feature of the present invention is the intensification of a main air-flame by means of an energy addition from an outside source. In the present invention, applied to a rotary kiln, the intensifying energy is supplied to a main flame by means of an auxiliary oxy-fuel burner which is inserted into the kiln through the hood and is entirely separate from the main burner system. Energy for intensifying the main flame is supplied to a localized region of the main flame so that increased heat transfer resulting from local intensification is directed primarily at the load rather than generally around the periphery of the kiln in the burning zone.

One of the chief advantages of the present invention is the use of a thermal oxygen flame to intensify a main flame reaction rate and thus increase the temperature of the main flame. The increase in temperature of the main flame produces a corresponding increase in the local mean temperatures of the flames for heating and increasing the heat transfer to the load. Thus, as a consequence of using a relatively small amount of auxiliary reactants burned in a small auxiliary burner a large increase in temperature and heat transfer may be achieved. This is not only more economical than prior methods but is also more effective in many apparatus than the prior methods or apparatus.

Because the auxiliary energy source is made to act in a catalytic fashion, the point of intersection of the main and auxiliary flames can be varied within wide limits with beneficial effects throughout the main flame. Thermal output and chemistry are controllable over a wide range.

In an especially advantageous embodiment for use with a rotary kiln, an auxiliary oxygen-fuel flame is caused to impinge on a main coal-air flame at an acute angle. The axes of the two flames define a plane which is normal to the chord formed by the upper surface of the load in the kiln.

While the present invention is described with regard to apparatus in which the major portion of the heat requirement is supplied by a coal-air burner, it is to be understood that burners utilizing other types of fuel may also be used, such as fuel oil, or manufactured or natural gas. However the invention has been found to be especially advantageous where a luminous flame is produced by the burning fuel.

In one advantageous embodiment an auxiliary oxygen-fuel burner may be used to secure a 500° F. elevation in temperature over that which results from the combustion of the fuels usually used in firing a rotary kiln, such as coal, fuel oil, and natural or manufactured gas. About seven-eighths of the total heat requirement is obtained from fuel burned with air in a main burner. The additional one-eighth of the heat requirement is obtained from fuel gas which is burned in an auxiliary burner with oxygen to satisfy about ¼ to ¾, or higher, of the stoichiometric oxygen requirement for complete combustion of the auxiliary fuel gas. It has been found advantageous to have hot uncombined oxygen present in the combustion products of the auxiliary flame. This condition occurs when the amount of oxygen mixed with the auxiliary fuel exceeds the stoichiometric requirement for complete combustion.

The flame so produced has a flame temperature that approaches 4000° F. When the oxygen-gas flame is impinged at an angle to, and preferably above, the center of a coal-air flame, the resultant coal flame burns at a maximum temperature of about 3700° F., compared with the usual 3200–3300° F.

It has been discovered that the angular relationship of the gas-oxygen flame and the coal-air flame affects the maximum temperature of the coal-air flame.

The major axis of the auxiliary burner is located in a plane defined by the coal pipe axis and the perpendicular bisecting plane to the load's chord (which is also a plane). The angle of the axis of the auxiliary burner will be within (subtend) an acute angle (A hereafter) with the axis of the coal pipe depending on the coal flame pattern. This insures that the load in the burning zone of the kiln receives the major part of the intensified radiation from the flame and that the unprotected brick work within the kiln is shielded from the radiation-emitting intensified region of the coal flame by the unintensified balance of the coal flame. Especially advantageous results are obtained where angle A is between 5 and 10°, preferably 8°, with a narrow cone flame. Also the best results are obtained where the gas-oxygen burner is skewed at an acute angle (B hereafter) from that of the coal-air burner, in a plane at right angles to the plane through the discharge ends of the burners. This is preferably an upward skew with relation to the kiln load. Especially advantageous results are obtained where the angle B is between about 5 to 10°, preferably 8°, with a narrow cone flame. Similar results may be obtained with broad cone flames, providing allowance is made for the flame cone angle.

It has been found desirable that the discharge ends of the burners be substantially coextensive with relation to a discharge plane of the rotary kiln. However, operable results have been obtained where the gas-oxygen burner was in front of or behind the discharge end of the coal-air burner. Particularly advantageous results of maximum energy transfer from the auxiliary flame to the main flame have been obtained where the gas-oxygen burner was between about 4 inches in front of the coal-air burner, to about parallel with the coal-air burner.

In order to avoid either damage to the coal pipe by contact with the auxiliary flame or excessive penetration of the coal pipe flame, which is wasteful and harmful to the kiln, the auxiliary burner end should be spaced so that its discharge end is separated about two to six inches from the periphery of the coal pipe.

The foregoing embodiment is shown in FIGURES 1, 2 and 3. FIGURES 1 and 2 show the relative position of a coal-air burner **12** and a gas-oxygen burner **10** useful in the practice of this invention. As is shown in the view of FIGURE 1, the coal-air burner **12** is located on the center line **14** of the kiln and extends through the hood **16**, indicated in phantom. The gas-oxygen burner **10** also extends through the hood and at its discharge end **18** is shown coextensive with the discharge end **20** of the coal-air burner.

The center line **22** of the flame path from the gas-oxygen burner **10** forms the angles A and B with the center line **24** of the flame path from the coal-air burner **12**, which in FIGURES 1–3 is coincident with the kiln center line **14**. As may be seen in FIGURE 1, the flame path from the gas-oxygen burner **10** forms the angle A with the flame path from the coal-air burner **12**, the angle A being measured in a plane including the center lines of both burners. As may be seen in FIGURE 2, the flame path from the gas-oxygen burner **10** forms the angle B with the flame path from the coal-air burner **12** in elevation. The center lines **22** and **24** of the flame paths from the two burners need not intersect. Rather the center line **22** of the flame path of the gas-oxygen burner **10** may be skewed with regard to the center line **24** of the flame path **24** of the coal-air burner. The flames from the respective burners are relatively large and the flame from the gas-oxygen burner **10** impinges on the flame from the coal-air burner **12**.

In a typical industrial embodiment, the coal-air burner may consist of two concentric pipes **26** and **28** (FIGURE 3) the outer pipe **26** being about 10 inches nominal diameter, and containing combustion air, and the inner pipe **28** serving as a conduit for powdered coal and high pressure air. A cooling water conduit **27** may be defined between them.

As may be seen in FIGURE 4, the load **102**, due to the rotation of the kiln **100** in the direction of the arrow **104**, lies off-center of the bottom of the kiln and substantially in a quadrant III as defined by vertical plane **106** and substantially horizontal plane **108** which run the length of the kiln. The load **102** forms an angle, typically 35 to 45 degrees, with the horizontal.

As may be seen in FIGURE 4, the flame **112** from the coal burner has a high temperature portion **114** which is adjacent the load. Ideally the high temperature flame portion **114** is centered about a plane **116** which is defined by the center of the load **102** and the axis of rotation **110** of the kiln. The high temperature flame lies substantially in quadrant III.

In a typical industrial embodiment, such as is shown in FIGURES 5 and 6, the gas-oxygen burner **10** is comprised of four concentric conduits **30, 32, 34, 36.** Fuel gas flows in space **38** through the innermost conduit **30** which may be one inch pipe. Substantially pure oxygen, commercial grade, for example 99.95%, flows through the annular space **40** in the conduit **32** surrounding the gas duct **30**. The oxygen duct **32** is somewhat longer than the gas duct **30**, typically 3 inches, permitting the fuel-gas and oxygen to commence mixing before they discharge from the end **18** of the burner **10**. The oxygen conduit **32** may be a 2 inch pipe in a typical industrial embodiment. Conduits **34** and **36**, with conduit **32**, define two annular passageways **42, 44** for cooling water and are so interconnected that cooling water entering from conduit **46** passes through the inner annular passageway **42**, passes into the outer annular passageway **44** and is discharged through conduit **48**. The innermost water channel may be formed of 2½ inch copper pipe and the outer water pipe formed of 3½ inch copper pipe in a typical industrial embodiment and may be spaced apart with spacers **50** to define the water passageways. The burner may be provided with suitable valves and fittings to arrange for the connection and control of the flow of the fuel-gas, oxygen and cooling water, such as are shown in the drawings and as will be apparent to those skilled in the art.

The oxygen-fuel gas burner may be a rocket burner of the type described in Shepherd Patents 3,092,166 and 3,127,156. However, it is to be understood that the burner design is not limited to such rocket burners but is capable of variations within the skill of those skilled in the burner art.

In order more clearly to disclose the nature of the present invention, specific examples of the practice of the invention are hereinafter given. It should be understood, however, that this is done solely by way of example and is intended neither to delineate the scope of the invention nor limit the ambit of the appended claims.

Example 1

The present invention may be practiced in burning dolomite in a single step in a rotary kiln utilizing improved combustion apparatus and techniques in order to achieve temperature levels up to at least 3300° F. The present invention permits the burning of dead burned dolomite in a rotary kiln but at an increased temperature and in a manner to produce a denser product which is more resistant to hydration than the products of any of the earlier known methods. The maximum temperature which the dolomite reaches during the burning process is controlled in practicing this invention to between about 3300° F., and the melting point of the dolomite, preferably to about 3660° F. Attempts to make the product with the dolomite reaching a maximum temperature of 3200° F. were not successful.

The temperature of the dolomite grain apparently depends upon the exact purity of the raw material, and therefore will vary as the stone from the quarry varies in impurities. The temperature required for the process may be described as that temperature at which sufficient energy is imparted to the particles to permit shrinkage of the particles to a high density particle. Because the required energy varies with the amount of flux (impurities) in the grain, the definition of temperature varies with the amount of impurities.

The dolomite product obtained by the present process can be as pure as the raw material used; therefore the process is capable of producing a highly pure, dead burned dolomite grain. The purity of the grain product is such that the total flux impurity is less than 2.0% by weight.

The hydration resistance of this material which need not be crushed after burning, is high. The hydration resistance is, in fact, higher than that of fettling grain and equal to or higher than that of pure grain produced by any other process. A measure of hydration resistance is the standard ASTM Method No. 0492-62T for hydration susceptibility (the converse of hydration resistances). The present process consistently produces dead burned dolomite grain with an average hydration susceptibility less than 5.0% and has produced grain with hydration susceptibility as low as 0.4%. This is an exceptionally good result at high purity levels and compares with the usual result of 12% or more, using other processes.

The product further has a uniformly high density. Material produced according to this invention will have a bulk density greater than 3.20 and a specific gravity about 3.40 or greater. The density is greater and more consistent than that produced from shaft kiln clinker and equal to or greater than that produced by the cumbersome and expensive two-step burning process.

The closed pore volume of the product is between about 1 and 2% as determined by the use of a Beckman Air Pycnometer. This compares favorably with the closed pore volume products made by other processes, for instance the two-step process.

The outer surfaces of the particles are fire polished and uniform in their properties. This distinguishes them from dolomite products which have a non-uniform, non-fire polished surface, usually resulting because the products are crushed after burning.

The product is best made in a rotary kiln which by mere rotation tends to forge or peen the grains and may be one of the reasons why a superior product is obtainable that is not obtainable in a stationary furnace, such as a shaft kiln where the tumbling action does not occur.

The present invention was practiced in a standard rotary kiln having an internal diameter of 10 feet and being about 300 feet long. The major portion of the heat requirement was supplied by a coal-air burner, and a propane-oxygen burner was used to supply the balance of the heat requirement. A product meeting the requirements of a high purity commercial dolomite refractory brick grain was made. The product was satisfactory in all respects. The objectives of the test were to operate at approximately 3450° F. and to limit the total heat input to the kiln so as to sustain a speed of 48–50 r.p.h. (revolutions per hour of the kiln).

As shown by the results in Table I, the total heat input was adjusted to maintain the product at a temperature between 3300–3400° F. The temperature maintained the product discharge temperature below 2800° F. and served to protect the brick in the kiln nose section.

It was found that kiln speeds in excess of 30 r.p.h. could be used while still maintaining the hydration susceptibility quality of the product when a gas-oxygen burner was used.

It was also found that when using the gas-oxygen burner the kiln operators were able to improve the burning qualities of the dolomite within a couple of hours. Previously, burning quality problems required from five to six hours to solve.

The brick grain feed was turned into the kiln and at 10:00 a.m. on the first day the gas-oxygen burner was started. Readings were taken at about hourly intervals and are reported in part in Table I. Initially the fuel gas and oxygen volumes were set at 8,000 and 12,000 c.f.h. (cubic feet per hour), respectively, as shown in Table I. An acceptable product was being made by 3:00 p.m. on the first day.

The burner angle A in Table I is the angle between the center line of the coal-air burner and the center line of the propane-oxygen burner. The angle was varied from time to time as shown in Table I. The discharge ends of the two burners were substantially coextensive.

The load temperature shown in Table I was measured at the end of the stabilization zone and was the highest temperature reached by the load.

In order to produce a hotter flame the fuel gas and oxygen were increased to 10,000 and 15,000 c.f.h., respectively. At 2:15 p.m. instead of obtaining a hotter flame a cooler flame resulted because of malfunctioning of an oxygen-gas analyzer. Because of the malfunction the kiln was slowed to 25 r.p.h. at 3:40 p.m. Effects of the cooler kiln are shown in the hydration susceptibility results for the 4, 5, and 6 p.m. samples. The oxygen-gas analyzer was put back in service at 7:00 p.m. and with the guidance of this instrument the heat input to the kiln was increased as was the speed of rotation from 32 to 40 r.p.h.

The oxygen rate was increased to 18,000 c.f.h. at 10:25 a.m. on the third day, and the kiln speed was increased from 30 to 47 r.p.h. by 3:00 p.m. It was found that the low hydration susceptibility of the brick grain was maintained during the rapid changes.

Examples 2–7

The procedure of Example 1 was repeated in a number of different runs. The results are recorded below in Table II.

The terms and expressions which have been employed are used as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention.

TABLE I

Time	Kiln Speed, r.p.h.	Flame Temp., ° F.	Load Temperature, ° F.	Feed, lbs./hr.	Discharge, lbs./hr.	Coal Flow, lbs./hr.	Gas Flow, c.f.h.	O_2 Flow, c.f.h.	Burner Angle A	Hydration Susceptibility, Percent
First Day:										
10:40 a.m.	40	3,540	3,340	40,200	17,800	6,975	8,000	12,000	7°	
11:00 a.m.	55	3,530	3,360				8,000	12,000		
11:30 a.m.	58	3,560	3,410				8,000	12,000	5°30′	
11:50 a.m.	58	3,480	3,410				8,000	12,000		
12:25 p.m.	50	3,460	3,360				8,000	12,000		
1:00 p.m.	42	3,460	3,340				8,000	12,000	7°	
2:00 p.m.	42	3,440	3,360				8,000	12,000		
2:45 p.m.	42	3,480	3,340				10,000	15,000		
3:30 p.m.	40	3,440	3,130				10,000	15,000	7°45′	2.55
4:05 p.m.	25	3,500	3,180				10,000	15,000		8.68
4:35 p.m.	25	3,530	3,240				10,000	15,000		
5:05 p.m.	30	3,560	3,220				10,000	15,000		20.95
5:50 p.m.	30	3,560	3,210				10,000	15,000		14.33
6:45 p.m.	32	3,560	3,270				10,000	15,000		6.09
7:35 p.m.	34	3,560	3,310				10,000	15,000		
8:00 p.m.	36	3,560	3,300				10,000	15,000		3.86
8:50 p.m.	36	3,560	3,310				10,000	15,000		
9:30 p.m.	38	3,590	3,360				10,000	15,000		
10:00 p.m.	38	3,600	3,350				10,000	15,000		1.35
11:00 p.m.	40	3,600	3,360				10,000	15,000		
11:30 p.m.	40	3,600	3,370				10,000	15,000		
12:00 p.m.	38	3,570	3,230				10,000	15,000		0.75
Second Day:										
1:00 a.m.	38	3,650	3,260	44,400	18,900	6,520	10,000	15,000	7°45′	
2:00 a.m.	38	3,670	3,350				10,000	15,000		0.75
2:50 a.m.	38	3,640	3,350				10,000	15,000		
4:00 a.m.	40	3,620	3,300				10,000	15,000		0.72
5:00 a.m.	40	3,650	3,320				10,000	15,000		
6:00 a.m.	40	3,620	3,370				10,000	15,000		1.05
6:55 a.m.	40	3,630	3,380				10,000	15,000		
7:40 a.m.	40	3,660	3,400				10,000	15,000		
8:05 a.m.	40	3,600	3,380				10,000	15,000		1.34
9:15 a.m.	40	3,600	3,380				10,000	15,000	8°30′	
10:00 a.m.	42		3,450				10,000	15,000		
11:00 a.m.	42	3,670	3,440				10,000	15,000		3.94
12:00 a.m.	40	3,630	3,450				10,000	15,000		
1:00 p.m.	40	3,610	3,430				10,000	15,000		4.82
2:00 p.m.	40	3,650	3,400				10,000	15,000		1.09
4:45 p.m.	40	3,680	3,240				10,000	15,000		0.72
6:45 p.m.	38	3,620	3,330				10,000	15,000		0.46
7:50 p.m.	36	3,620	3,340				10,000	15,000		
9:00 p.m.	36	3,690	3,370				10,000	15,000		0.99
10:00 p.m.	38	3,660	3,300				10,000	15,000		
11:15 p.m.	40	3,630	3,350				10,000	15,000		1.10
Third Day:										
12:30 a.m.	40	3,620	3,320	48,000	30,800	9,850	10,000	15,000	8°30′	
1:15 a.m.	40	3,580	3,330				10,000	15,000		1.90
2:00 a.m.	38	3,570	3,320				10,000	15,000		
3:00 a.m.	40	3,560	3,380				10,000	15,000		3.34
4:00 a.m.	40	3,590	3,380				10,000	15,000		
5:00 a.m.	40	3,550	3,390				10,000	15,000		3.07
6:00 a.m.	40	3,540	3,380				10,000	15,000		
7:00 a.m.	38	3,540	3,380				10,000	15,000		
8:00 a.m.	42	3,630	3,410				10,000	15,000		3.50
8:25 a.m.	42	3,460	3,350				10,000	15,000		
9:05 a.m.	42	3,580	3,360				10,000	15,000		
10:10 a.m.	30	2,940	3,170							5.75
11:00 a.m.	35	3,560	3,250				10,000	18,000		
11:30 a.m.	38	3,560	3,310				10,000	18,000		
12:00 a.m.	40	3,600	3,360				10,000	18,000		1.69
1:00 p.m.	41	3,580	3,340				10,000	18,000		
1:50 p.m.	43	3,600	3,370				10,000	18,000		1.90
2:25 p.m.	45	3,590	3,330				10,000	18,000		
3:25 p.m.	47	3,500	3,430				10,000	18,000		
4:00 p.m.	47	3,500	3,410				10,000	18,000		1.70
5:00 p.m.	42	3,520	3,350				10,000	18,000		
6:00 p.m.	40	3,590	3,400				10,000	18,000		0.44
7:00 p.m.	40	3,540	3,430				10,000	18,000		
8:00 p.m.	40	3,580	3,340				10,000	18,000		0.48
9:00 p.m.	43	3,510	3,340				10,000	18,000		

TABLE II.—BRICK GRAIN INFORMATION

Exhibit	Hydration Susceptibility, percent	Apparent Density	Specific Gravity	Closed Pore Volume, percent	Amsler Bulk Density
2	3.35	3.336	3.397	1.80	3.264
3	1.90	3.349	3.442	2.71	3.300
4	2.01	3.351	3.423	2.12	3.216
5	1.28	3.316	3.381	1.94	3.270
6	3.23	3.324	3.406	2.42	3.168
7	5.07	3.315	3.397	2.39	3.199

What is claimed is:

1. A method of increasing the flame temperature of a localized area of a combustion system comprising mixing a first fuel with air and igniting the mixture; mixing a second fuel with oxygen and igniting the mixture; impinging the fuel-oxygen flame on a localized area of the fuel-air flame so that the fuel-air flame temperature is increased to a substantially higher temperature in the area of impingement than in the remaining portion of the fuel-air flame.

2. A method for raising the temperature of the components of a combustion system comprising burning a first fuel to provide a major portion of the heat requirement, burning a second fuel to provide the remainder of the heat requirement, impinging the second flame on the first flame after said second flame becomes well established, said impingement occurring in a first portion of the first flame so that said first portion of said first flame is heated to a higher temperature than the remaining portion and the rate of energy release in said first portion of said first flame is substantially increased.

3. A method for heating a rotary kiln comprising burning an air-fuel mixture to provide a major portion of the heat requirement, burning an oxygen-fuel mixture to provide the remainder of the heat requirement, impinging the fuel-oxygen flame on the fuel-air flame after said fuel-oxygen flame becomes well established, said impingement occurring in the quadrant of the fuel-air flame adjacent the load so that said quadrant is heated to a higher temperature than the remaining quadrants.

4. A method of heating a rotary kiln according to claim 3 where said fuel burned in oxygen is different from said fuel burned in air.

5. A method of heating a rotary kiln according to claim

4, wherein coal is burned in air and fuel gas in said oxygen.

6. A method of heating a rotary kiln according to claim **3** where the load is heated above 3300° F.

7. A method of heating a rotary kiln according to claim **3** where the temperature difference between the hotter portion and the colder portion of the combined flame is at least 400° F.

8. A method as in claim **3** where said fuel-air mixture provides at least four times the heat release provided by said fuel-oxygen mixture.

9. A method of increasing the flame temperature of fuels comprising, mixing a first fuel with air and igniting the mixture; adjusting the ratio of fuel and air to produce a luminous flame; mixing a second fuel with oxygen and igniting the mixture; impinging the fuel-oxygen flame after it becomes well established on the fuel-air flame to increase the flame temperature in a localized region.

10. A method according to claim **9** wherein the first fuel is coal.

11. A method according to claim **9** wherein the first fuel is fuel oil.

12. A method according to claim **9** wherein the second fuel is fuel gas.

13. A method according to claim **9** wherein the oxygen is present in excess of the stoichiometric requirements for the complete combustion of said second fuel, such that hot uncombined oxygen exists in the combustion products of said second flame.

14. An improved combustion apparatus comprising a first burner adapted to burn a fuel and air mixture and to provide the major portion of a total heat requirement, and a second burner adapted to burn a fuel and oxygen mixture and to provide a minor portion of the total heat requirement, disposing said second burner so that the axis of the flame therefrom is at an acute angle to the axis of the flame from said first burner and said second flame impinges on a portion of said first flame, whereby the temperature of the impinged-on portion of the flame from said first burner is increased.

15. An improved combustion apparatus comprising a first burner adapted to burn a fuel and air mixture and a second burner adapted to burn a fuel and oxygen mixture, said second burner being placed at an angle to said first burner such that the flame from said second burner impinges on the flame from said first burner, whereby the temperature of the flame from the first burner is increased in a localized region.

16. A combustion apparatus as described in claim **15** wherein said first burner provides up to about 80% of the total heat requirement of the combustion system, and said second burner provides the remainder.

17. A combustion apparatus as described in claim **15** wherein the discharge ends of said burners are disposed in a plane so that the flame path from the second burner is disposed at an angle of about 5° to 10° from the flame path of said first burner in the plane in which said burners are disposed.

18. Apparatus as described in claim **17** wherein said flame path from said second burner is at an angle of about 5 to 10 degrees with regard to a plane substantially at right angles to the plane in which said first and second burners are disposed.

19. Apparatus as described in claim **15** wherein one of said burners is disposed forward of the other of said burners in the direction of the movement of fuel mixtures.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,397,256 August 13, 1968

Robert A. Paul et al.

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading to the printed specification, line 6, after "Pa." insert -- , a corporation of Pennsylvania --; line 7, cancel "both corporations of New York" and insert -- a corporation of New York --. Column 5, line 52, "resistances" should read -- resistance --. Column 10, line 36, "110-22XR" should read -- 110-22AXR --.

Signed and sealed this 20th day of January 1970.

(SEAL)

Attest:

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