A direct coal fired burner system (22) for a rotary kiln (20) in which the burner (36) has a multi-barrel construction through which primary air for conveying coal is heated with tertiary air sourced from the rotary kiln (20), and the shape of the emerging flame is controlled by a first annulus of swirling tertiary air adjacent the primary airstream and by a second annulus of laminar tertiary air defining an outer envelope for the flame. The volume and relative velocities of air in the tertiary air supplies are all controllable through the use of respective dampers provided in tertiary air supply conduits.
— with amended claims

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
ROTOR KILN BURNER

Technical Field

This invention relates to a solid fuel burner for a rotary kiln and particularly relates to a direct coal firing system using a burner with a multi-barrel construction.

Background Art

In a direct coal firing system, hot air is drawn from a rotary kiln hood and is used to dry coal before it is sent to a mill for pulverization. The pulverized coal is entrained in a primary airflow for conveying the coal to a burner, the airflow also supplying 35 to 45% of stoichiometric air requirements for combustion of the coal. The balance of the stoichiometric air requirements is supplied by a super heated secondary air flow contained by a kiln hood at the discharge end of the rotary kiln.

In indirect firing systems, pulverized coal is separated from the air required in the pulverizing mill using a cyclone or the like and the coal is stored so that it can be withdrawn as and when required. Coal and primary air firing rates are independent of the coal pulverizing mill and the volume of relatively cool primary air used to convey the coal to the burner is kept to a minimum so as not to exceed 20% of stoichiometric air requirements and thereby improve burner efficiency. Because of improved efficiency, indirect firing systems are generally preferred over direct firing systems and new rotary kiln installations usually include the infrastructure required to support an indirect coal firing system.

While many improvements have been made to burners for indirectly fired rotary kiln installations to still further increase efficiencies, very little effort has been devoted to improving the efficiency of direct fired rotary kiln installations, many of which continue to operate throughout the world at margins which cannot justify
the cost of modifying the installations to accommodate the additional
equipment required to support an indirect fired burner system.

Some improvements to indirect fired burner systems include
pre-heating primary air with recirculated flue gas as in US 4,387,654. In
US 4,206,712, a multi-barrel burner construction with a tertiary warm air
supply for preheating a coarse coal fraction is disclosed. A small
quantity of high-pressure, high velocity control air is directed at the fuel
stream through a swirling air annulus to create and maintain a turbulent
region around the tip of the burner nozzle. The quantity of air is varied
from between 5 to 15% of stoichiometric air requirements.

In US 4,838,185, a cool air jacket defined by a third barrel in
the burner is provided to isolate a swirling jet of burning gases from the
wall of the combustion chamber so that combustion can take place
without damage to its walls and in US 5,299,512, it is submitted that it is
preferable to introduce primary air, in an axial direction to avoid rotation
of the primary air stream altogether.

There are thus widely divergent views on whether spiral air
deliveries are desirable in indirect coal fired burners and since the
volumes of primary air fed into an indirect fired burner are significantly
lower than those required in direct fired burners, the fluid flows and
dynamics also differ considerably. Any teachings found in these prior
art devices are clearly inappropriate for use in direct coal fired burners.

An object of this invention is to provide a system which can
easily be integrated

into existing direct coal fired burner installations to improve their
efficiency without any significant capital investments.

**Disclosure of the Invention**

In accordance with the invention, there is provided a direct
coal fired burner system for a rotary kiln in which the burner has a
multi-barrel construction through which primary air for conveying coal
is heated with tertiary air sourced from the rotary kiln, and the shape of the emerging flame is controlled by a first annulus of swirling tertiary air adjacent the primary airstream and by a second annulus of laminar tertiary air defining an outer envelope for the flame. The volume and relative velocities of air in the tertiary air supplies are all controllable through the use of respective dampers provided in tertiary air supply conduits.

**Description of the Drawings**

In order that the invention may be more clearly understood, a preferred embodiment is described with reference to the accompanying drawing(s), in which:

Fig. 1 is a schematic illustration of a rotary kiln burner system in accordance with the invention.

Fig. 2 is a schematic illustration, drawn to a smaller scale, of the burner system of Fig. 1 integrated into a rotary kiln installation;

Fig. 3 is a longitudinal sectional view of a second conduit forming part of a burner for a rotary kiln; and

Fig. 4 is a cross-section of the conduit of Fig. 3 taken on line 4-4.

**Best Mode For Carrying Out The Invention**

A burner system for heating a rotary kiln designated by numeral 20 is generally designated by reference numeral 22 in Fig. 1 of the accompanying drawings. Only the discharge end of the rotary kiln 20 is shown in Fig. 1. As is common, the rotary kiln 20 terminates in a kiln hood 24 or plenum which is disposed over the discharge end of the rotary kiln 20 and which receives hot air which is blown by means of fan 23 through hot clinker emerging from the rotary kiln 20 into a clinker cooler 25 (Fig. 2). A hot air pipe 28 is coupled to the kiln hood 24 and supplies hot dusty air having a temperature of up to 1600°F to a dust
cyclone 30 for removing particulates from the air and from which dust is
returned to the kiln hood 24. Clean hot air emerging from the cyclone
30 as indicated by arrows 32, 34 passes through the hot high pressure air
fan 26 before being supplied to a burner generally indicated by reference
36.

The rotary kiln 20 is disposed at the feed end in a smoke
chamber 37 operatively connected to an induced draft fan 39. Because
the rotary kiln 20 forms part of a direct coal fired system, some hot air
from the kiln hood 24 is directed through conduit 41 into a coal mill 43
and into the burner 36. A damper 45 upstream from the coal mill 43, is
provided in the conduit 41 to cool the air in the conduit, as necessary.
Coal fines leave the coal mill 43 through a coal mill fan 45 where they
are discharged into a fuel supply conduit 40.

The burner 36 comprises a number of concentric pipes
disposed so as to extend axially into the discharge end of the rotary kiln
20.

The burner 36 comprises a first primary conduit 38 made of
310 stainless steel and having a 12-14 inch nominal diameter. Typically,
the conduit 38 has a length of 18 feet and defines the primary conduit for
receiving primary air and fuel for combustion. The fuel supplied to the
first conduit 38 comprises minus 200 mesh coal fines or petroleum coke
or combinations of these and may include auxiliary fuels such as fuel
oils or natural gas. The coal fines are supplied directly to the burner 36
from the coal mill 43, without any intermediate storage, through the fuel
supply conduit 40 which typically will supply 35 to 45% of the
stoichiometric air required for combustion. Such high volumes of
primary air are typical of direct fired coal burners as starving the air
supply would otherwise create back pressures in the coal mill and
disrupt the coal supply. Because the coal in the coal mill may have
varying levels of humidity, the temperature of the primary air will often
fluctuate but is typically about 200°F.
In accordance with one aspect of the invention, hot tertiary air is supplied from hot air pipe 28 into a first hot air pipe branch 42 in fluid communication with the hot air pipe 28 and the first conduit 38. A manually set butterfly valve or damper 44 is provided in the first hot air pipe branch 42 to control the volume of air supplied.

A second conduit 46 axially receives the first conduit 38 and extends between an intermediate portion of the conduit 38 and a nozzle 48 for the burner 36 which is disposed inside the plenum 24. The second conduit 46 is, like the first conduit 38, in fluid communication with the hot tertiary air pipe 28 by means of a second hot air pipe branch 50. A butterfly valve 52 is provided in the second hot air pipe branch 50 to control the volume of hot air supplied to the second conduit 46. Adjacent to the nozzle 48, the second conduit 46 has a series of eight external scroll vanes 54 with a wrap of 180° (Figs. 3 & 4) and which have a pitch relative to the middle of the conduit 46 of about 45°. The vanes 54 extend inwardly over a length of about 18 inches away from the nozzle 48. The second conduit is also fabricated from 310 stainless steel and has a nominal internal diameter of 13-15 inches while the scroll vanes 54 are constructed from flat bar having a cross-section of a ½ inch to ¾ inch.

A third conduit 56 axially receives the second conduit 46 and extends between an intermediate portion of the second conduit 46 and the nozzle 48. The third conduit 56 has a respective third hot air pipe branch 58 and butterfly valve 60 through which hot tertiary air is supplied from the hot air pipe 28. The third conduit 56 is also made of 310 stainless steel and has a nominal internal diameter of 14-16.0 inches.

The hot high pressure fan 26 has been specially designed to operate at a high temperature of up to 1400°F and high pressure of 40 inch water gauge. It is currently available from Garden City. Because of the maximum operating temperature of the fan 26 is 1000°F, the temperature of the hot air upstream from the fan must be regulated.
Accordingly, a thermocouple 62 is disposed upstream from the fan 26 and the thermocouple 62 is electrically connected to a controller 64 through which ambient air may be admitted into a fresh air duct 66 having a butterfly valve 68 and disposed in the hot air pipe 28 upstream of the fan 26.

Industrial Applicability

In use, the tertiary air fan 26 draws hot air from the kiln hood 24. The hot air is cleaned through the cyclone 30 to remove any heavy dust particles. The hot air is delivered to the kiln burner 36 for the purpose of shaping the flame and also to boost the temperature and velocity of the primary air supplied to the first conduit 38.

The second or middle conduit 46 has relatively long scroll swirl vanes 54 which modify the pulverized fuel flame shape and intensity by increasing or decreasing the amount of swirl air to produce short through long flames, respectively.

The outer or third conduit 56 carries hot high velocity laminar air and by increasing the air flow in the third conduit and also reducing the air flow in the second conduit 46, a longer cooler flame may be produced. All adjustments to air flow in the first, second and third conduits are done using the manual butterfly valves 44, 52, 60. Before starting the hot high pressure fan, a blanking plate may be installed into the first hot air pipe branch 42 for safety considerations and all of the aforementioned hot air butterfly valves 44, 52, 60 are closed.

With a double flap gate air seal 70 at the bottom of the dust cyclone 30 properly balanced, the hot high pressure fan 26 is put into operation once normal operating temperatures are achieved by combustion of fuel and primary air in the first conduit 38. Flame shaping procedures may then be started by adjusting the butterfly valves 52, 60. A greater flow of air delivered to the second conduit 46 will create a flame which is short and bushy while a greater flow of air
through the third conduit 56 will produce a flame which is long and pencil shaped.

Removal of a blanking plate and adjusting the butterfly valve 44 allows hot tertiary air into the first conduit 38 and this is adjusted subject to the correct balance of combustion conditions suited to the product being produced. It will be understood that the tertiary air fan 26 must be maintained in operation in order to eliminate the possibility of any fuel dust leaking into the hot air pipe 28.

In order to shut down the burner, the butterfly valves 44, 52, 60 are closed and a blanking plate may be installed. The hot high pressure fan 26 is closed after normal shut down procedures for the burner 36.

It will be understood that in prior art devices using solid fuels which have a swirling device in the burner, there has been a tendency to deflect the solid fuel radially in order to mix with it the incoming parallel flow of secondary air indicated in the drawing by arrow 72. In such systems, the coarser fractions of solid fuel gain sufficient momentum to tend to exit the flame 74 which leads to delayed combustion and particle impingement on the refractories of the kiln 20.

By contrast, the burner 36 in accordance with the invention uses a long scroll swirling device which causes hot tertiary air to swirl around the main centre jet of pulverized fuels, quickly entraining and driving inwards the hot secondary air into the outer regions of the flame which are air starved and combustible gas rich. The central axis of the main fuel jet is largely undisturbed and retains its position to the kiln feed bed to maximize radiant heat transfer from flame to bed. In part, aspiration of superheated secondary air (800°F to 1000°F) is achieved by maintaining a high pressure high velocity air flow in the second conduit 46 and the third conduit 56 such that the velocity is approximately 90 metres per second with an air pressure of 39 inches water gauge while the air velocity in the first conduit 38 is approximately 35 to 45 metres
per second. By adjusting the air flow in the second and third conduits 46, 56, the back pressure or the flow rate of the primary air and pulverized fuel exiting the coal mill in a direct firing process is not affected. Otherwise, any increase in back pressure on the primary air and pulverized fuel supply in the direct firing process would slow down or cripple the pulverized the solid fuel system resulting in decreased firing rates or even a kiln shut down.

It is expected that the burner in accordance with the invention may be used to burn existing fuels at higher temperatures and to stabilize the combustion of high ratios of petroleum coke in petroleum fuel mixtures and also to burn lower quality solid fuels more effectively so as to deliver from 100 to 500 million BTU/hr.

It will be understood that several variations may be made to the above described embodiment of the invention within the scope of the appended claims. In particular, it will be appreciated that the temperature of hot tertiary air is limited only by the currently available technology for providing a hot high pressure fan and that this temperature could increase if such hot air could be accommodated. The burner construction described above is subject to modification and not limited by the materials of construction indicated.

It will be appreciated that the system described will be adapted to improve burning efficiency in existing direct coal burners without any significant disruptions.
## Index of References Signs

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>Rotary Kiln</td>
<td>66</td>
<td>fresh air duct</td>
</tr>
<tr>
<td>22</td>
<td>burner system</td>
<td>68</td>
<td>butterfly valve</td>
</tr>
<tr>
<td>23</td>
<td>fan</td>
<td>70</td>
<td>air seal</td>
</tr>
<tr>
<td>5</td>
<td>kiln hood</td>
<td>72</td>
<td>arrow</td>
</tr>
<tr>
<td>25</td>
<td>clinker cooler</td>
<td>74</td>
<td>flame</td>
</tr>
<tr>
<td>26</td>
<td>fan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>hot air pipe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>cyclone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>arrow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>arrow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>burner</td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>smoke chamber</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>first conduct</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>draft fan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>fuel supply conduit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>conduit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>first hot air pipe branch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>coil mill</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>butterfly valve</td>
<td>44</td>
<td>butterfly valve</td>
</tr>
<tr>
<td>45</td>
<td>coal mill fan</td>
<td>45</td>
<td>coal mill fan</td>
</tr>
<tr>
<td>46</td>
<td>second conduit</td>
<td>46</td>
<td>second conduit</td>
</tr>
<tr>
<td>48</td>
<td>nozzle</td>
<td>48</td>
<td>nozzle</td>
</tr>
<tr>
<td>50</td>
<td>second hot air pipe branch</td>
<td>50</td>
<td>second hot air pipe branch</td>
</tr>
<tr>
<td>25</td>
<td>butterfly valve</td>
<td>52</td>
<td>butterfly valve</td>
</tr>
<tr>
<td>54</td>
<td>scroll vanes</td>
<td>54</td>
<td>scroll vanes</td>
</tr>
<tr>
<td>56</td>
<td>third conduit</td>
<td>56</td>
<td>third conduit</td>
</tr>
<tr>
<td>58</td>
<td>third hot air pipe branch</td>
<td>58</td>
<td>third hot air pipe branch</td>
</tr>
<tr>
<td>60</td>
<td>butterfly valve</td>
<td>60</td>
<td>butterfly valve</td>
</tr>
<tr>
<td>30</td>
<td>thermocouple</td>
<td>62</td>
<td>thermocouple</td>
</tr>
<tr>
<td>64</td>
<td>controller</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Claims:

1. A burner system (22) for heating a rotary kiln (20), the burner system (22) including a burner (36) coupled to a supply of hot tertiary air from the rotary kiln (20), and terminating in a nozzle (48) disposed in a hot secondary air supply defined by a kiln hood (24) disposed at an outlet for the rotary kiln (20), characterized in that the burner (36) has a first conduit (38) for receiving pulverized solid fuel and primary air supplying at least 30% of stoichiometric requirements for combusting the solid fuel,

   a second conduit (46) axially receives the first conduit (38) therethrough, and extending between an intermediate portion of the first conduit (38) and the nozzle (48), the second conduit (46) having at least one internal scroll (54) adjacent the nozzle (48) for imparting a swirling motion to air exiting from the second conduit (46),

   a third conduit (56) axially receives the second conduit (46) therethrough, and extends between an intermediate portion of the second conduit (46) and the nozzle (48),

   each of the first (38), second (46), and third (56) conduits have a respective tertiary hot air supply (42, 50, 58) and respective damping means (44, 52, 60) for independently controlling the volume of hot tertiary air from the rotary kiln (20) supplied to said conduits (36, 40, 56).

   a hot high pressure fan (26) receives hot tertiary air from the rotary kiln (20) and delivers hot tertiary air to said first (38), second (46), and third (56) conduits,

   a damper (68) in a fresh air duct (66) is disposed upstream from said hot high pressure fan (26) and is in fluid communication with said supply of hot tertiary air for receiving ambient air to cool the hot tertiary air, as required,

   the volume of hot tertiary air through each of said first (38), second (46), and third (56) conduits being adjustable to allow the air
velocity in the second (46) and third (56) conduits to exceed the air
velocity in the first conduit (38) by a factor of at least 2:1.

2. A burner system (22) according to Claim 1 in which the
second conduit (46) has a plurality of long scroll vanes (54) for swirling
air, the vanes (54) having a pitch to the middle of the second conduit of
at most and a wrap of at least 150°.

3. A burner system (22) according to Claim 2 in which the pitch
of the vanes (54) is about 45°.

4. A burner system (22) according to Claim 1 in which the
internal wall of the third conduit (56) is substantially smooth so that the
air flow through the third conduit (56) is substantially laminar.

5. A method of operating a burner system (22) for heating a
rotary kiln (20), the burner system (22) including a burner (36) coupled
to a supply of hot tertiary air from the rotary kiln (20), and terminating
in a nozzle (48) disposed in a hot secondary air supply defined by a kiln
hood (24) disposed at an outlet for the rotary kiln (20), characterized in
that

the burner (36) has a first conduit (38) for receiving pulverized
solid fuel and primary air,
a second conduit (46) axially receives the first conduit (38)
therethrough, and extending between an intermediate portion of the first
conduit (38) and the nozzle (48), the second conduit (46) having at least
one internal scroll (54) adjacent the nozzle (48) imparting a swirling
motion to air exiting from the second conduit (46),
a third conduit (56) axially receives the second conduit (46)
therethrough, and extends between an intermediate portion of the second
conduit (46) and the nozzle (48), the air emerging from third conduit (56) having laminar flow characteristics,

each of the first (38), second (46), and third (56) conduits have a respective tertiary hot air supply (42, 50, 58) and respective damping means (44, 52, 60) for independently controlling the volume of hot tertiary air from the rotary kiln (20) supplied to said conduits (38, 46, 56),

a hot high pressure fan (26) receives hot tertiary air from the rotary kiln (20) and delivers hot tertiary air to said first (38), second (46), and third (56) conduits,

a damper (68) in a fresh air duct (66) is disposed upstream from said hot high pressure fan (26) and is in fluid communication with said supply of hot tertiary air, receiving ambient air to cool the hot tertiary air, as required, to a temperature which is less than the operating temperature of the hot high pressure fan,

in which the volume of primary air supplied through said first conduit (38) is at least 30% of stoichiometric requirements for combusting solid fuel, and

the volume of hot tertiary air supplied through each of said first (38), second (46), and third (56) conduits is adjusted so that the air velocity in each of the second (46) and third (56) conduits exceeds the air velocity in the first conduit (38) by a factor of at least 2:1.

6. A method according to Claim 5 in which the temperature of the hot tertiary air is maintained at a maximum of 1400°F.

7. A method according to Claim 5 in which the volume of hot tertiary air admitted to the first conduit (38) is varied in accordance with the humidity of pulverized solid fuel supplied to the first conduit (38).

8. A method according to Claim 5 in which the volume of hot
tertiary air admitted to the second conduit (46) is increased to create a shorter, bushier flame.

9. A method according to Claim 5 in which the volume of hot tertiary air admitted to the third conduit (56) is increased to create a longer, cooler flame.

10. A method according to Claim 5 in which the air velocity in the first conduit (38) is maintained between 35 and 45 m/sec and the air velocities in the second (46) and third (56) conduits are operated at approximately 90 m/sec.

11. A method according to Claim 5 in which the hot tertiary air supplied in each of second (46) and third (56) conduits does not exceed 10% of stoichiometric air required for combustion.

12. A method according to Claim 5 in which the hot tertiary air supplied in each of the second (46) and third (56) conduits is approximately 6% of stoichiometric air required for combustion.
AMENDED CLAIMS
[received by the International Bureau on 18 June 2001 (18.06.01)
original claims 1-12 replaced by new claims 1-14; (5 pages)]

1. A burner system (22) for heating a rotary kiln (20), the burner
   system (22) including a burner (36) coupled to a supply of hot tertiary
   air from the rotary kiln (20), and terminating in a nozzle (48) disposed in
   a hot secondary air supply defined by a kiln hood (24) disposed at an
   outlet for the rotary kiln (20), characterized in that
   the burner (36) has a first conduit (38) for receiving pulverized
   solid fuel and primary air supplying at least 30% of stoichiometric
   requirements for combusting the solid fuel,
   a second conduit (46) axially receives the first conduit (38)
   therethrough, and extending between an intermediate portion of the first
   conduit (38) and the nozzle (48), the second conduit (46) having at least
   one internal scroll (54) adjacent the nozzle (48) for imparting a swirling
   motion to air exiting from the second conduit (46),
   a third conduit (56) axially receives the second conduit (46)
   therethrough, and extends between an intermediate portion of the second
   conduit (46) and the nozzle (48),
   each of the first (38), second (46), and third (56) conduits have
   a respective tertiary hot air supply (42, 50, 58) and respective damping
   means (44, 52, 60) for independently controlling the volume of hot
   tertiary air from the rotary kiln (20) supplied to said conduits (36, 40,
   56),
   a hot high pressure fan (26) receives hot tertiary air from the
   rotary kiln (20) and delivers hot tertiary air to said first (38), second
   (46), and third (56) conduits,
   a damper (68) in a fresh air duct (66) is disposed upstream
   from said hot high pressure fan (26) and is in fluid communication with

AMENDED SHEET (ARTICLE 19)
said supply of hot tertiary air for receiving ambient air to cool the hot tertiary air, as required,

the volume of hot tertiary air through each of said first (38), second (46), and third (56) conduits being adjustable to allow the air velocity in the second (46) and third (56) conduits to exceed the air velocity in the first conduit (38) by a factor of at least 2:1.

2. A burner system (22) according to Claim 1 in which the second conduit (46) has a plurality of long scroll vanes (54) for swirling air, the vanes (54) having a wrap of at least 150°.

3. A burner system (22) according to Claim 2 in which the scroll vanes (54) have a wrap of about 180°.

4. A burner system (22) according to Claim 2 in which the scroll vanes (54) extend inwardly over a length \( x \) away from the nozzle (48), the second conduit (46) having a nominal internal diameter \( y \), and the ratio \( x/y \) being in the range of 1.4 to 1.2.

5. A burner system (22) according to Claim 2 in which the pitch of the vanes (54) is about 45°.

6. A burner system (22) according to Claim 1 in which the internal wall of the third conduit (56) is substantially smooth so that the air flow through the third conduit (56) is substantially laminar.

7. A method of operating a burner system (22) for heating a
rotary kiln (20), the burner system (22) including a burner (36) coupled to a supply of hot tertiary air from the rotary kiln (20), and terminating in a nozzle (48) disposed in a hot secondary air supply defined by a kiln hood (24) disposed at an outlet for the rotary kiln (20), characterized in that

the burner (36) has a first conduit (38) for receiving pulverized solid fuel and primary air,

a second conduit (46) axially receives the first conduit (38) therethrough, and extending between an intermediate portion of the first conduit (38) and the nozzle (48), the second conduit (46) having at least one internal scroll (54) adjacent the nozzle (48) imparting a swirling motion to air exiting from the second conduit (46),

a third conduit (56) axially receives the second conduit (46) therethrough, and extends between an intermediate portion of the second conduit (46) and the nozzle (48), the air emerging from third conduit (56) having laminar flow characteristics,

each of the first (38), second (46), and third (56) conduits have a respective tertiary hot air supply (42, 50, 58) and respective damping means (44, 52, 60) for independently controlling the volume of hot tertiary air from the rotary kiln (20) supplied to said conduits (38, 46, 56),

a hot high pressure fan (26) receives hot tertiary air from the rotary kiln (20) and delivers hot tertiary air to said first (38), second (46), and third (56) conduits,

a damper (68) in a fresh air duct (66) is disposed upstream from said hot high pressure fan (26) and is in fluid communication with said supply of hot tertiary air, receiving ambient air to cool the hot
tertiary air, as required, to a temperature which is less than the operating temperature of the hot high pressure fan,

in which the volume of primary air supplied through said first conduit (38) is at least 30% of stoichiometric requirements for combusting solid fuel, and

the volume of hot tertiary air supplied through each of said first (38), second (46), and third (56) conduits is adjusted so that the air velocing in each of the second (46) and third (56) conduits exceeds the air velocing in the first conduit (38) by a factor of at least 2:1.

8. A method according to Claim 7 in which the temperature of the hot tertiary air is maintained at a maximum of 1400°F.

9. A method according to Claim 7 in which the volume of hot tertiary air admitted to the first conduit (38) is varied in accordance with the humidity of pulverized solid fuel supplied to the first conduit (38).

10. A method according to Claim 7 in which the volume of hot tertiary air admitted to the second conduit (46) is increased to create a shorter, bushier flame.

11. A method according to Claim 7 in which the volume of hot tertiary air admitted to the third conduit (56) is increased to create a longer, cooler flame.

12. A method according to Claim 7 in which the air velocity in the
first conduit (38) is maintained between 35 and 45 m/sec and the air velocities in the second (46) and third (56) conduits are operated at approximately 90m/sec.

13. A method according to Claim 7 in which the hot tertiary air supplied in each of second (46) and third (56) conduits does not exceed 10% of stoichiometric air required for combustion.

14. A method according to Claim 7 in which the hot tertiary air supplied in each of the second (46) and third (56) conduits is approximately 6% of stoichiometric air required for combustion.
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC 7 F23C7/00 F23D1/00 F23L15/00 F27B7/34

According to International Patent Classification (IPC) or to both national classification and IPC.

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 F23C F23D F23L F27B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched.

Electronic data base consulted during the international search (name of data base and where practical search terms used)

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>US 4 690 074 A (NORTON CHARLES L) 1 September 1987 (1987-09-01) column 3, line 37 -column 4, line 39 figures 1,3,5 ---</td>
<td>1-3,5,6, 8,9</td>
</tr>
<tr>
<td>A</td>
<td>US 4 387 654 A (BINASIK CHESTER S ET AL) 14 June 1983 (1983-06-14) cited in the application column 4, line 37 -column 5, line 22 column 6, line 48 -column 7, line 30 column 7, line 67 -column 8, line 22 column 8, line 46 - line 68 column 9, line 21 - line 44 figures 1,2,4 ---</td>
<td>1,5</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of box C. Patent family members are listed in annex.

* Special categories of cited documents:
  *"A*" document defining the general state of the art which is not considered to be of particular relevance
  *"E"* earlier document but published on or after the international filing date
  *"L"* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  *"O"* document referring to an oral disclosure, use, exhibition or other means
  *"P"* document published prior to the international filing date but later than the priority date claimed
  *"T"* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
  *"X"* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
  *"Y"* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
  *"S"* document member of the same patent family

Date of the actual completion of the international search 9 April 2001

Date of mailing of the international search report 23/04/2001

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epos nl Fax: (+31-70) 340-3016

Authorized officer Coquau, S
<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>US 4 838 185 A (FLAMENT GERARD) 13 June 1989 (1989-06-13) cited in the application column 4, line 7 - line 46 column 5, line 5 - line 15 column 6, line 31 - line 36 figure 1</td>
<td>1, 5, 10</td>
</tr>
<tr>
<td>Patent document cited in search report</td>
<td>Publication date</td>
<td>Patent family member(s)</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>-----------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>US 4690074 A</td>
<td>01-09-1987</td>
<td>NONE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AT 45621 T</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AU 582647 B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AU 5708286 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CA 1289416 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 3665097 D</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DK 202686 A,B,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 0200644 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ES 554556 D</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ES 8708258 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FI 861783 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IN 167334 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 61256108 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PT 82483 A,B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 4919611 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ZA 8603209 A</td>
</tr>
</tbody>
</table>