Abstract: A cyclone furnace and method uses a cyclone burner having a cyclone barrel with a re-entrant throat connected to a main furnace for passing combustion products including flue gas that is rich in carbon dioxide. Crushed coal and oxygen are supplied the cyclone burner and at least some of the flue gas from the main furnace is recirculated to the cyclone barrel.
CYCLONE FURNACE FOR OXYGEN FIRED BOILERS
WITH FLUE GAS RECIRCULATION

Field and Background of Invention

[001] The present invention relates generally to the field of furnaces, and in particular to a new and useful cyclone furnace which produces reduced emissions of NOx.

[002] Cyclone furnaces have been in use since the early 1950's as an efficient method for combusting coal. They also allow for a smaller boiler because up to 90% of the ash is tapped out of the furnace bottom permitting a smaller convection pass without slagging on the heat transfer surface. However, with the more stringent NOx emissions in today's environment, cyclone furnaces are no longer a desirable method of coal combustion because of their heavy NOx production.

[003] More information about the construction and operation of cyclone furnaces can be found in the publication STEAM-ITS GENERATION.
Summary of Invention

[004] It is an object of the present invention to provide a cyclone furnace method and apparatus which reduces NOx emissions while retaining many of the advantages of cyclone furnaces.

[005] One new technology being studied to facilitate carbon sequestration by concentrating carbon dioxide is firing a boiler with oxygen injected into recirculated flue gas instead of air. A concentrated CO$_2$ stream is of interest because it can be more easily sequestered. An additional benefit of oxygen firing a boiler is that it also results in very low NOx emissions because the nitrogen normally introduced with air firing is no longer present in the recirculated flue gas. However, along with the high concentration of carbon dioxide in the recirculated flue gas is also a high concentration of moisture. Because of these two concentrations, complete combustion of the coal becomes problematic with pulverized coal firing methods.

[006] The present invention uses cyclone burners in a new boiler utilizing oxygen combustion with recirculated flue gas for the purpose of concentrating carbon dioxide. This combination takes advantage of the combustion efficiency of cyclone furnaces to overcome the problems of high moisture inherent in recirculated flue gas and eliminates the high NOx levels produced by air-fired cyclones. Additional benefits are: 1) the lower fly-ash produced allows high convection pass velocities resulting in a closer spaced convection pass design and a smaller boiler and 2) the elimination of pulverizers, since only crushed coal is needed, reduces auxiliary power helping to compensate for the power consumption needed to produce oxygen.
Accordingly, an object of the present invention is to provide a cyclone furnace comprising: a cyclone burner having a cyclone barrel with a re-entrant throat; a main furnace connected to the re-entrant throat for passing combustion products from the re-entrant throat to and along the main furnace, the combustion products including flue gas that is rich in carbon dioxide; crushed solid fuel supply means connected to the cyclone barrel for supplying fuel to the cyclone burner; oxygen supply means connected to the cyclone barrel for supplying oxygen that is substantially free of nitrogen to the cyclone burner; and means for recirculating at least some of the flue gas from the main furnace to the cyclone barrel.

Another object of the present invention is to provide a method of operating a cyclone furnace having a cyclone burner with a cyclone barrel and a re-entrant throat, and a main furnace connected to the re-entrant throat, the method comprising: supplying crushed solid fuel to the cyclone barrel; supplying oxygen that is substantially free of nitrogen to the cyclone barrel; igniting the oxygen and crushed fuel in the cyclone burner for creating combustion products that are passed to and along the main furnace, the combustion products including flue gas that is rich in carbon dioxide; and recirculating at least some of the flue gas from the main furnace to the cyclone barrel.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this disclosure. For a better understanding of the invention, its operating advantages and specific objects attained by its uses, reference is made to the accompanying drawings and descriptive matter in which a preferred embodiment of the invention is illustrated.
Brief Description of the Drawings

[0010] In the drawings:

[0011] Fig. 1 is the only figure in the drawings and is a schematic side elevation view of a cyclone furnace according to the present invention.

Description of the Preferred Embodiments

[0012] Referring now to the drawing, Fig. 1 shows a cyclone furnace generally designated 10 having a cyclone burner generally designated 12 with a generally cylindrical cyclone barrel 14 having an outlet or re-entrant throat 16 for discharging combustion products that have been produced in the cyclone furnace as will be explained later in this disclosure. The throat 16 is connected to the lower end of a main furnace 18 with the upwardly directed arrows identify the combustion products which include flue gases that are rich in carbon dioxide.

[0013] Heat from these hot combustion products are taken away preferably by tubes containing water and/or steam in the environment of a boiler where the heat is used for other purposes.

[0014] Crushed rather than pulverized coal is stored in a coal bunker 20 and, using known equipment, is supplied along a fuel supply line 22 to a crushed coal inlet at the top of a radial burner 24. Primary and tertiary flue gas are supplied to burner 24 by supply means 26 while primary flue gas is supplied in a tangential direction to the cyclone barrel 14 by primary flue gas supply means 28.

[0015] According to the present invention, one or more of the primary, secondary and tertiary flue gas supplies, rather than supplying air to the
cyclone furnace, supply oxygen which is substantially free of nitrogen although pure oxygen is not necessary.

[0016] The oxygen enriched flue gas is then mixed with the crushed coal and ignited by a main oil or gas burner in a known manner to produce a swirling mass of combustion products symbolized by the swirl lines within barrel 14.

[0017] According to a significant feature of the present invention, at least some of the carbon dioxide rich flue gases are recycled or recirculated along a recirculation line 30 back to the cyclone furnace. The recirculated flue gas is supplied separately or as part of any one of the primary, secondary or tertiary flue gas streams or oxygen mixed in the streams.

[0018] It has been found that by reducing or eliminating the presence of nitrogen by using oxygen enriched flue gas instead of air and by recirculating the carbon dioxide rich flue gas that the efficiency of the cyclone furnace is maintained while the NOx emissions are significantly reduced.

[0019] Various gas purifying mechanisms symbolized by box 32 can be provided before the flue gas is returned to the cyclone furnace which may be nothing more than filtering out of larger particles or may be a more elaborate scrubbing and filtration process.

[0020] Although crush coal is the preferred fuel for the present invention, other crushed solid fuel may be utilized.

[0021] Advantages of the invention over conventional pulverized coal firing include:

1. High combustion efficiency of the coal even with high concentrations of carbon dioxide and moisture in the recycled flue gas.

2. Low fly-ash discharge in the flue gas allows for smaller particulate removal equipment.
3. Low fly-ash discharge in the flue gas allows for higher convection pass velocities and thus a smaller boiler.

4. Because the cyclone furnaces use crushed coal, no expensive pulverizers are required saving capital cost and eliminating significant auxiliary power.

[0022] While a specific embodiment of the invention has been shown and described in detail to illustrate the application of the principles of the invention, it will be understood that the invention may be embodied otherwise without departing from such principles.
Claims

We claim:

1. A cyclone furnace comprising:
   a cyclone burner having a cyclone barrel with a re-entrant throat;
   a main furnace connected to the re-entrant throat for passing combustion products from the re-entrant throat to and along the main furnace, the combustion products including flue gas that is rich in carbon dioxide;
   crushed solid fuel supply means connected to the cyclone barrel for supplying fuel to the cyclone burner;
   oxygen supply means connected to the cyclone barrel for supplying oxygen that is substantially free of nitrogen to the cyclone burner; and
   means for recirculating at least some of the flue gas from the main furnace to the cyclone barrel.

2. A cyclone furnace according to claim 1, including means for supplying primary, secondary and tertiary flue gas to the cyclone furnace, at least one of the primary, secondary and tertiary flue gas supply means forming the oxygen supply means.

3. A cyclone furnace according to claim 1, wherein the crushed solid fuel supply means comprise means for supplying crushed coal to the cyclone furnace.

4. A method of operating a cyclone furnace having a cyclone burner with a cyclone barrel and a re-entrant throat, and a main furnace connected to the re-entrant throat, the method comprising:
   supplying crushed solid fuel to the cyclone barrel;
   supplying oxygen that is substantially free of nitrogen to the cyclone barrel;
igniting the oxygen and crushed fuel in the cyclone burner for creating combustion products that are passed to and along the main furnace, the combustion products including flue gas that is rich in carbon dioxide; and recirculating at least some of the flue gas from the main furnace to the cyclone barrel.

5. A method according to claim 4, including supplying primary, secondary and tertiary flue gas to the cyclone furnace, wherein at least one of the primary, secondary and tertiary flue gas is enriched with oxygen.

6. A method according to claim 4, including supplying crushed coal as the crushed solid fuel.
A. CLASSIFICATION OF SUBJECT MATTER

IPC: F23D 1/00 (2006.01)

USPC: 110/347,266

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)

U.S. : 110/347,266

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 practicable, search terms used)

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>Y</td>
<td>US 2,847,979 A (SIFRIN et al) 19 August 1958 (19.08.1958), see figure 1.</td>
<td>1-6</td>
</tr>
<tr>
<td>Y</td>
<td>US 5,309,850 A (DOWNS et al) 10 May 1994 (10.05.1994), see figure 1.</td>
<td>1-6</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

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