The unburned carbon content of ash is reduced by entraining a stream of the ash into a stream of oxidant and combusting the unburned carbon with oxygen in the oxidant.
OXYGEN-ENHANCED COMBUSTION OF UNBURNED CARBON IN ASH

FIELD OF THE INVENTION

[0001] The present invention relates to treating ash to reduce the amount of unburned carbon and carbon compounds in the ash.

BACKGROUND OF THE INVENTION

[0002] When solid fuels, such as coal or petroleum coke, are used to fire furnaces or boilers, combustion inefficiencies often lead to the ash (also termed “fly ash”) containing a small amount of unburned carbon (“UBC”). This problem is often exacerbated when conventional combustion-based technologies are employed to lessen the amount of nitrogen oxides (“NOx”) emitted. This unburned carbon, typically measured by the loss on ignition (LOI) test, can present several problems. First, since unburned carbon in the ash represents unrealized heating value of a portion of the fuel, this increment of heating value must be made up by firing more fuel. Second, and typically most critical, ash can be used to replace a portion of the cement used in concrete, but when the level of the unburned carbon in the ash exceeds some threshold (typically 3-6%) the ash is typically no longer acceptable for use as a cement replacement in concrete—causing the boiler operator to have to pay to dispose of the ash. This is further compounded by the fact that as the amount of unburned carbon increases, the mass of ash that must be disposed of also increases.

[0003] Although several air-based processes have been proposed to burn the residual unburned carbon to allowable levels permitting the ash to be used for cement replacement, they are often expensive and extremely complicated. For example, currently available processes include circulating fluidized bed arrangements that can be maintenance intensive. Experience has also shown that these processes are limited in the ranges of unburned carbon content they can effectively beneficiate. Although oxygen-based and oxygen enhanced systems have also been proposed for these processes, they are also very complicated systems and have met with limited commercial success.

[0004] The present invention provides the advantages described herein, in a method that is less complex in its operating conditions and in the equipment that is used to practice the method.

BRIEF SUMMARY OF THE INVENTION

[0005] One aspect of the invention is a method for reducing the carbon content of ash that contains unburned carbon, comprising

[0006] entraining particles of ash containing unburned carbon into a flowing stream of gaseous oxidant that contains more than 21 vol. % oxygen to form a flowing mixed stream of said ash mixed with said oxidant and passing the flowing mixed stream through a combustion chamber wherein unburned carbon in the ash in the flowing mixed stream combusts to produce a flowing product stream of ash having a reduced carbon content entrained in a gaseous stream comprising combustion products,

[0007] wherein the heat contained in the stream of oxidant into which the particles of ash are entrained is enough to maintain said combustion of unburned carbon in the ash in said combustion chamber but is not so high that the particles of ash begin to melt,

[0008] optionally providing additional gaseous oxidant into the combustion chamber which, if provided, contacts unburned carbon in the ash after ignition thereof and combusts with additional unburned carbon in the ash or with combustion products, and

[0009] withdrawing said flowing product stream from said combustion chamber, feeding it to apparatus wherein ash having reduced carbon content is separated from said flowing product stream and obtaining from said apparatus ash having a reduced carbon content and a gaseous product stream comprising combustion products.

[0010] Another aspect of the invention is a method for reducing the carbon content of ash that contains unburned carbon, comprising

[0011] entraining particles of ash containing unburned carbon and particles of solid combustible matter having a lower ignition temperature than the ignition temperature of said unburned carbon into a flowing stream of gaseous oxidant that contains more than 21 vol. % oxygen to form a flowing mixed stream of said ash and solid combustible matter mixed with said oxidant and passing the flowing mixed stream through a combustion chamber wherein the solid combustible matter and unburned carbon in the ash in the flowing mixed stream combust to produce a flowing product stream of ash having a reduced carbon content entrained in a gaseous stream comprising combustion products,

[0012] wherein the heat contained in the stream of oxidant into which the particles of ash and solid combustible matter are entrained is enough to maintain said combustion of unburned carbon and solid combustible matter in said combustion chamber but is not so high that the particles of ash begin to melt,

[0013] optionally providing additional gaseous oxidant into the combustion chamber which, if provided, contacts unburned carbon in the ash after ignition thereof and combusts with additional unburned carbon in the ash, with additional solid combustible matter, or with combustion products, and

[0014] withdrawing said flowing product stream from said combustion chamber, feeding it to apparatus wherein ash having reduced carbon content is separated from said flowing product stream and obtaining from said apparatus ash having a reduced carbon content and a gaseous product stream comprising combustion products.

[0015] The invention is useful in methods in which the unburned carbon in the ash comprises at least 50% of the total mass of combustible matter being combusted in the combustion chamber, and in methods in which fuel other than the unburned carbon in the ash is simultaneously being combusted in the combustion chamber, so that the unburned carbon in the ash comprises less than 50% of the total mass of combustible matter being combusted (such as when the ash is fed into a coal-fired boiler or other combustion device).

[0016] As used herein, “unburned carbon” means carbonaceous solids, such as residual unburned material that remains from combustion of carbonaceous fuel.

[0017] As used herein, a material’s “ignition temperature” in an atmosphere having a given oxygen content is the lowest temperature at which a product in contact with an
atmosphere having that oxygen content begins to combust even without a separate source of ignition such as a spark igniter or a pilot flame.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIG. 1 is a flowsheet of a method of the present invention.

[0019] FIG. 2 is a cross-sectional view of one component of the apparatus depicted in FIG. 1.

[0020] FIG. 3 is a cross-sectional view of a preferred embodiment useful in the present invention.

[0021] FIG. 4 is a flowsheet of a preferred embodiment of the present invention.

[0022] FIG. 5 is a cross-sectional view of another embodiment of apparatus with which the method of the present invention can be practiced.

DETAILED DESCRIPTION OF THE INVENTION

[0023] FIG. 1 depicts one type of apparatus with which the present invention can be practiced. Referring to FIG. 1, combustor 1 is provided in which ignition and combustion of the ash take place. Combustor 1 can be simply a hollow tube or other hollow vessel, with suitable inlets for ash and oxidant streams and a suitable outlet for combusted ash. Combustor 1 can also be a rotary kiln or a boiler such as a coal-fired boiler that generates electric power. Combustor 1 should be large enough to provide the desired capacity and residence time for the operations described herein; its interior should be able to withstand the temperatures which are reached inside the combustor as described herein; thus the combustor could be made of refractory material, or lined with refractory material, or surrounded by tubes of material that absorbs heat (such as water or other liquid that evaporates, or material that undergoes endothermic reaction).

[0024] Stream 3 of ash passes into the combustor, preferably near one end of the combustor. Ash treated in accordance with the present invention is typically comprised of the residue of a carbonaceous ash-containing fuel that has been exposed to a high temperature process, such as a combustor or gasifier.

[0025] Stream 5 of oxidant is fed into combustor 1, preferably at or near the same end of combustor 1 into which ash stream 3 is fed. Oxidant stream 5 contains more than 21 vol. % oxygen, but may contain higher oxygen concentrations such as at least 25 vol. %, at least 50 vol. %, or even at least 90 vol. %, One preferred embodiment of feeding ash stream 3 and oxidant stream 5 is illustrated in FIG. 2.

[0026] Optionally, supplemental oxidant 7 can also be fed into the interior of combustor 1. As described in more detail below, the supplemental oxidant is fed so that it comes into contact with the ash after unburned carbon in the ash has ignited and begun to combust within combustor 1. Supplemental oxidant 7 can comprise air, oxygen-enriched air, or oxygen in commercially available purity. The supplemental oxidant thus will generally contain 21 vol. % to 99.9 vol. % oxygen.

[0027] The desired oxygen composition of the oxidant stream and of any supplemental oxidant streams can be attained by employing oxygen in a commercially available purity, or by combining oxygen in a commercially available purity with air until the desired overall oxygen content is attained.

[0028] Stream 9 contains ash having a reduced unburned carbon content compared to the unburned carbon content of the ash fed into combustor 1. Stream 9 also contains gaseous combustion products such as carbon dioxide and water vapor, and may contain carbon monoxide. Stream 9 passes from a suitable outlet in combustor 1, preferably at the end opposite from the end into which ash stream 3 is fed, to a separatory apparatus 11 in which solids, comprising the ash, are separated from gaseous components of stream 9. Stream 13 represents solids recovered from separatory apparatus 11. Stream 15 comprises substantially all of the gaseous component of stream 9. A typical preferred separatory apparatus 11 is a cyclone, of conventional design provided that it is capable of sustained operation at the elevated temperatures to which it is exposed from the material conveyed in stream 9 into apparatus 11. If desired, the stream 9 can be cooled, for instance by heat transfer via indirect heat exchange with another stream, or by quenching.

[0029] Referring to FIG. 2, the interior of combustor 1 is shown. Ash is provided as stream 3 of ash particles from any suitable container or conveyor system, such as a screw feeder or a vibratory hopper. Ash stream 3 preferably enters the interior of combustor 1 from above oxidant stream 5, to take advantage of the assistance of gravity.

[0030] Stream 5 of oxidant is fed into the interior of combustor 1 at a sufficient velocity and momentum that it entrains the particles of ash in ash stream 3 into the oxidant stream, thereby forming a flowing mixed stream of oxidant and ash. The minimum velocity of oxidant stream 5 effective to achieve entrainment of the ash into the oxidant stream can readily be determined based on the feed rate and the particle size distribution of the ash stream.

[0031] The stream of ash 3 and oxidant stream 5 are preferably fed separately into combustor 1, as shown in FIG. 2, so that entrainment of the stream of particles of ash into the stream of oxidant occurs entirely within combustor 1. However, in other embodiments, the entrainment of the stream of ash particles into the stream of oxidant can occur upstream of the combustor itself. FIG. 5 depicts one such embodiment.

[0032] FIG. 2 also shows that supplemental oxidant 7, if employed, is fed into the interior of combustor 1 downstream from the formation of the mixed stream of oxidant and ash, so that unburned carbon in the ash is ignited and begins to combust in the combustor 1 before the combusting particles become exposed to the supplemental oxidant in the combustor. If desired, supplemental oxidant can be fed to combustor 1 in one or more than one such stream.

[0033] The relative mass flow rates of the stream of ash particles, the oxidant stream, and the stream (or streams) of supplemental oxidant (if used), fed to combustor 1, should be established so that the total amount of oxygen fed in the oxidant stream and in any supplemental oxidant streams contains enough oxygen relative to the amount of unburned carbon in the ash stream to combust the desired amount of unburned carbon that is in the ash stream fed into combustor 1 (which may be all, or less than all, of the unburned carbon). The amount of oxygen in the oxidant stream(s) and the mass flow rates of the oxidant stream(s) are adjusted accordingly. While combustible less than 100% of the unburned carbon is sometimes sufficient, it is preferred to provide enough oxygen (as the aggregate of oxygen contained in all oxygen-containing streams fed) to combust all of the unburned carbon in the ash. Thus, it is preferred to
feed sufficient oxygen (as the aggregate of all oxygen-containing streams fed) to comprise 100% to 105 or 110% of the amount of oxygen required to combust all of the unburned carbon in the ash.

[0034] The flowing mixture of oxidant into which the ash has been entrained should contain sufficient heat so that the unburned carbon in the flowing mixed stream of ash and oxidant ignites, i.e. begins to combust (whether in the combustion chamber, or upstream from the combustion chamber but after the ash has been entrained into the oxidant), and so that the combustion is sustained in the combustion chamber. This heat content can be provided by heating the oxidant before the oxidant is mixed with the ash, or by combining the oxidant and the ash with supplemental combustible matter that ignites and combusts in the combustion chamber and thereby provides additional heat to the ash. However, the total heat content of the mixture of the oxidant and the ash should be below the point at which particles of ash entrained in the oxidant stream begin to melt, such as they become adherent to each other.

[0035] The temperatures at which the particles of ash risk beginning to melt and becoming adherent to each other may vary among different ash compositions, and can readily be determined for a given ash. Avoiding the situation in which the particles begin to melt requires taking into consideration several factors, including the heat content of the oxidant stream as it first contacts the ash particles, and the heat content within the combustion chamber which in turn is affected by the evolution of heat of combustion as unburned carbon in the ash combusts, the evolution of heat of combustion of any other matter that is also combustible in the combustion chamber, and heat losses to the combustion chamber walls, especially if heat is transferring through the walls such as to circulating water or steam as in an electric power generation boiler. Thus, the heat content of the oxidant stream should be sufficiently low that, even as heat of combustion of the unburned carbon and of any other combustible matter present raises the heat content of the mixture of oxidant and combustible ash, the heat content of the mixture still remains below a point at which the particles of ash begin to melt.

[0036] In embodiments such as those that promote ignition and combustion of the ash by entraining the ash into a stream of oxidant that is at a temperature above ambient, the temperature and heat content of the oxidant stream can be raised in any of several ways. The oxidant stream can be heated by passing it through a chamber that is already heated, so that the oxidant is heated by direct heat transfer from the interior surfaces of the chamber, or by passing the oxidant stream through a heat exchanger in which the stream is heated by indirect heat exchange from a hotter stream such as flue gas from another combustion operation, or such as the hot gas recovered from separator 11 as stream 15.

[0037] A preferred technique for providing a heated oxidant stream is illustrated in FIG. 3. In this embodiment, a flowing stream of gaseous hot oxidant is formed by mixing fuel and oxygen and combusting a portion of the oxygen in the mixture with said fuel in a chamber, whereby uncombusted oxygen emerges from the chamber as a hot oxidant stream that contains oxygen and products of said combustion.

[0038] Referring to FIG. 3, thermal nozzle 31 comprises a chamber or lance from which hot oxidant stream 5 exits. In the practice of this embodiment oxidant stream 33 having an oxygen concentration of at least 30 vol. % and preferably at least 85 vol. % is provided into chamber 34. Most preferably the oxidant in stream 33 is technically pure oxygen having an oxygen concentration of 99 vol. % or more. Within chamber 34 the oxidant has an initial velocity which is generally within the range of from 50 to 300 fps and typically will be less than 200 fps.

[0039] While the oxidant in chamber 34 can be heated by any suitable means such as by combustion, by an electric arc, by electrical resistance heating, or by heat exchange as described above, FIG. 3 illustrates a preferred embodiment of the invention wherein the oxidant in chamber 34 is heated by combustion within chamber 34. In this preferred practice of the invention, fuel stream 36 is provided into chamber 34 through fuel nozzle 37 which may be any suitable nozzle generally used for fuel injection. The fuel may be any suitable combustible fluid examples of which include natural gas, methane, propane, hydrogen and coke oven gas. Preferably the fuel is a gaseous fuel. Liquid fuels such as number 2 fuel oil may also be used, although it would be harder to maintain good mixing and reliable and safe combustion within chamber 34 with a liquid fuel than with a gaseous fuel.

[0040] The fuel provided into chamber 34 combuts with oxidant in chamber 34 to produce heat and combustion reaction products such as carbon dioxide and water vapor. Within chamber 34 the combustion reaction products mix with the remaining oxygen thus providing heat to the remaining oxidant that was fed as stream 33 and raising its temperature. Preferably, fuel stream 36 is provided into chamber 34 at a high velocity, typically greater than 200 fps and generally within the range of from 500 to 1500 fps. The high velocity serves to entrain oxidant into the combustion reaction 38 thus establishing a stable flame. The high velocity enables further entraining of combustion reaction products and oxidant into the combustion reaction, thus improving the mixing of the hot combustion reaction products with the remaining oxygen within chamber 34 and thus more efficiently heating the remaining oxygen.

[0041] The heated oxidant formed in chamber 34 passes out through opening 35 as hot oxidant stream 5. The oxidant stream 5 formed in this way preferably contains at least 50 vol. % oxygen. The stream formed in this manner can be expected to have a velocity sufficient to entrain the stream of particles of ash. The velocity can be adjusted, as desired, by controlling the temperature of the stream of hot oxidant (with higher temperatures correlated with higher velocities) and by suitably dimensioning the orifice through which the stream emerges. This mode of forming a hot oxidant stream and of providing the desired velocity are described further in U.S. Pat. No. 5,266,024.

[0042] Another mode of providing sufficient heat so that the flowing stream of oxidant and ash to be combusted ignites in the combustion chamber and combuts so that the combusion is maintained, is to mix with the oxidant and ash supplemental combustible matter that ignites in the combustion chamber and liberates heat of combustion which promotes ignition and combustion of the unburned carbon in the ash. FIG. 4 illustrates this embodiment of the invention. All reference numerals that appear in both FIG. 4 and FIG. 1 have the meanings described herein with respect to FIG. 1.

[0043] In FIG. 4, stream 41 of supplemental combustible matter is fed to combustor 1. By “supplemental combustible
mater" is meant matter which is combustible in combustor 1 with the oxidant and the ash containing unburned carbon. Examples include virtually any liquid or solid matter that can combust with oxygen and liberate heat of combustion. Preferred matter includes any solid hydrocarbon and/or carbohydrate matter. More specific examples include coal, coke, plant material, and solid waste containing sufficient volatile matter. The most preferred embodiment of the supplemental combustible matter is pulverized coal. The supplemental combustible matter used in this embodiment of the invention should have an ignition temperature lower than the ignition temperature of the unburned carbon in the ash being fed to the combustor. This property enables the supplemental combustible matter to increase the ability of unburned carbon in the ash to ignite, thereby increasing the ability to maintain combustion of the unburned carbon.

Stream 41 of supplemental combustible matter can be preblended with the ash so that a combined stream of ash and the combustible matter is entrained into the flowing stream of oxidant. Alternatively, stream 41 can be fed to combustor 1 as a steam separate from the stream of ash, in which case the stream of ash particles and the stream of supplemental combustible matter are each entrained into the flowing stream of oxidant (either within combustor 1, or upstream from combustor 1). The supplemental combustible matter, if fed separately, should be fed near the entrance of the oxidant into combustor 1 so that the supplemental combustible matter is entrained into the stream of oxidant.

The supplemental combustible matter can be added in any amount that maintains or increases the ability of the unburned carbon in the ash to ignite and combust in the combustor 1. Preferred amounts of the supplemental combustible matter are up to 15 wt. % based on the mass of the ash stream.

In the embodiments which employ supplemental combustible matter to promote ignition and combustion of the unburned carbon in the ash, separate heating of the oxidant stream before or after it is mixed with the ash stream may not be necessary.

The present invention is also useful when practiced in conjunction with a coal-fired combustion apparatus, such as a utility boiler that combusts coal to generate steam and/or electric power. Ash formed in the combustion of the coal, if it contains unburned carbon in amounts that one would like to reduce, can be treated by the method described herein to reduce the unburned carbon content of the ash. If desired, a suitable amount of the coal that is already available for use in the coal-fired boiler can be pulverized and used as supplemental combustible matter in the embodiment described above with respect to FIG. 4, with the pulverized coal serving as stream 41. The stream 15 of gas obtained upon separation from the ash that exited the combustor 1 can be recycled to the coal-fired boiler and used to preheat incoming combustion air or oxygen, or fed into the combustion chamber of the boiler.

FIG. 5 depicts another embodiment in which the present invention can be practiced in conjunction with a coal-fired combustion system such as a boiler. The system includes combustion device 51, such as a coal-fired boiler. Combustion device 51 houses combustion chamber 53, which is a space that can withstand the high temperatures that are attained by the combustion that is carried out in combustion chamber 53. Products of the combustion pass out of combustion chamber through flue 55. The heat that is generated by the combustion can be used in any of various ways (not shown in FIG. 5) such as forming steam in pipes that surround combustion chamber 53 or that are arrayed across flue 55.

Burner 61 is provided through a surface of combustion device 51. In actual practice, anywhere from 1 to 20 or more burners may be provided, depending on the size of the installation. Furthermore, the burners can be wall-mounted, roof-mounted, or corner-mounted. Fuel-air stream 62 comprising a mixture of fuel and air, and primary air stream 63, are fed through burner 61 and consumed in combustion chamber 53. Preferred fuel is pulverized coal, which is mixed with transport air to form the fuel-air mixture that is carried to and through the burner.

The burner can be configured, if desired, to feed secondary and even tertiary streams of air into combustion chamber 53. The combustion of the fuel and air forms flame 65 whose base is at the burner. Optional overfire air stream 64 of air is fed into combustion chamber 53 downstream from flame 65, between flame 65 and flue 55. When more than one burner is employed, the air streams 63 (and overfire air streams 64, when used) can be fed from a common windbox or plenum (not shown) which is conventional in current industrial practice. In addition, small amounts of oxygen can also be fed into the flame, from suitable feed lances in or near the burner.

Injector 71 receives ash stream 73 and oxidant stream 75. Ash stream 73 can comprise all or a portion of the ash produced by combustion in combustion chamber 53 of the fuel that is fed through burner 51. The ash from stream 73 is entrained into oxidant from stream 75 within injector 71. Accordingly, oxidant stream 75 is fed with sufficient velocity to entrain the ash as desired. As with the embodiments described above, the oxidant stream in which the ash is entrained preferably contains at least sufficient oxygen to combust 100% of the unburned carbon in the ash.

Injector 71 feeds the resulting flowing mixed stream of ash and oxidant into combustion chamber 53. In this embodiment of the invention, the ongoing combustion in combustion chamber 53 of the fuel fed through burner 51 ignites and maintains combustion of the unburned carbon in the ash. The oxygen in the oxidant stream in which the ash is entrained also promotes ignition and combustion of the unburned carbon.

The present invention presents several advantages. One advantage is that by entraining the particles of ash into the oxidant stream, the unburned carbon content of the ash can then be reduced to levels of below 2 wt. % or even below 1 wt. % in a remarkably short residence time, typically of two minutes or less and even of one minute or less.

Another advantage is that there is no need to retain inert solids in the combustion chamber, such as are provided in some prior art processes purportedly for purposes of heat transfer or solids dispersion. Thus, the only solids that would be present within the combustion chamber are the ash that is fed into the combustion chamber and passes through it, combusting therein to be withdrawn as a product stream.

Also, combustion chambers such as the combustor 1 are advantageous in that ash can be treated in accordance with the present invention in a method which completes the reduction of the unburned content to the desired low final levels in only one passage of the ash through the combustor. That is, if desired, recycle back into the combustor of all or
of a portion of the ash that is obtained from the combustor is not necessary and can be avoided.

What is claimed is:

1. A method for reducing the carbon content of ash that contains unburned carbon, comprising entraining particles of ash containing unburned carbon into a flowing stream of gaseous oxidant that contains more than 21 vol. % oxygen to form a flowing mixed stream of said ash mixed with said oxidant and passing the flowing mixed stream through a combustion chamber wherein unburned carbon in the ash in the flowing mixed stream combusts to produce a flowing product stream of ash having a reduced carbon content entrained in a gaseous stream comprising combustion products, wherein the heat contained in the stream of oxidant into which the particles of ash are entrained is enough to maintain said combustion of unburned carbon in the ash in said combustion chamber but is not so high that the particles of ash begin to melt, optionally providing additional gaseous oxidant into the combustion chamber which, if provided, contacts unburned carbon in the ash after ignition thereof and combusts with additional unburned carbon in the ash or with combustion products, and withdrawing said flowing product stream from said combustion chamber, feeding it to apparatus wherein ash having reduced carbon content is separated from said flowing product stream and obtaining from said apparatus ash having a reduced carbon content and a gaseous product stream comprising combustion products.

2. A method according to claim 1 wherein said flowing stream of oxidant is produced by mixing fuel and oxygen and combusting a portion of the oxygen in the mixture thus formed.

3. A method according to claim 1 further comprising heating said flowing stream of gaseous oxidant before entraining said particles of ash into said flowing stream of oxidant.

4. A method according to claim 3 wherein said flowing stream of gaseous oxidant is heated before entraining said particles of ash into said flowing stream of oxidant by heat transfer from a heated chamber through which said flowing stream is passed.

5. A method according to claim 3 wherein said flowing stream of gaseous oxidant is heated before entraining said particles of ash into said flowing stream of oxidant by indirect heat exchange from a hotter stream.

6. A method according to claim 1 wherein said flowing stream of gaseous oxidant into which said particles of ash are entrained contains at least 50 vol. % oxygen.

7. A method according to claim 1 wherein additional gaseous oxidant is provided into the combustion chamber and contacts unburned carbon in the ash after ignition thereof and combusts with additional unburned carbon in the ash or with combustion products.

8. A method for reducing the carbon content of ash that contains unburned carbon, comprising entraining particles of ash containing unburned carbon and particles of solid combustible matter having a lower ignition temperature than the ignition temperature of said unburned carbon into a flowing stream of gaseous oxidant that contains more than 21 vol. % oxygen to form a flowing mixed stream of said ash and solid combustible matter mixed with said oxidant and passing the flowing mixed stream through a combustion chamber wherein the solid combustible matter and unburned carbon in the ash in the flowing mixed stream combust to produce a flowing product stream of ash having a reduced carbon content entrained in a gaseous stream comprising combustion products, wherein the heat contained in the stream of oxidant into which the particles of ash and solid combustible matter are entrained is enough to maintain said combustion of unburned carbon and solid combustible matter in said combustion chamber but is not so high that the particles of ash begin to melt, optionally providing additional gaseous oxidant into the combustion chamber which, if provided, contacts unburned carbon in the ash after ignition thereof and combusts with additional unburned carbon in the ash, with additional solid combustible matter, or with combustion products, and withdrawing said flowing product stream from said combustion chamber, feeding it to apparatus wherein ash having reduced carbon content is separated from said flowing product stream and obtaining from said apparatus ash having a reduced carbon content and a gaseous product stream comprising combustion products.

9. A method according to claim 8 wherein said flowing stream of oxidant is produced by mixing fuel and oxygen and combusting a portion of the oxygen in the mixture thus formed.

10. A method according to claim 8 further comprising heating said flowing stream of gaseous oxidant before entraining said particles of ash into said flowing stream of oxidant.

11. A method according to claim 10 wherein said flowing stream of gaseous oxidant is heated before entraining said particles of ash into said flowing stream of oxidant by heat transfer from a heated chamber through which said flowing stream is passed.

12. A method according to claim 10 wherein said flowing stream of gaseous oxidant is heated before entraining said particles of ash into said flowing stream of oxidant by indirect heat exchange from a hotter stream.

13. A method according to claim 8 wherein said flowing stream of gaseous oxidant into which said particles of ash are entrained contains at least 50 vol. % oxygen.

14. A method according to claim 8 wherein additional gaseous oxidant is provided into the combustion chamber and contacts unburned carbon in the ash after ignition thereof and combusts with additional unburned carbon in the ash or with combustion products.

15. A method according to claim 1 wherein fuel other than unburned carbon in said ash is simultaneously being combusted in said combustion chamber, and unburned carbon in said ash comprises less than 50% of the total mass of combustible matter being combusted.

16. A method according to claim 15 wherein said flowing stream of oxidant is produced by mixing fuel and oxygen and combusting a portion of the oxygen in the mixture thus formed.

17. A method according to claim 15 further comprising heating said flowing stream of gaseous oxidant before entraining said particles of ash into said flowing stream of oxidant.
18. A method according to claim 17 wherein said flowing stream of gaseous oxidant is heated before entraining said particles of ash into said flowing stream of oxidant by heat transfer from a heated chamber through which said flowing stream is passed.

19. A method according to claim 17 wherein said flowing stream of gaseous oxidant is heated before entraining said particles of ash into said flowing stream of oxidant by indirect heat exchange from a hotter stream.

20. A method according to claim 15 wherein said flowing stream of gaseous oxidant into which said particles of ash are entrained contains at least 50 vol. % oxygen.

21. A method according to claim 15 wherein additional gaseous oxidant is provided into the combustion chamber and contacts unburned carbon in the ash after ignition thereof and combusts with additional unburned carbon in the ash or with combustion products.