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(54) POPCORN DE-ASHING PROCESS

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(57) **ABSTRACT**

A process for de-ashing coal wherein a wet or methanol soaked coal is subjected to a high current pulse of electrical energy to induce rapid heating, causing an explosive release of vapor breaking the coal particles apart and separating the organic fraction from the inorganic. The particles are swept along by the large volume of gas and the particles are separated by fluidization. Heavier ash particles are gravity separated from the lighter organic coal particles. The de-ashed organic coal particles leave the top of the fluidized bed. They are then separated in a cyclone separator from the vapor. The vapor is then condensed to a liquid and discharged or recycled.

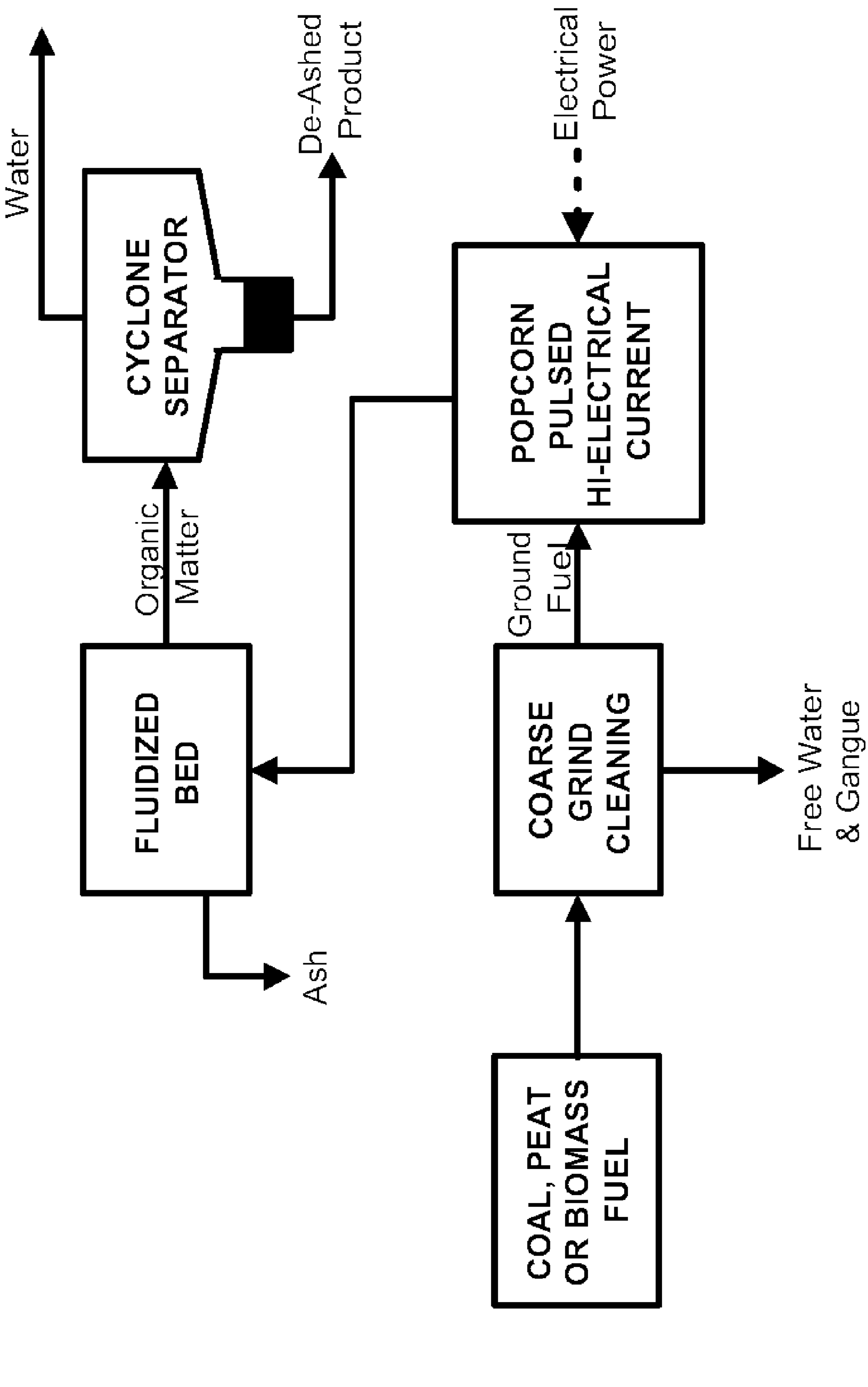
COAL, PEAT OR BIOMASS FUEL
COARSE GRIND CLEANING
Free Water & Gangue
Ground Fuel
POPCORN PULSED HI-ELECTRICAL CURRENT
Electrical Power
FLUIDIZED BED
Ash
Organic Matter
CYCLONE SEPARATOR
Water
De-Ashed Product

FIG. 1

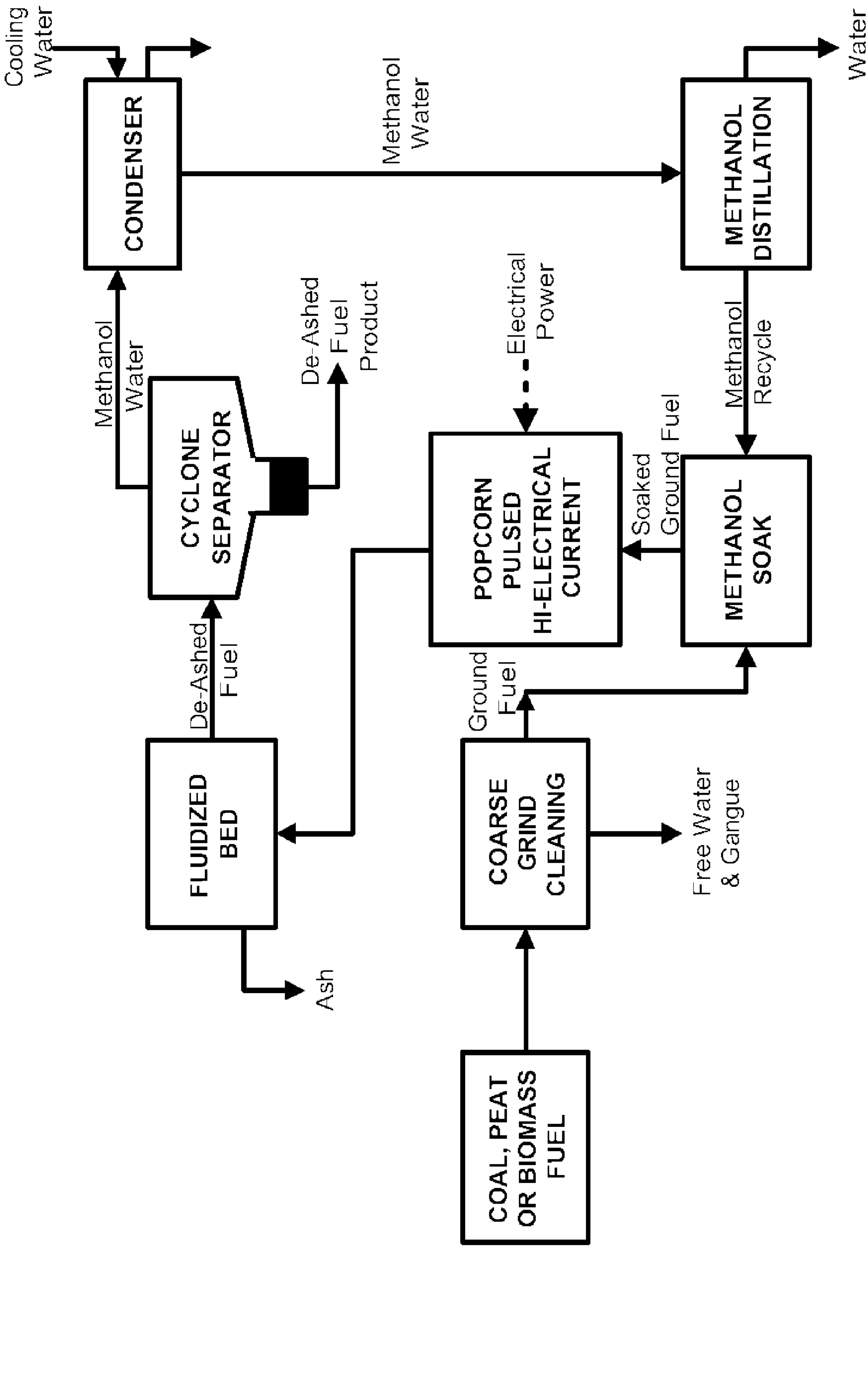
Cooling Water
CONDENSER
Methanol Water
METHANOL DISTILLATION
Water
Methanol Water
CYCLONE SEPARATOR
De-Ashed Fuel Product
Electrical Power
Methanol Recycle
POPCORN PULSED HI-ELECTRICAL CURRENT
Soaked Ground Fuel
METHANOL SOAK
De-Ashed Fuel
FLUIDIZED BED
Ground Fuel
COARSE GRIND CLEANING
Free Water & Gangue
Ash
COAL, PEAT OR BIOMASS FUEL

FIG. 2

POPCORN DE-ASHING PROCESS

FIELD OF THE INVENTION

[0001] The process is used for de-ashing of coal, peat and biomass fuels typically consumed in the boiler and power-plant industry.

BACKGROUND OF THE INVENTION

[0002] The objects of the present invention are to maintain a low cost process that simplifies the ash removal process for all grades of coal, peat and biomass; consumes less water and power than existing processes; maximizes heating value recovery in the product; delivers an ash and sulfur content lower than current technologies for comparable grades of feed; and, minimizes pollution discharges.

[0003] Solid carbonaceous natural fuel, including coal (lignite or bituminous), peat and biomass, contains varying amounts of mineral ash matter associated with the carbonaceous organic matter. Generally, the lower the ash content and higher the heating value, the more costly and complicated the process.

[0004] One of the benefits of the present invention is its potential to deliver a higher fraction of the organic component of the fuel without secondary processing. For example, when coal is crushed in typical cleaning processes some of the organic particles remain locked within the inorganic particles. Called middlings, these particles are lost to the process unless they are subjected to another, fine-particle crushing process. Since the present invention bursts the particles, just like popcorn, it holds a strong potential for liberating a higher fraction of the organic component in a single process than is possible with current technology.

[0005] The carbonaceous organic matter consists of the actual fuel value of the natural fuel. Natural fuel also contains water and small amounts of sulfur and nitrogen, which are considered contaminants.

[0006] The ash and contaminants in the natural fuel lower its heating value. They represent an operational problem when the fuel is used in energy conversion processes, especially during combustion. Upon combustion, the non-combustible ash forms a solid waste and the sulfur, nitrogen, and ash particulates are air pollutants that have been released to the atmosphere.

[0007] Contaminant releases are undesirable as they are subject to strict regulation by The United States Environmental Protection Agency. The ash content of these fuels is also problematic as it precludes their safe utilization in energy conversion devices such as in turbogenerators. Ash content in the fuels tends to erode the blades, so it is a practical necessity for the ash to be removed before such fuels may be utilized in combustion turbines. While much effort has been expended in attempts to separate ash from the organic matter of natural fuels, an economical and efficient process has yet to be developed. The Popcorn De-Ashing Process responds to this need for an efficient and economical method for de-ashing solid carbonaceous natural fuel.

DESCRIPTION OF RELATED ART

[0008] De-ashing and cleaning processes are often referred to as beneficiation processes. Beneficiation processes typically involve both dry and wet processes. However, the prior art de-ashing and cleaning processes do not include the process steps utilized in the present invention. For simplicity of discussion, coal is used herein as the primary example such processes.

[0009] Raw coal is composed of combustible organic material and non-combustible inorganic material. The inorganic material in coal, commonly referred to as ash, normally includes pyrite, clays, and other aluminosilicate materials. The presence of large amounts of these inorganic materials is deleterious to combustion processes, typically causing slagging, fouling and pollution. Sulfur is present in raw coal in two forms, organic sulfur and inorganic sulfur. The inorganic sulfur is found in pyrite and sulfates found in ash forming materials and it is the inorganic sulfur that is typically removed in coal cleaning processes.

[0010] The dry processes for de-ashing and cleaning coal typically involve electrostatic separation, which usually involve pulverizing the coal and then separating the particles by electrostatically charging the particles.

[0011] In the dry processes, the inherent nature of the particles permit giving them an electric charge, which provides the means to selectively attract them, thus separating them. An electric field may be used to attract the particles and gravity is utilized to enhance separation. U.S. Pat. No. 1,153,182 describes one of the first such electrostatic separation processes.

[0012] These processes are generally effective only when grinding is sufficiently fine to liberate the mineral content from the organic component and when the electrical properties of the organic and mineral content are sufficiently different.

[0013] Improvements in the dry processes generally relate to means for enhancing the differences between the electrical properties of the organic component and the mineral component in coal. For example, U.S. Pat. No. 3,941,685 discloses a process of mixing a powdered coal with a selected fatty acid glyceride as a conditioning substance and then performing electrostatic separation in a multiple stage process. Another example is U.S. Pat. No. 3,493,109 disclosing a process for electrostatically charging the particles by turbulent flow and particle-wall contact in the separation chamber.

[0014] The problems with the dry processes are that very fine grinding required is expensive, the particles are an explosion hazard since the increased particle surface area promotes rapid oxidation, the particles tend to clog the separations equipment because van der Waals forces of attraction dominate over electrostatic forces, and rapid erosion may be experienced depending on the means for electrostatic charging.

[0015] The wet processes typically require that the coal be first ground to very fine particles to achieve maximum performance in liberating mineral content in the coal. Typically, the finer the grind, the more power required in the process. A size classification process such as screens is often used together with a water wash and separation using cyclones, vibrators, screens, conventional or column flotation, selective agglomeration, and gravity. A type of sink/float process is sometimes favored wherein the crushed particles are introduced into a medium with a density between the organic component and the inorganic component. The inorganic component sinks and the organic component floats and is separated. This process is sometimes assisted by cyclones and using magnetic particles in the medium to assist in separation. Dewatering may or may not be involved depending on the product. The wet processes are typically less effective as the amount of ash in the feed coal increases.

[0016] U.S. Pat. No. 5,794,791 discloses a process involving many of these process steps. For example, in the 791 patent, raw coal feed is first sized to remove fine coal particles. The coarse fraction is then separated into clean coal, middlings, and refuse. Middlings are comminuted for beneficiation with the fine fraction. The fine fraction is deslimed in a countercurrent cyclone circuit and then separated as multiple fractions of different size specifications in dense medium cyclones. The dense medium contains ultrafine magnetite particles of a narrow size distribution, which aid separation and improves magnetite recovery.

[0017] U.S. Pat. No. 6,599,434 is an example of a process using cyclone separators, a vibrating screen, a centrifuge and a flow path to clean, recover and dewater fine coal. When a cyclone is used, the organic component is generally removed as the overflow product while the inorganic component becomes the underflow product.

[0018] Flotation is not efficient for treating fine coal containing significant amounts of mixed-phase particles. Clay particles are often entrained with the cleaned coal concentrate. A disadvantage of gravity and medium separation is that ultrafine clay particles are not easily rejected. Water washing also removes a quantity of orgainic fines, diminishing the recovery rate. Sequential cleaning processes are sometimes used to reduce ash and sulfur content to designated levels. However, repeated cleaning usually adversely affects recovery rate and increases costs. Current processes consume wash water at rates between about 2,000 and 20,000 gallons per ton of feed coal and can significantly contaminate the water with the hazardous and toxic elements commonly found in coal.

BRIEF SUMMARY OF THE INVENTION

[0019] A method for producing a de-ashed coal, peat or biomass fuel. The fuel is first ground to coarse particles and the free water and gangue removed. The particles are then fractionated by subjecting the particles to a current of electrical energy sufficient to induce rapid heating and vaporization of interstitial liquids within the particles causing the particles to burst. The fractionated products are then separated from each other, producing de-ashed product.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. **1** is a flow diagram of the process using interstitial water in the fuel.

[0021] FIG. **2** is a flow diagram of the process using a methanol soak.

DETAILED DESCRIPTION OF THE INVENTION

[0022] The Popcorn De-Ashing Process produces a de-ashed coal, peat or biomass fuel. The fuel is first ground to coarse particles and the free water and gangue removed. The particles are then fractionated by subjecting the particles to a current of electrical energy sufficient to induce rapid heating and vaporization of interstitial liquids within the particles causing the particles to burst. The fractionated products are then separated from each other, producing de-ashed product.

[0023] In the simplest and preferred embodiment shown in FIG. **1**, any excess or free water in the as-mined coal, peat or biomass fuel is drained or siphoned off during coarse grinding and is removed together with any gangue. Only a coarse grind is necessary for this process. The grind must be sufficient to permit removal of the free water and gangue in the raw fuel. In comparison to traditional de-ashing processes, a coarse grind will minimize the power requirements for this step.

[0024] The coarse ground fuel is then subjected to a high current pulse of electrical energy to induce rapid heating, as shown in FIG. **1**. The sudden internal heating by electrical currents causes high-pressure expansion of the fluids in the organic component, releasing these fluids in a vapor form, which leads to the immediate disintegration of the solid carbonaceous natural fuel into fine particles.

[0025] The disintegration of the coarse fuel particle into organic carbon and the inorganic ash occurs because of differences in the nature and porosity of the fuel particles. The organic component within the coarse fuel particle contains a pre-existing network of fine canals that are a fossilized product of biological structures. These are present in coal, peat and biomass, for example as the hollow stems of grasses. The canals contain moisture. Such biological canal network does not permeate the ash component of the fuels. It is the sudden heating of the liquid within the canals that causes an explosive release of water vapor (a thousand fold increase in volume), breaking the coarse ground fuel particles apart and separating the organic fraction from the inorganic, each fraction inherently having different particle sizes.

[0026] In the preferred embodiment, the electrical current is delivered by electrodes placed across a flowing stream of ground particles for direct resistance heating. In an alternative embodiment, the current is delivered by an induction coil, which surrounds the stream of particles. Other means will be evident to those skilled in the art. The amount of current and voltage is only enough to induce rapid heating and vaporization of interstitial liquids within the particles and bursting of said particles. In the process, the coal never reaches ignition temperature.

[0027] The exit stream from this disintegration or fractionation step is organic matter, vapor and ash. In this fractionation step, a rapid flow of the released gaseous fluid from the coarse fuel particles entrains the particles in the exit stream. This is shown in the preferred embodiment diagrammed in FIG. **1**.

[0028] In the next step of the preferred embodiment, the stream enters a bed where the particles are separated by fluidization and gravity. Thus, separation of the two fractions occurs as a function of particle size, more specifically as a function of the ratio of particle surface area to volume. The lighter, finer organic particles flow out of the bed at the top in the gaseous stream, while the larger ash particles tend to drop out for disposal. Other means of particle separation may be employed.

[0029] In the next step of the preferred embodiment, the gaseous stream containing the organic particles is introduced into a cyclone separator, which separates the solids from the water vapor. Other means of separating water vapor from the organic particles may be employed. The water vapor may be discharged directly or condensed to a liquid and discharged.

[0030] In an alternative embodiment shown in FIG. 2, after the coarse grind, the ground fuel is soaked in a liquid methanol bath. The aforementioned canals can also be permeated with fluids other than water, which in this embodiment is methanol. Enhancing the liquid supply within the canals can enhance the performance of the disintegration step. Water may still be present in the canals, but soaking in methanol swells the organic fraction of the coarse ground particles and allows methanol to penetrate and occupy the interstitial canals of the organic fraction. The methanol-saturated coarse ground particles are then suddenly electrically heated as previously described. The electrical current similarly causes the methanol to explosively volatilize, breaking apart the raw particles. Here again, the amount of current and voltage is only enough to evaporate the methanol and water content. In the process, the coal never reaches ignition temperature.

[0031] In this alternative embodiment, a large volume of vaporized methanol and residual water vapor carry the ash and organic particles into a fluidized bed where the larger ash particles are separated from the lighter smaller organic particles. The effluent from the fluidized bed is sent to a cyclone separator where the fine de-ashed organic coal, peat or biomass particles are collected. The gaseous methanol and residual water vapor is sent to a condenser for recovering the methanol. The methanol is separated from the condensed residual water by distillation and is recycled to the methanol-soaking vessel.

[0032] For coal, an estimate of the amount of energy required to drive the Popcorn De-Ashing Process can be made based on the maximum water content of a lignite and bituminous coal. A lignite coal contains about 0.462 g-mol of water per g-mol of moisture and ash free coal. It, thus, takes 4.62 Kcal of electrical energy to volatilize this water content in a mole of coal.

[0033] The sensible heat required to raise the temperature of the coal a maximum of 100° C. is negligible compared to the latent heat of vaporization required to turn the liquid to a vapor. The higher heating value (HHV) of lignite is 110.3 Kcal/mol of moisture and ash free coal. Thus, the amount of energy to de-ash lignite by the Popcorn De-Ashing Process assuming a combined cycle electricity production efficiency of 60%, is about 7.0% of the lignite higher heating value, which is the maximum energy efficiency penalty that can be incurred by the Popcorn De-Ashing Process. A de-ashing process with this small a penalty on the overall thermal efficiency of an electrical power plant would be a significant improvement over the state of the art. A similar penalty is expected for the embodiment using a methanol soak.

[0034] For a bituminous coal, the water content is only 0.086 moles of water per g-mol of moisture and ash free coal. Since the HHV of bituminous coal is 119 Kcal/mol, at 60% electrical cycle efficiency, it takes only 1.2% of the higher heating value of the bituminous coal to de-ash by the Popcorn De-Ashing Process and this represents a maximum loss in energy efficiency of about 1.2%.

[0035] While there has been described herein what is considered to be the preferred exemplary embodiments of the present invention, other modifications of the present invention shall be apparent to those skilled in the art from the teachings herein, and it is therefore, desired to be secured in the appended claim all such modifications as fall the true spirit and scope of the invention. Accordingly, what is desired to be secured by Letters Patent of the United States the invention as defined and differentiated in the following claims in which.

What is claimed is:

1. A process for de-ashing coal, peat and biomass comprising the steps of,

(a) grinding a coal, peat or biomass fuel into particles and while doing so, removing non-interstitial liquids and any gangue;

(b) fractionating the ground particles by subjecting them to a current of electrical energy sufficient to induce rapid heating and vaporization of interstitial liquids within the particles and bursting of said particles wherein the exit stream is organic matter, vapor and ash;

(c) removing the ash from the exit stream;

(d) removing the vapor from the stream; and

(e) using the organic matter as a de-ashed product.

2. The process of claim 1 further comprising the steps of soaking the ground particles in a working fluid prior to fractionating the particles; condensing the vapor removed from the stream to a liquid; separating the water from the working fluid in the liquid; and recycling the working fluid back into the process.

3. The process of claim 2 wherein the working fluid is methanol.

4. The process of claim 1 wherein the step of removing the ash from the exit stream is accomplished in a fluidized bed.

5. The process of claim 1 wherein the step of removing the vapor from the stream is accomplished by cyclone separation.

6. The process of claim 1 wherein the current of electrical energy is produced by electrodes placed across a stream of flowing ground particles for direct resistance heating.

7. The process of claim 1 wherein the current of electrical energy is produced by induction with a coil configuration surrounding a stream of flowing ground particles.

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