SWITCH GRASS FUEL OBJECTS WITH HIGH HEAT OUTPUT AND REDUCED AIR EMISSIONS DESIGNED FOR LARGE-SCALE POWER GENERATION

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ABSTRACT

A Novel fuel object comprised of a proportion of switch grass and a proportion of wood fiber combined with a basically reacting compound. The fuel comprises fiber of the appropriate size and moisture content combined with an inorganic base. An appropriately sized fuel object is readily manufactured, provides high heat output, is consistent in fuel characteristics, and is sized and configured for use in power generation facilities. Based on fiber selection and processing, the fuel object may be used in a variety of current power generation technologies including stoker, fluidized bed, gasifier, cyclonic, direct-fired, and pulverized coal technologies, and results in significant reduction of air emissions (including sulfur dioxide, nitrogen oxides, hydrochloric acid, carbon monoxide, carbon dioxide, and mercury) compared to coal with no loss of boiler or furnace efficiency.
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FIELD OF THE INVENTION

[0001] The invention relates to a high-energy, low-emission solid fuel made from natural renewable feedstocks.

BACKGROUND OF THE INVENTION

[0002] In large part, energy generation in the United States and worldwide is based on combustion of conventional non-renewable fossil fuels such as coal, oil byproducts, petroleum-based oils and natural gas products. These energy sources provide a source of energy for power plants, industrial facilities, and institutions, however, they are not renewable in nature, have significant environmental impacts, are decreasing in supply, and increasing in cost. Continued use of these fossil fuel energy sources results in cumulative environmental impacts including increased local and global concentrations of greenhouse gases, sulfur dioxide, nitrogen oxides, and mercury.

[0003] The decreasing supply and environmental impacts associated with fossil fuel use have led to consideration of potential for energy derived from combustion of natural products, typically cellulosic materials. Many of the natural sources comprising potential cellulosic fuels have not achieved commercial success in the past due to a variety of problems including high moisture content, low fuel heating value, impurities in the fuel, inconsistent fuel characteristics, transportation costs, difficulties in handling, and high processing costs. Further, such materials often have combustion problems or composition that result in the formation of adverse emissions and substantial quantities of ash.

[0004] We have found, in the energy market segment, a substantial need for a new cellulosic based fuel containing substantially no conventional BTU source from fossil fuels such as coal, petroleum, natural gas or other such non-renewable sources. This need relates to a fuel that has a substantial heating value, is consistent in nature, is low in moisture, can be readily made at low cost, can be transported and handled at low cost, can be used in existing solid fuel systems with little or no modifications, has lower emissions than fossil fuels, and is specifically adapted for use in modern power plant installations.

SUMMARY OF THE INVENTION

[0005] We have now found a fuel source that provides a substantial heat output satisfactory for use in large-scale power generation, even in the absence of coal, oil, gas or other conventional fossil fuels. A formed briquette or object is comprised of a blend of cellulosic material including switch grass and wood. As used herein, the term "cubed," "object," "briquette," "formed object," or "fuel object" are roughly synonymous and refer to a discrete particle of any size or shape that contains the natural cellulosic materials described herein. The major dimension of the fuel object is less than about 6 cm. The volume of the fuel object is about 10 to 100 cm³. "Conventional fossil fuel" refers to coal 20 products including bituminous coal, anthracite coal, peat, coke and coking by-products and to petroleum products such as oil, gas, natural gas liquids and products derived from shale and tar sands.

[0006] We have found that moisture content and particle size of the switch grass and wood fiber particles in the final fuel object are important for product formation, handling, and effective combustion.

[0007] We have found that the addition of an effective amount of a chemical base material reduces corrosive and acidic byproducts from the combustion of the cellulosic materials and reduces emissions of sulfur oxides, nitrogen oxides, hydrogen chloride and other acidic materials. The processing and blend of materials provides a high energy output without the addition of any fossil fuels such as coal, oil or natural gas as found in prior art materials.

[0008] We have also found that the fuel object of the invention can be made without conventional binder materials such as that used in forming a number of the prior art materials. Such binders, in the prior art, are typically polymeric binders or are additional lignent or hemi-cellulosic materials.

[0009] We have found that the fuel object, based on sizing and specifications, may be used immediately in existing solid fuel energy facilities (including those employing stoker, fluidized bed, gasifier, cyclonic, direct-fired, and pulverized coal technologies) and operate with an efficiency and higher heating value similar to some coals with a significant reduction in air emissions per million BTU of energy output compared to fossil fuels.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 shows the fuel object is a densified object of processed switch grass, wood and inorganic base.

[0011] FIG. 2 shows a flow chart of the process for forming the Fuel object of the invention.

DETAILED DESCRIPTION

[0012] The embodiment that is the subject of this application includes a fuel in the form of an object, briquette, cube or other such formed object comprised of switch grass, wood and an inorganic base. The invention involves a fuel object processed, sized and configured for use in large-scale modern combustion energy generating systems. Composition, particle size, moisture content, and fuel object size and structure, result in the fuel object having a high energy value, low emissions upon combustion, and highly efficient combustion, in a range of commercially available combustion technologies.

[0013] A fuel object can have a volume of about 10 to 100 cm³; does not need to be symmetrical, but it is preferred that the fuel is in the form of an object substantially symmetrical in shape such as cylinder, cube, solid parallel-piped or the like. A fuel object can be roughly a cylinder, rectangular prism or a cube that is 1 to 6 cm on a side. Typical density of the fuel object is 30 to 40 lbs/ft³.

[0014] The fuel object typically comprises about 60 to 80 weight percent switch grass and 20 to 40 weight percent wood. The switch grass component has a particle size of about 80 to 25,000 microns with about 85 percent of the particles greater than 1,000 microns. The wood fiber has a particle size of about 100 to 30,000 microns with about 90 percent of the particles greater than 1,000 microns.

[0015] The reduction size of the switch grass and wood fiber to these proportions provides an input to the process that forms the fuel object leading to a mechanically stable fuel object that can be manufactured, stored, transported and used
in modern combustion installations as is or is easily comminuted to a small particle size depending on the nature of the combustion process. 

[0016] Chemical bases that can be used in a fuel object of the invention include typically alkali metal and alkaline earth metal bases. Such bases can be made from sodium potassium, calcium, magnesium, and other similar metal species. The base can be used in the form of oxides, hydroxides, carbonates, bicarbonates, phosphates, and any other inorganic anion that produces a basically reacting solution, a pH greater than 7.5, when the base is mixed in at an amount of about 0.5 to 10%. The important characteristic of the chemical base is that during the combustion process the chemical base can react with combustion byproducts such as sulfur oxides, nitrogen oxides, chloride, hydrochloric acid and other acidic producing gaseous species neutralized such species and substantially reduced the effects of corrosive action on combustion equipment. Specifically, switch grass has higher chlorine content than wood and use of the base additive helps reduce chlorine/chloride gases upon combustion of the fuel object. A preferred base to neutralize acids in combustion is a bicarbonate or dolomite.

[0017] The fuel objects have a typical heating value of at least about 7,000 BTU/lb. (about 3,500 cal./g); about 7,500 BTU/lb. (about 3,650 cal./g) and typically at least 8,000 BTU/lb. (about 4000 cal./g) all on a dry basis.

[0018] Detailed Description of the Drawings

[0019] FIG. 2 is a diagram of the process for the manufacture of the fuel object of the invention. The process 500 includes, as primary processing stations, raw materials and fuel storage 501, raw materials dryer unit 503, a cooling unit 504 and a cubing or object forming unit 505. These primary stations take blended wood fiber and renewable fuel component, adjust particle size, reduce moisture to a preferred level, cool the material and then form the fuel object as needed. Once formed, the fuel is then stored or transferred to an industrial combustion or burn unit (not shown).

[0020] The raw materials used in making the object of the invention is delivered to and stored in raw material delivery and storage unit 501. That material is then transferred to a pretreatment screen 511 for the purpose of separating fines from useful material. Useful material is then transferred to a pretreatment hammer mill which adjusts the fiber size to appropriate dimensions for final object formation. Fine materials from both the prescreening, pretreatment and from the hammermill are transferred to the cowl exhaust bag house 515 through the conduit A-A. The sized fuel is transferred to a feed bin 512 for temporary storage. The sized fuel source is then transferred using a dryer and feed conveyor 513 to the dryer drum 503 for drying purposes. The output from dryer 503, having moisture content of about 0.1 to 14 wt. % moisture, is then directed to drop out chamber 514(a) that separates fines from the appropriately sized materials in a dried form. The fuel for the dryer 503 is generated by Burner 506 and blending chamber 507. Fuel for the burner 506 is stored in bin 510. Fuel is transferred to the burner 506 through transfer line B-B from bin 510. Heat and recycle gas stream from dryer 514b is sent conduit 508 through chamber 507 to the dryer 503. Heat is recycled to the burner 506 through conveyer 509.

[0021] The fines are directed to cyclone dryer 514(b) while the appropriately sized materials are directed to cooling drum in feed conveyor 517. Exhaust from the cyclone material is directed to recycle fan 522 which directs the exhaust either to ambient air or to the recycle through blending chamber 507.

The cold exhaust bag house 515 takes fines from the screen and hammermill station 511 and from the cubing stations 505. Those bag house fines are collected on the particulate conveyor 516 which are combined from the output from the cyclone dryer 514(b) and are directed to the pulling drum and feed conveyor 517. Cooling drum 504 cools the particulate material from the infeedment conveyor 517 and then conveys that material on conveyor 519 to the fuel object formation stations 505. Optionally, if the cooling drum is not required for processing the fiber, the fiber before entry into the cooling drum in conveyor 517 can be directed to a dryer bypass bulk conveyor 518 and then to an optional dryer cooling drum bypass feed conveyor 523 that directs the fiber to the object formation stations 505. Fines from screen 511, through airlock 521, the object forming units 505 and from drum 504 or conveyor 517 are directed to baghouse 515. Air is vented to ambient from baghouse 515 from vent 520. The input material placed in delivery and storage unit 501 is typically preblend with the appropriate amount of wood fiber and renewable fuel source. Once formed, the fuel objects of the invention can be stored in product stockpile 502 and then transferred to a combustion unit (not shown) for energy generation.

[0022] Reduced Air Emissions

[0023] The composition of the fuel and base additive are designed to minimize air emissions from combustion of the fuel object. The fuel objects contain less than 0.5 percent sulfur by weight percent and therefore emit approximately 95 percent less sulfur dioxide emissions than derivation of a similar amount of energy from coal. Because wood and switch grass are biogenic in nature, combustion of the fuel object is considered carbon neutral under carbon registries and trading programs in place in the United States today and therfore results in a 100 percent reduction in creditable greenhouse gas emissions than derivation of a similar amount of energy from coal.

[0024] Object and Particle Size

[0025] The size and density of the fuel object is significant in that it allows for ease of handling, transportation, storage and conveyance in most power generation facilities. Object size also is important in that it allows the fuel object to burn on the grate of stoker-type combustion units and not combust prematurely.

[0026] Particle size within the fuel object also is significant in both manufacturing a fuel object that maintains its integrity though shipping and handling and that burns efficiently. Efficient combustion reduces emissions of nitrogen oxides and carbon monoxide and leaves minimal residue, such as ash, which would have to be disposed in a waste site. Sizing of the fuel particles also is critical to allow a fuel object to break into discrete particles in certain applications such as pulverized coal-type units.

[0027] Combustion Efficiency

[0028] The blend, composition, moisture and size of the fuel object allow efficient operation in existing power generation facilities. We anticipate no loss of boiler or furnace efficiency when using the fuel object when compared to use of coal.
[0029] **Switch Grass**

The term “switch grass” refers to a summer perennial grass native to North America with the technical name of *Panicum virgatum*. Switch grass is a natural component of the tall-grass prairie species that covers most of the great plains but is also found in prairie soils of Alabama and Mississippi. Switch grass is naturally resistant to many pests and plant diseases and is capable of producing high yields with very low application of moisture and fertilizer. Switch grass can also be tolerant of poor soils, flooding, and drought.

[0031] There are two main varieties of switch grass upland and low land types. Upland types can grow to 6 feet tall and are adapted to well drained soils. Low land types grow up to 12 feet tall and are typically found on heavy soils and bottom lands. A number of varieties have been found for forage sources. As such, switch grass is a useful source of relatively low moisture cellulosic material that can be produced in large volumes for energy production.

[0032] **Wood Fiber**

[0033] The term “wood fiber” refers to a product derived from some part of a tree as that term is commonly used in the art. A number of direct products and byproducts can be derived by taking trees or portions of trees and reducing their particle size. The term “wood fiber” may refer to materials derived from fruit, leaves, sap, bark and other such tree byproducts. Wood fiber is typically derived from either the woody part of the tree within the bark and typically refers to either wood-like components of tree trunks, tree limbs and tree roots. Wood fiber is typically primarily cellulosic in nature but is known to be derived from wood cells that typically comprise a substantial proportion of cellulosic materials in combination with lignin and hemicellulosic materials in a fibrous woody cell structure. Wood fiber can be derived from a number of tree sources including both hard and soft woods. Such wood fiber materials can be derived from the processing of trees into sized lumber, the byproduct of clearing and shredding trees, the byproducts derived from any process that begins with a wood containing plant part leading to the formation of a substantially cellulosic wood fiber material.

**General Method of Manufacturing a Fuel Object**

[0034] The process for manufacturing fuel objects described herein starts by grinding cellulosic material. The cellulosic material can be ground by feeding a pulverizer or grinder to reduce the cellulosic material to a predetermined size. The switch grass component is ground to a size of about 80 to 25,000 microns with about 85 percent of the particles greater than 1,000 microns. The wood fiber is ground to a particle size of about 100 to 30,000 microns with about 90 percent of the particles greater than 1,000 microns.

[0035] After grinding, cellulosic materials a may be fed through a dryer. A dryer ensures that moisture content of the cellulosic material is at less than about 14 wt. % and often less than 10 wt. %. Preferably, moisture of a finished fuel object should be between 7 wt % to 14 wt. %. Moisture content of the cellulosic material is significant to the integrity of a fuel object since moisture content of cellulosic material assists in bonding all of the materials in the composition prior to and following the pelletizing of the composition. However, an increase in the moisture of the cellulosic material beyond a disclosed limit would jeopardize the characteristics of the fuel object and its ability to withstand being transported. It is important that a fuel object maintain its integrity prior to precombustion processing or burning. A fuel object should be rigid enough to be handled mechanically without crumbling. Achieving proper and desired moisture content for a fuel object is critical to achieve a desired heat output and in maintaining the ability to transport fuel objects without harming its integrity, shape, or composition.

[0036] After the cellulosic material has been sufficiently dried to desired moisture content, the cellulosic material can be fed through a secondary pulverizer as necessary. A secondary pulverizer can be the final grinding process for the cellulosic materials.

[0037] The base additive may be added once organic components have been appropriately sized and conditioned. Components of a fuel object may be further blended together by means of a blender, drum or other mechanical equipment.

[0038] A densification process can create a final composition of materials. Densification allows materials to be mixed and blended in a controlled manner with other particles comprising a fuel object. After the components of a fuel object have been sufficiently blended, the components/materials are processed and forced through a shape forming die. Such equipment could include commercially available machines such as those produced by Warren and Baerg. Shaping equipment forces a blended composition through a die of a forming machine, thereby creating a fuel object. Faceplate temperature of the extrusion equipment typically is between 165°F and 185°F. A fuel object exits a shaping die at a temperature of about 110°F and not greater than 145°F. When a fuel object exits the shaping die, there can be a slight coating on the external surface of the object. This coating can comprise lignin, which is a naturally occurring substance of the cellulosic material. Shaped objects are then transferred to the finished product conveyor/cooler.

[0039] Following formation, fuel objects are cooled down by a cooling means including, but not limited to, an air cooler, an air conditioner, or liquid nitrogen. The cooling process causes the objects to harden into the shape created by the forming equipment and allows components of the object to maintain their integrity. In an embodiment, fuel objects are placed through a shaker screen after sufficiently cooling and hardening. This process separates fine and discrete particles of the composition. The discharge for the fine particles can be separated from a fuel object and are again recycled or forced through a shaping die. This process minimizes the potential for waste generated by any excess particles that comprise a fuel object. The final object maintains its structure and provides an ease of handling and a highly consistent product for good combustion at the end user power facility.

**Use Integration at Power Facilities**

[0040] The fuel object is designed for immediate use in existing solid fuel fired systems. This may include facilities that produce heat or steam for cooling, heating, or electrical generation or direct induration or drying of a product. Such facilities may include power plants, industrial furnaces and boilers and steam and power generation facilities at large institutions such as universities and hospitals. The formed, shaped and densified fuel is ideal for transport by truck, rail, and conveyor and storage in bunkers and silos that are designed for transport and storage of coal. In most instances the objects may be unloaded, stored, and transported at a facility by the existing mechanisms that transport coal without physical modification.

[0041] The fuel object is ideal for use in stoker fired systems where fuel is discharged on a large grate and burns on the
grate over a period of time. The fuel object also works in systems where fuel is pulverized prior to entry of the combustion chamber and then combusted in suspension such as pulverized coal, cyclonic combustion, and direct-fired units. Because individual particles in the fuel object are reduced in size prior to cubing and dried to a low moisture content, they burn efficiently and with low emissions when fed through such suspension-based systems and do not result in lagging or increased ash or sparklers from unburned fuel. Because the fuels have a high heating value, burn efficiently, and reduce emissions, facilities that use the fuel object may reduce emissions without capital expenditure on emission controls and maintain unit efficiencies.

EXAMPLE

Switch Grass Fuel Object

A fuel object derived from switch grass and wood was produced and was substantially free of coal. The switch grass fuel object was substantially cylindrical in shape with a length of 5.4 cm and a diameter of 2.6 cm.

FIG. 1 shows an embodiment of the invention.

<table>
<thead>
<tr>
<th>Volume</th>
<th>14.04 cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>8.27 wt. %</td>
</tr>
<tr>
<td>Amount of particulate derived from switch grass/fiber size 80 to 25,000 microns</td>
<td>63.2 wt. %</td>
</tr>
<tr>
<td>Amount of particulate derived from wood fiber/fiber size 100 to 30,000 microns</td>
<td>34.4 wt. %</td>
</tr>
<tr>
<td>Sodium bicarbonate (inorganic base)</td>
<td>2.4 wt. %</td>
</tr>
</tbody>
</table>

In testing, this switch grass fuel object provided about 7,386 BTU/pound (lb.).

Although the invention has been disclosed in the context of certain embodiments and examples, it will be understood by those skilled in the art that the invention extends beyond the specifically disclosed embodiments to other alternative embodiments and/or uses and obvious modifications and equivalents thereof. Accordingly, the invention is not intended to be limited by the specific disclosures of preferred embodiments herein, but instead by reference to claims attached hereto. Reference to a single element in the claims is not intended to exclude one or more of the same element. The above specification, examples and data provide a complete description of the manufacture and use of the composition of the invention. The invention resides in the claims hereinafter appended.

What is claimed is:

1. A fuel source comprising a object having maximum dimension of about 6 cm, a volume of about 10 to 100 cm³, a moisture content of less than about 14 wt. %, the fuel comprising:
   (i) about 60 to 80 wt. % of a particulate derived from switch grass having a particle size of about 80 to 25,000 microns;
   (ii) about 20 to 40 wt. % of a wood fiber having a particle size of about 100 to 30,000 microns;
   (iii) about 1-10 wt. % of an inorganic base; and
   (iv) wherein the fuel source is substantially free of coal as a heat source and the fuel provides at least 7,000 BTU-lb⁻¹ (3500 cal-gm⁻¹).

2. The fuel source of claim 1 wherein the object comprises a cubic or cylindrical unit with a side dimension of 2 to 6 cm.

3. The fuel source of claim 1 wherein the object comprises about 60 to 80 wt. % of a particulate derived from switch grass having a particle size of about 80 to 25,000 microns.

4. The fuel source of claim 1 wherein the object comprises about 20 to 40 wt. % of a particulate derived from wood fiber having a particle size of about 100 to 30,000 microns.

5. The fuel source of claim 1 wherein the inorganic base comprises about 1 to 10 wt. % of sodium bicarbonate, dolomite or mixtures thereof.

6. The fuel source of claim 1 wherein the BTU source of the fuel consists essentially of about 60 to 80 wt. % of switch grass and 20 to 40 wt. % of wood fiber wherein the fuel source is substantially free of coal as a heat source and the fuel provides at least 7,000 BTU-lb⁻¹ (3500 cal-gm⁻¹).

7. The fuel source of claim 1 wherein the density of the fuel object is 30 to 40 lbs/ft³ (0.5 to 0.65 gm-cm⁻³).

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