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(54) PROCESS FOR GASIFYING ORGANIC FIBROUS MATERIAL AND THE PRODUCT THEREOF

(71) I, RUDOLF WILHELM GUNNERMAN, a citizen of the United States of America, of, 2800 City View Drive, Eugene, Oregon, United States of America, do hereby declare the invention, for which I pray that a Patent may be granted to me, and the method by which it is to be performed to be particularly described in and by the following statement:-

This invention relates to a method for producing a combustible gas and to the gas *per se.*

It has been proposed heretofore to burn wood and other organic waste materials under conditions which produce a combustible gas which can be burned as a fuel. It is known to burn wood in a vessel commonly called a gasifier or digester which is usually cylindrical with a diameter of about four feet (1.22m) and a height of about twelve feet (3.66m) or similarly proportioned vessels. Various types of wood waste such as hogfuel or other wood waste material is burned in the bottom of this high slender tank with air added slowly from the bottom. The wood contains a high percentage of water and is burned under conditions which produce a temperature of about 1200°F. (648°C) and produces a gas which contains some relatively low molecular weight hydrocarbons and oxides such as methane, carbon monoxide and carbon dioxide. In such a process the carbon of the wood only is converted into combustible gas so the quantity of heat output of the gas is low.

According to the present invention, there is provided a method of converting organic fibrous material into combustible products comprising the steps of supporting in an enclosed space a mass of combustible free flowing fibrous organic fuel pellets, igniting the fuel pellets near the bottom of the mass, flowing air upwardly through the resulting burning region; maintaining the depth of the fuel mass above the burning region and maintaining the flow rate of air upwardly through the burning region whereby the temperature in the burning region is at least 2700°F (1482°C) to carbonize said fuel pellets in the mass above the burning region producing combustible products that become mixed with gaseous combustible products obtained by oxidation of carbon when the fuel is burned; and recovering the resulting combustible products.

Compressed organic fibrous material such as sawdust or other wood waste material, peat moss, or the like made into pellets may be burned in a vessel while simultaneously maintaining a heat insulating layer of pellets over the burning mass and dispersing air substantially uniformly through the burning mass at a rate whereby the burning mass is at a temperature of at least 2700°F (1482°C). It is believed that at such temperatures, the gas that is produced contains combustible gaseous carbon compounds and gaseous nitrogen compounds produced by the chemical reaction of nitrogen with elements of the fuel such as alkali metals (primarily sodium and potassium), calcium and possible other materials contained in the fuel. It is the burning of these nitrogen containing combustion products along with those produced from the carbon of the fuel which is believed to be responsible for the surprisingly large quantity of heat produced when the combustible gas is burned.

It is preferred to co-ordinate the thickness of the fuel mass above the burning fuel with the air flow introduced into the burning fuel so that the temperature is about 3000°F (1648°C) to 3500°F (1927°C) in the centre of the burning mass. The fuel burns under these conditions somewhat like the fuel in a blacksmith's forge and the fuel pellets in the insulating layer which is immediately above the burning fuel becomes charred and the pellets are converted to a large extent into a charcoal layer. The fuel pellets should be free flowing and may be introduced continuously to the fuel bed from above at a controlled rate. Alternatively, the vessel in which the fuel is burned may be equipped with a device which monitors the height of the fuel and triggers a fuel feed mechanism when the height of the fuel bed reaches the point where additional fuel is required to maintain the insulating blanket of pellets which maintains the burning temperature at about 2700°F. (1482°C) or higher. A commerically available device sold under the trade name (BINDICATOR) may be used for this purpose.

Any suitable organic fibrous material may be used to form the pellets such as, for example, straw, corn husks, sawdust, shavings, hogfuel, wood chips, peat moss and paper. An organic fibrous material is pelletized into a form which adapts it to be burned substantially uniformly in a furnace by a process which involves adjusting the particle size of the fibrous material to not more than about 85% of the minimum dimension of the pellet to be formed, adjusting the moisture of the fibrous material to a substantially uniform content of from about 16% to about 28% by weight, and shaping and compressing the fibrous material while at the adjusted moisture content into substantially symmetrical pellets having a maximum dimension of one half inch (12.7mm) or less.

It is preferred to form a pellet by transporting an organic fibrous material such as agricultural or wood waste materials by a conveyor adapted to separate rocks, metal and other non-combustible contaminants from the wood waste to a hammer mill or the like where the organic fibrous material is ground to a substantially uniform particle size or not more than about 85% of the minimum dimension of the pellets to be formed therefrom, the ground material is then conveyed to a hot air dryer where the moisture content is adjusted to from about 16% to about 28% by weight water, and the product having the adjusted size and water content is then conveyed to a pelletizing machine equipped with its own measuring screw device for feeding the mass through the dies of the pellet mill and the resulting pellet is then dried until its moisture content is substantially in equilibrium with the atmosphere. The fibrous material is pressed at a pressure whereby the temperature of the pellet in the die is from about 325°F. (163°C) to about 350°F. (177°C).

While the moisture content of most organic fibrous material will be above 28% by weight and will require drying, it is to be understood that, if material having a moisture content below 16% is available for pelletizing, its moisture content should be adjusted by humidification or the like to a moisture content between about 16% and about 28% before pelletizing. As broadly contemplated by the invention, the moisture content may be within the broad range of about 16% to 28% by weight but it has been found that the best results are obtained when the moisture content of the organic fibrous material at the time of pelletizing is between about 20% and 24% by weight so it is preferred that the moisture content be within this more limited range. The pellets may be freed from surface moisture by blowing air over them immediately after they emerge from the pellet mill.

It was found that by adjusting the organic fibrous material particle size to about 85% or less of the minimum dimension of the pellet to be formed and adjusting the moisture content prior to compression to from about 16% to about 28% by weight free water content, preferably about 20% to about 24%, a pellet having a protective wax-like surface formed by exudation from the fibrous material which will burn substantially uniformly without the formation of an undesirabble quantity of ash is produced provided that the shaping and pressing is conducted at a temperature of from about 325° (163°C) to about 350°F (177°C). In order that the burning rate of a mass of pellets will be substantially uniform, the pellets are dried after they have been formed to a substantially uniform moisture content which is in close equilibrium to the surrounding atmosphere. These pellets can be used to advantage for making a combustible gas in accordance with this invention. The pellets can be easily conveyed on commercially available inclined belt conveyors or with conventional stoking equipment. The pellets are of substantially uniform shape and dimensions and may be conveyed pneumatically if desired.

It is preferred that the pellet be substantially cylindrical, parallelepipedal or the like having a maximum cross-section within the range of from about 1/8 inch (3mm) to about 1/2 inch (12.7mm). The actual pellet size is determined by the exterior surface area and the composition of the material within the pellet. The maximum thickness of the pellet in any one direction will seldom be more than about one inch (25.4mm) and will seldom be below about 1/8 inch (3mm). The absolute density of the pellet produced is above 50 pounds per cubic foot (800 kg/m^3) and often is from 65 to 90 pounds per cubic foot (1041 to 1442 kg/m^3) or higher at 13% moisture content. The density of the particles used to make the pellets is about 10 to 30 pounds per cubic foot (160 to 480 kg/m^3) at the same moisture content. The absolute density of a commercial Pres-to-log, on the other hand, is less than 65 pounds per cubic foot (1041 kg/m^3) and thus lighter than water.

In carrying out the process of the invention it is not necessary to use the tall slender vessel of the known art for producing carbon containing gases from wood waste materials. In fact, it is preferred to use a vessel which is somewhat larger in cross-section than it is high. For example a cold rolled steel vessel having an upper right cylindrical chamber of circular section and a substantially frusto-conically shaped bottom portion may be used. This vessel has a closed top provided with a removable cover for access to its interior and a centrally disposed opening for the introduction of fuel to the fuel bed. A pipe may be welded to the top with its end about the fuel feed opening and a conventional air-lock installed in the pipe to avoid loss of gas. A small conically shaped bin for storage of fuel may be installed above the air-lock or any other reliable source of fuel pellets may be connected to the pipe. A monitoring device such as a BINDICATOR may be installed on the tank with its responsive element at the desired level and connected to a solenoid actuated valve in the pipe between the bin and airlock for automatic control of the height of the fuel bed in the vessel. For safety purposes, a safety valve responsive to say about five pounds pressure may also be installed in the top of the vessel.

A perforated stainless steel plate for supporting the fire bed is disposed across the tank at a point spaced from the apex of the conical bottom of the vessel. This plate has substantially evenly spaced holes of substantially equal cross-section so that air entering from below is dispersed substantially uniformly through the fire bed. An opening is provided in the wall of the vessel adjacent to the fire bed for the insertion of an acetylene torch or other device for initially igniting the fuel supported on the plate. Preferably, an imperforate margin is left around the periphery of the plate so that air does not enter the fuel bed along the sides of the vessel. In this way a protective layer of non-burning fuel is provided around the fuel bed against the inner wall of the vessel and it is not necessary to apply insulation to the vessel wall. However, in some instances it may be advantageous to provide a shroud or jacket about the bottom of the vessel and to circulate the air to be introduced into the vessel through the shroud to preheat the air. In other embodiments, it may be desirable to line at least that part of the vessel wall about the fire bed with a ceramic such as fire brick.

An opening if provided in the apex of the bottom portion of the vessel for introducing air below the perforated fuel bed supporting plate. A pipe or other conduit is attached to the vessel around the opening and to a source of air. The fitting used to connect the pipe to the vessel may be T-shaped with one leg of the T disposed vertically for collecting a material in the fuel such as rocks, metal scrap or the like which does not burn and falls through the perforations in the plate. A cap can be provided on the leg to be removed for periodically dumping the non-combustible material.

The gas produced by burning the fuel is removed from the vessel at a point above the fuel bed. An opening may be provided in the sidewall of the vessel for this purpose. The opening may be attached by a pipe directly to a burner which will burn the fuel or it may be attached to a suitable tank or other storage vessel for the gas.

The combustible gas produced by this invention may be used for producing energy in any suitable apparatus which burns a combustible gas. For example, it may be used to produce steam for heating or for industrial purposes or it may be used in the generation of electricity. When this mixture burns a much higher quantity of heat is produced than would be produced if only carbon products from the fuel were present in the gas. In one gas generator using the above method, it was found that at an air pressure of about one pound per square inch (6.8948×10^{-4} h bar) burned to produce about four times the quantity of heat obtained when fuel was burned in an open furnace under normal conditions. During one hour in which about 104 pounds (47 kg) of fuel was burned in about 250 cubic feet (70 m^3) of air per minute at a pressure of about 5 1/2 inches of water (10.3 torr), a gas was produced which, when burned, developed 4×10^6 BTU (4220×10^6 joules). The same fuel pellets when burned under normal conditions to produce reaction products only from carbon produced about 9,000 BTU per pound (20,934,000 J/kg) or 936,000 BTU (987,480,000 J) for 104 pounds (47 kg). These tests were made in a Heil Drum Dryer at 14×10^6 BTU (14770×10^6 joules) per hour capacity while burning natural gas as normal fuel. After operating the gas generator for seventy two to ninety six hours continuously, eight tests of one hour duration each were made with the production of the same quantity of heat.

The invention will now be described by way of example only with reference to the accompanying drawing showing a preferred embodiment of an apparatus for carrying out the method in accordance with the invention. The apparatus comprises a digester 10 which may be conveniently about five feet (1.5m) in diameter and about four feet (1.2 m) deep. Digester 10 has a substantially flat top 11 and a frusto-conically shaped bottom 12. The wall of the frusto-cone is sloped at about 30° - 45° with respect to the horizontal. An opening 13 (preferably about 3 inches (76mm) or 4 inches (102mm) in diameter is provided at the apical region of the frusto-conically shaped bottom and a pipe 14 connected to a source of air under a positive pressure is secured to the tank about the opening. A perforated stainless steel plate 15 is disposed above the air intake opening across the tank to provide a base for supporting the fuel bed 16. An acetylene torch 17 is inserted in an opening in the wall of the digester to ignite the fuel. As shown in the drawing, the fuel is fed from a bin 18 through airlock 19 and pipe 20 to provide a conically shaped fuel bed 16 above the fire bed 21 on plate 15. At an air flow of up to about 250 cubic feet (70 m^3) per minute (at a pressure of 5 1/2 inches water) and a fuel consumption of about 100 pounds (45 kg) per hour the temperature of the fire bed 21 is about 3000°F (1648°C) to about 3500°F (1927°C).

In an apparatus of the dimensions described, plate 15 may be provided with one-four inch (6.3 mm) holes drilled on one-half (12.7mm) centres to insure substantially uniform air dispersion through the fuel bed. An imperforate margin of about two inches (50.8mm) or more in larger tanks and narrower in smaller tanks is left around the edge of plate 15 so that fuel can accumulate around the fire bed and insulate the digester wall from the heat of the fire bed. The pressure in the tank may be maintained at about one to two pounds force per square inch or less (6.8948×10^{-4}h bar to 13. 7896×10^{-4}h bar). As illustrated in the drawing, the fuel mass immediately above the fire bed is converted into charcoal before it falls into the fire bed and is consumed. A safety valve 20 responsive to a pressure of about five pounds force per square inch (34.474×10^{-4} h bar) is disposed on top 11. A manhole 23 for access to the inside of the digester 10 is provided in the flat top.

In the embodiment illustrated in the drawing, the fuel is fed from above and assumes a substantially conical shape above the fire bed. The gas produced by the burning of the fuel passes through the fuel bed into the area about the conically shaped bed and through a pipe 24 to a burner 25. Burner 25 may be any suitable device used to generate heat by the burning of the gaseous combustion product obtained when the fuel is burned. In one example of a burner suitable for use with the apparatus described above, a shroud about 24 inches (609 mm) long and about 14 inches (355 mm) in diameter is provided about the burner. The flame developed when the gas was burned was a deep blue and was as much as two feet (o.61 m) in diameter and from 8 to 12 feet (2.44 to 3.65 m) in length depending upon the amount of air which was induced into the shroud to achieve a swirl in the flame pattern. About 5×10^6J) per hour was obtained and the amount of ash produced was negligible.

WHAT I CLAIM IS:-

1. A method of converting organic fibrous material into combustible products comprising the steps of supporting in an enclosed space a mass of combustible free flowing fibrous organic fuel pellets, igniting the fuel pellets near the bottom of the mass, flowing air upwardly through the resulting burning region, maintaining the depth of the fuel mass above the burning region and maintaining the flow rate of air upwardly through the burning region whereby the temperature in the burning region is at least 2700°F (1482°C) to carbonize said fuel pellets in the mass above the burning region producing combustible products that become mixed with gaseous combustible products obtained by oxidation of carbon when the fuel is burned; and recovering the resulting combustible products.

2. The method according to claim 1 wherein the organic fuel pellets are substantially completely converted into combustible products.

3. The method according to claim 1 or claim 2 wherein the combustible products include chemical reaction products of nitrogen from air with an alkali metal contained in the fuel pellets, or mixtures thereof.

4. The method according to claim 3 wherein the alkali metal is potassium.

5. The method according to any one of the preceding claims wherein the fuel is pelletized from an organic fibrous material such as wood particles, straw, corn husks, peat, moss and paper.

6. The method according to any one of the preceding claims wherein air is mixed with combustible products obtained by burning the fuel above the burning fuel.

7. The method according to any preceding claim wherein the thickness of the fuel mass above the burning fuel and the air flow into it are co-ordinated to give a temperature of 3000°F (1648°C) to 3500°F (1927°C).

8. A method of converting organic fibrous material into combustible products, the method being substantially as herein described with reference to the single figure of the accompanying drawing.

9. A combustible product whenever produced by a method as claimed in any one of the preceding claims.

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1581692 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*