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R. W. CHICK ET AL

2,973,306

PROCESS FOR PRODUCING CHARCOAL AND APPARATUS THEREFOR

Filed Feb. 18, 1957

2 Sheets-Sheet 1

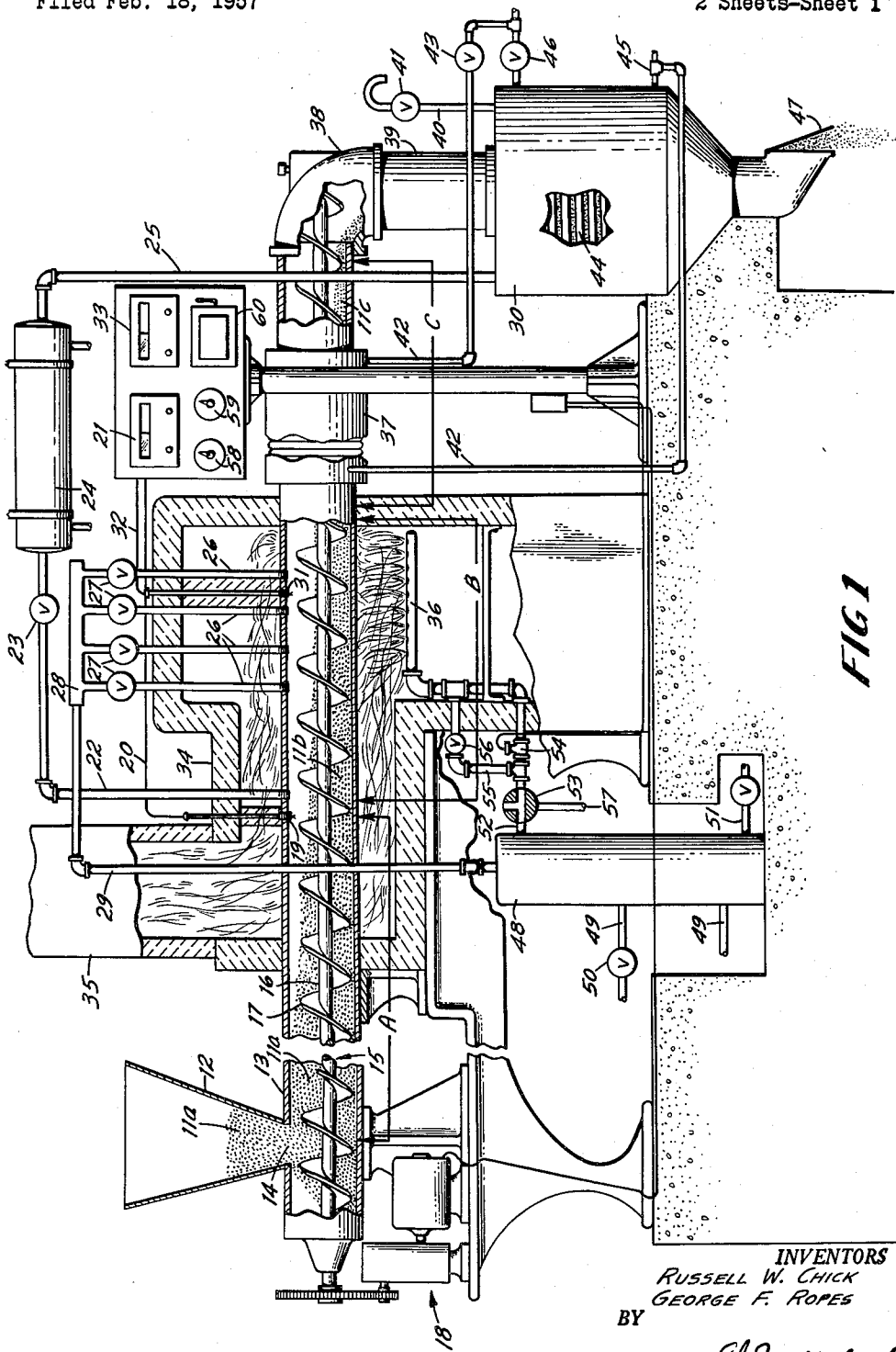


FIG 1

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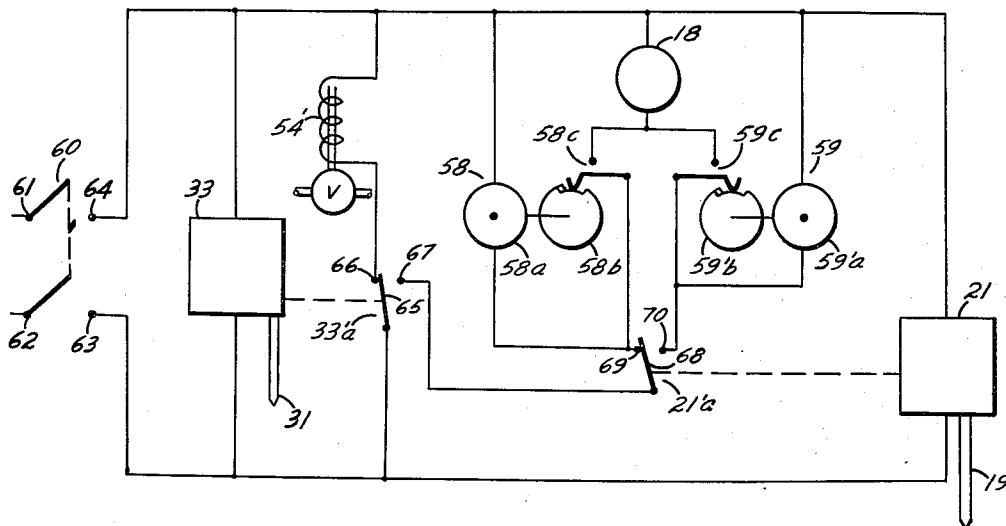


FIG. 2

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PROCESS FOR PRODUCING CHARCOAL AND APPARATUS THEREFOR

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2 Claims. (Cl. 202—21)

The invention pertains to the production of charcoal and particularly to a method for the production of charcoal and byproducts from finely divided material capable of being converted to charcoal by destructive distillation and to apparatus for performing such a method.

The basic principles underlying all known methods of producing charcoal have been known for many years. Thus, if a starting charge of a material capable of being converted to charcoal by destructive distillation is thermally decomposed in the absence (or in the presence of a limited amount) of oxygen, charcoal is formed as a residue after the volatile elements in the starting charge are driven off. Wood is the principal material best adapted and most widely used for the purpose of producing charcoal, although other organic materials may also be used.

Many variables, however, complicate production of charcoal from wood. First of all, considerable labor must be expended to cut down trees, trim them into logs of manageable size and transport such logs to the location at which they are to be converted into charcoal. Even if the cost of supplying a large number of logs from a given area be absorbed, it has been very difficult in the past to control the quality of the final product. One of the reasons for variations in the quality of the product is that wood varies greatly in physical and chemical properties from genus to genus and even from tree to tree.

The moisture content of the wood is especially critical. Unless the wood is properly seasoned, either as by air-drying for a long period or as by passing it through a drier, poor results are often obtained. Variations in the amount of sap present in the wood have a like adverse effect on the quality of the final product. Fortunately, the same drying methods that are used to eliminate variations in the moisture content of the wood are almost as effective in removing excess sap so that two separate steps are not required.

After the wood has been properly prepared according to prior art, the problem of raising it to a sufficiently high temperature to drive off the volatile elements and decompose the residue remains. Wood, being a poor conductor of heat, is difficult to bring up to the proper temperature uniformly throughout the charge, especially when almost all oxygen must be excluded to prevent combustion of the wood. However, when a certain temperature is reached, say about 300° C., an exothermic reaction takes place. By properly designing the kiln or retort in which the carbonizing is being carried out, advantage may be taken of the heat generated in this reaction. Nevertheless, it is necessary to heat the wood for hours and even days to be sure that all the wood used as a charge has been converted to charcoal. In passing, it should be noted that about the same length of time is presently required to cool newly-made charcoal as was taken to form it.

The smaller the size of the individual pieces of wood, the more difficult they are to heat. Thus, when the

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pieces of wood are reduced to the size of sawdust, heating to the required temperature is almost impossible in the conventional kiln or retort, the air spaces between individual particles of sawdust preventing conduction of heat from particle to particle. To facilitate heating, it has been recognized that a mass of sawdust must be agitated in order to be heated throughout. One way of agitating a mass of sawdust is to use a so-called rotary retort. However, known rotary retorts are cumbersome, require virtually gas-tight connections between the moving and stationary parts, and must be equipped with special inlet and outlet valves to prevent combustion of the wood or newly-formed charcoal. However, even if the most advanced design is used, known rotary retorts are ineffective in converting sawdust to charcoal. The inefficiency of presently known retorts prevents production of charcoal in a highly desirable granulated form, commonly known as fines. Many uses to which charcoal is put in industry require fines. It is evident that a process producing fines would be advantageous, since the necessity of pulverizing large pieces of charcoal would be obviated.

As mentioned hereinbefore, close control of the quality of the charcoal produced by known methods is almost impossible to achieve. Consistently high quality is rarely obtained with known equipment even when highly experienced operators are employed. The outward manifestations upon which such operators depend to determine the progress of the process, such as the color and amount of the gases being evolved as the process goes on, are at best only rough indications of the conditions inside the kiln or retort being used. Further, the necessity for human interpretation of such rough indications adds to the difficulty of holding close limits on the quality of charcoal produced by known methods.

Another deficiency of known methods of producing charcoal may be mentioned here. Although more than one known process is commonly thought to be continuous, a close analysis shows that none is. By continuous, it is meant that, in any unit period of time, substantially as much charcoal is produced as is possible from the amount of wood introduced as a charge during that period. That is, if a certain amount of wood is introduced continuously at the inlet end of a retort, a corresponding amount of charcoal is removed from the outlet end. While it is obvious that the older kiln methods of producing charcoal do not meet such a definition, it is also evident that newer methods such as exemplified by the rotary retort method do not meet the definition either. The requirement that there be special valves on both the inlet and outlet of such retorts makes it necessary that there be intermittent introduction of wood to the retort and intermittent removal of charcoal therefrom. When the wood is in the form of sawdust and the charcoal produced is in the form of fines, such intermittent action is highly undesirable.

Therefore, it is an object of the invention to provide a method of continuously producing charcoal;

Another object of the invention is to provide a method of producing charcoal of a predetermined quality;

Still another object of the invention is to provide a method of producing charcoal in the form of fines from sawdust, or other finely divided waste material capable of being carbonized by destructive distillation, and recovering byproducts to keep the process going and to provide additional products of value;

A still further object of the invention is to provide apparatus for carrying out the foregoing objects.

According to the invention in its simple and most general form, finely divided material capable of being carbonized by destructive distillation, for example, sawdust, is forced along an elongated cylindrical retort, prefer-

ably by means of a helical feed screw eccentrically mounted in the retort so that it is in close proximity to the inner wall of the retort on one side. A continuous supply of sawdust is provided from a feed bin which is disposed adjacent to the inlet end of the retort. A source of heat is arranged so as to heat the exterior of the retort at some distance from the inlet end and at the same time to heat the feed screw. The retort and feed screw, in turn, extend some distance beyond the source of heat. Two temperature sensitive control devices are disposed to detect the temperature at predetermined points along the length of the retort and to control the driving means for the feed screw in response to the temperature detected. The first of the temperature sensitive devices is disposed adjacent the source of heat. The first controller is so connected to the driving means for the feed screw that movement of the feed screw is prevented until the temperature of the retort adjacent the first controller reaches a temperature far above the temperature at which the exothermic reaction of any wood takes place. While this temperature is not critical, so long as both the retort and the feed screw radiate a substantial amount of heat, it may be changed to vary the carbon content of the charcoal produced in the retort. The second temperature sensitive controller is disposed between the feed bin and the source of heat approximately at the spot in the retort where the sawdust starts its exothermic reaction. The second controller varies the time any given amount of sawdust is in the retort, thus maintaining the degree of decomposition of the sawdust to charcoal automatically. As sawdust enters the retort from the feed bin, heat from the source of heat dries it. If the moisture content of the sawdust is too high when the sawdust reaches the position of the second controller, its moisture cools the retort, causing the second controller to operate on the driving means to slow down the feed screw. At the same time, the retort itself is so arranged that the moisture driven off from the sawdust within the retort forms a vapor seal at the feed bin, thus preventing air from entering the retort. After substantially all the moisture has been driven off, the sawdust is moved through a distilling area in the retort adjacent the source of heat. The gases evolved from the sawdust build up a positive pressure within the retort, thus keeping air from entering either end of the retort. The feed screw and retort contain between them a relatively small amount of sawdust that is easily heated above its decomposition temperature, thus permitting each particle to be reduced completely to charcoal. The feed screw agitates each particle throughout the length of the retort to facilitate this heating. After decomposition, the newly formed charcoal is forced through the remaining portion of the retort wherein it cools sufficiently that spontaneous combustion of the newly formed charcoal does not occur as soon as it passes out of the retort. The gaseous by-products of the foregoing process establish a pressure within the retort that is always positive with respect to the atmosphere. In fact, so much gas is evolved that provision must be made to remove almost all such gases to prevent the pressure within the retort from building up to undesired levels. Thus, the carbon dioxide and water vapor driven off just before the sawdust starts its exothermic reaction is directed into a storage bin for newly produced charcoal and the gases evolved by the exothermic reaction are passed through a condenser to recover condensable gases, the non-condensable gases being burned to keep the process in operation.

For a better understanding of the invention, reference is made to the following description which is to be read in connection with the accompanying drawing in which:

Fig. 1 is an isometric view of apparatus according to the invention, partially cut away better to show its internal construction;

Fig. 2 is a wiring diagram showing how the apparatus illustrated in Fig. 1 may be controlled automatically.

Referring now to Fig. 1, a practical apparatus for converting finely divided material capable of being carbonized by destructive distillation, as sawdust, to charcoal may be seen in detail. The apparatus also permits recovery of valuable distillates and the use of volatile gases evolved in portions of the apparatus to sustain the process and the use of other gases to provide a substantially oxygen-free atmosphere within the apparatus. Sawdust 11a, which may or may not be dried to remove substantially all the moisture therefrom, is placed in a feed bin 12. Since no drying means have been illustrated, it will be assumed that the sawdust 11a contains an appreciable amount of moisture. In any event, the sawdust 11a is fed into a cylindrical retort 13 through an opening 14 between the feed bin 12 and the retort 13. In the interest of simplicity no structure, as a conveyor, has been shown bringing sawdust 11a to the feed bin 12, nor has any structure, as an agitator, been shown forcing the sawdust 11a through the opening 14 without bridging. However, since such structures are well known in the art and are not essential to a complete understanding of the invention, the illustrated apparatus is very much simplified by their omission. After sawdust 11a has entered the retort 13, it is moved along the length of the retort 13 by a feed screw 15. This feed screw 15 may take several forms although it is preferably made having a shaft 16 with a helical thread 17 integrally attached to its outer surface as shown. Alternatively, the shaft 16 may be hollow to strengthen the construction of the feed screw 15 and at the same time to allow it to be heated by a flame within the shaft if desired. In this connection it has been found, however, that satisfactory results are obtained if the shaft 16 is solid and no internal heating is utilized. The pitch of the helical thread 17 may be changed as desired without affecting the invention. In fact, it may be desirable on occasion to incorporate paddles between the thread 17 in a known manner. In any event, it is highly desirable that the outer edge of the thread 17 be in close proximity to the inside of the retort 13, so as to be in thermally conducting relationship thereto. The feed screw 15 is mounted eccentrically of the retort 13 to accomplish this end. Movement of the feed screw 15 is accomplished in the illustrated case by an electric motor assembly 18 shown in outline as including a separate reduction gear and a gear train. These latter components are incidental to the invention, being illustrated only to show a practical connection between the motor and the feed screw 15. The control of the electric motor assembly 18 will be described in detail hereinafter. When the feed screw 15 is rotated, the sawdust 11a which has passed through the opening 14 is moved along the length of the retort 13 passing through three zones within the retort marked "A," "B" and "C" successively for reasons that will be pointed out in more detail hereinafter. In zone A, the sawdust 11a is dried, in zone B it is changed to charcoal 11b by destructive distillation, and in zone C it is cooled to charcoal particles 11c. At the junction of zones "A" and "B" a thermocouple 19 is positioned so as to detect the temperature within the retort 13. The thermocouple 19 is connected through appropriate lead wires 20 to a temperature controller 21. Adjacent the thermocouple 19 a pipe 22 is tapped into the retort 13. The pipe 22 is led through a valve 23 to a condenser 24. The condenser 24 is in turn connected through a pipe 25 to a storage bin 30. A number of pipes 26, in the illustrated case, four, are tapped into the retort 13 at more or less equal intervals in the zone "B." Each of the pipes 26 is led through a separate valve 27 to a manifold 28. The manifold in turn is connected by a pipe 29 to a condenser 48. A thermocouple 31 is also positioned in the hottest part of the zone "B" and connected by lead wires 32 to a controller 33. A firing chamber 34 encloses the retort 13 at the zone "B." The firing chamber preferably extends some distance into the zone "A"

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and terminates in a flue 35. A burner 36 is mounted in the firing chamber 34 as shown. It should be noted however that the particular shape or type of the burner 36 is not essential to the invention, it merely being convenient to show a conventional gas burner. The retort 13 is extended beyond the firing chamber 34 (as indicated by the zone "C"). A cooling coil 37 is disposed around the length of the retort 13 so extended. The extended length of the retort 13 is terminated in an elbow 38 which is connected by a length of pipe 39 to the storage bin 30. A vent pipe 40 having a pressure relief valve 41 is also connected to the storage bin 30 as shown. The cooling coil 37 is connected through pipes 42 and valve 43 to a source (not shown) of coolant, as water.

A cooling coil 44 is also disposed in the storage bin 30. Pipes 45 are led out of the storage bin 30 to connect the cooling coil 44 through a valve 46 to a source of coolant, again as water. It should be noted that the cooling coils 37, 44 are not essential to the invention but are advantageous in that they permit higher speeds of operation by accelerating the cooling of the charcoal particles 11c below the temperature at which self-ignition in air occurs. The bottom of the storage bin 30 may be shaped as shown, having a cover 47 to allow the contents of the storage bin 30 to be emptied when desired and to close the storage bin 30 to the atmosphere at all other times. Returning now to the pipe 29 leading from the manifold 28, it has been noted that the end of the pipe 29 away from the manifold 28 is connected to the condenser 48. The condenser 48 has also leading into it pipes 49 controlled by a valve 50 and two pipes 51, 52 leading out of it. Pipes 49 are used to bring a coolant (as water) into the condenser 48, while pipes 51, 52 are used to take off the products of the condenser 48. The pipe 51 carries off any condensate to barrels or tanks (not shown), while the pipe 52 carries off non-condensable products. A two-way valve 53 is connected in the pipe 52. In the position shown it permits the non-condensable products from the condenser 48 to pass through a solenoid valve 54 to the burner 36 or through a by-pass line 55 and a throttle valve 56 to the burner 36. When the two-way valve 53 is in its other position, a pipe 57 is connected to the burner 36. The pipe 57 is connected to a source (not shown) of gas so that the burner 36 may be fired when there are no non-condensable products emanating from the condenser 48. The purpose of the by-pass line 55 and valve 56 is to allow some gas to be burned at the burner 36 whether or not the solenoid valve 54 is open.

Turning now to Fig. 2, the electrical interconnections between the elements shown in Fig. 1 are clearly seen. In Fig. 2 the relative positions of the various elements have been changed to simplify the representation. However, corresponding elements illustrated in both Figs. 1 and 2 are similarly marked, except that all the elements in Fig. 2 have been assigned superscripts. Further, components of various elements have been indicated in Fig. 2 in order to clarify the electrical control circuit. The terminals 61, 62 on one side of a main switch 60 are connected to a source of electrical power (not shown). The main switch 60 may take any of a great number of known forms, is merely being convenient to show it as a simple double-pole switch. The terminals 63, 64 on the other side of the main switch 60 are connected to the various elements as will be described. First, the temperature controllers 21, 33 are preferably connected in parallel across the terminals 63, 64 of the main switch 60 as shown to energize them. It should be noted that no particular type of temperature controller is essential to the invention, it merely being necessary that each be independently adjustable so as to operate at a predetermined temperature. That is, the controller 33 must be capable of actuating the switch 33a (shown in Fig. 2) when the output of the thermocouple 31 corresponds to a certain temperature or a higher temperature, while

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the controller 21 must be capable of actuating the switch 21a when the output of the thermocouple 19 corresponds to a certain temperature, or higher. The switches 21a, 33a are preferably incorporated within the controllers 21, 33 respectively. The movable contact 65 is connected to terminal 63. The actuating coil 54' for the solenoid valve 54, which valve is shown in outline in Fig. 1 and as the combination of symbols for a solenoid and a valve in Fig. 2, is connected from contact 66 of the switch 33a to the terminal 64. The contact 67 of the switch 33a is connected to the movable contact arm 68 of the switch 21a. The movable contact arm 68 of the switch 21a in turn is actuated by the controller 21 in response to the output of the thermocouple 19. A proportional timer 58 is connected from one fixed contact 69 of the switch 21a and to terminal 64 while another proportional timer 59 is connected from the other fixed contact 79 of the switch 21a to terminal 64. The drive motor 18 is connected to both proportional timers 58, 59 as shown and to terminal 64. In passing it is noted that the proportional timers 58, 59 may be quite similar in construction and operation, the only difference between them being the length of time each allows energization of the drive motor 18. For example, the proportional timer 59 permits energization of the drive motor 18 for say 15 seconds out of each minute while the proportional timer 58 allows energization of the drive motor 18 for say 30 seconds out of each minute. Each timer 58, 59, as illustrated, consists of a motor 58a, 59a, driving a cam 58b, 59b. Each cam 58b, 59b, in turn controls a switch 58c, 59c. It is known to adjust the time the individual switches 58c, 59c are closed by changing the cam associated with each switch. It should be understood, of course, that the particular construction of the proportional timers 58, 59 is not essential to the invention. In fact, it will be evident that the proportional timers 58, 59 themselves are not essential, it merely being necessary that their function of changing the speed or cycle of operation of the drive motor 18 in response to the temperature detected by the thermocouple 19 be accomplished. Series resistors, for example, one of a certain value to cause the drive motor 18 to rotate at a desired high speed and the other of a value to cause the drive motor 18 to rotate at a desired low speed may be used in a known manner in place of the proportional timers 58, 59.

The apparatus operates in the following manner. A charge of sawdust 11a is placed in the feed bin 12, filling the opening 14 and the inside of the retort 13 adjacent thereto. The valves 23, 27 and the cover 47 on the storage bin 30 are closed so that the retort 13, and the storage bin 17 are substantially closed to the atmosphere. The two way valve 53 is positioned so that the source of gas (not shown) is connected to the burner 36. Preferably the throttle valve 56 is also opened. The valves in the various pipes 42, 45, 49 for coolants, that is, valves 43, 46, and 50 are preferably open. The temperature controllers 21, 33 are set to operate at predetermined temperature. For example, temperature controller 21 may be set to operate at 275° C. and temperature controller 33 may be set to operate at 800° C. While these temperatures are practical they are by no means limiting or critical. When the main switch 60 is closed, the temperature controllers 21, 33 are energized, the controller 33 moving the movable contact 65 to the contact 66 so that the solenoid valve 54 is also energized. This allows the maximum amount of gas to pass through the burner 36. When the gas is ignited, the retort 13 begins to heat up in the zone "B" first and by conduction in the zones "A" and "C" to a lesser extent. The coolant in the cooling coil 37 of course reduces the temperature rise in the zone "C." At the same time conduction of heat through the retort 13 to the feed screw 15 occurs. Since the feed screw 15 is in close contact along its bottom to the inner wall of the retort 15, the terminal tem-

perature of the feed screw 15 is substantially the same as that of the retort 13. When the temperature of the retort 13 in the zone "B" reaches the temperature set on the controller 33, in this example 800° C., the output of the thermocouple 31 is high enough to actuate the controller 33 to move the movable arm 65 from the contact 66 to the contact 67. This movement deenergizes the solenoid 54 causing the solenoid valve to close and simultaneously permits the drive motor 18 to be energized through the circuit shown in Fig. 2. In the interest of economy, the throttle valve 56 may be adjusted so that the proper amount of gas may be burned to keep the retort 13 in zone "B" slightly above the proper temperature. The zone "B" having reached its proper temperature, the drive motor 18 is actuated through one of the proportional timers 58, 59. If the temperature of the retort 13, as sensed by the thermocouple 19, is lower than the temperature set on the controller 21, the movable arm 68 is in contact with the contact 69, causing the proportional timer 58 to control the drive motor 18. This means, in the example given, that the drive motor 18 is actuated for 15 seconds out of every minute. The sawdust 11a that has been fed into the retort 13 is thus moved from the opening 14 toward the heated zone "B," being agitated as it is moved. The heat conducted along the retort 13 and the feed screw 15 into the zone "A" forces any moisture in the sawdust 11a out of the sawdust 11a in the form of steam or vapor. This steam or vapor is vented to the atmosphere through the opening 14, creating a seal there to prevent air from entering the retort 13. A small amount of this steam or vapor also escapes around the bearing between the retort 13 and the feed screw 15 preventing air from entering the retort 13 there. As the sawdust 11a approaches the end of the zone "A" its temperature approaches that temperature at which the known exothermic reaction takes place. By this time almost all the moisture contained in the sawdust 11a has been driven off, although some small amount of moisture may still be being liberated. However the character of the gases being evolved changes and incombustible gases, as carbon dioxide, are driven off in substantial quantities. Since the valves 23, 27 are closed and sawdust 11a is continually being introduced to the retort 13, all the evolved gases cannot be vented and pressure within the retort 13 rapidly builds up. The atmosphere within the retort 13 then becomes incapable of supporting combustion. The valve 23 may then be opened to allow enough of the gases being evolved within the retort 13 adjacent the pipe 22 to pass through the condenser 24 to the storage bin 30. The pressure within the retort 13, the storage bin 30 or any part of the structure cannot, of course, attain dangerous proportions because the relief valve 41 may be set to operate before excessive pressures occur. Immediately after the sawdust 11a passes the pipe 22, the known exothermic reaction takes place and the sawdust 11a begins its conversion to charcoal. The exothermic reaction, although it is very important, is not the sole cause operating to convert the sawdust 11a to charcoal. The temperature within the retort 13 in the zone "B" is so high that the retort 13 and the feed screw 15 radiate enough heat to greatly accelerate the destructive distillation of the individual particles of sawdust 11a. The particles of the sawdust 11a which are being decomposed to charcoal by destructive distillation are represented by the figure 11b. Copious amounts of volatile gases and wood tars in their gaseous state are distilled from the particles 11b. It may be seen, therefore, that the feed screw 15 in the zone "B" serves a dual purpose: to continuously agitate the particles 11b and to provide more efficient heating of the particles 11b. One or more of the valves 27 is opened to allow the volatile gases and tars to pass through the manifold 28 to the condenser 48. As the volatile gases and tars pass through the condenser 48, the condensable portions of the distillate from the zone "B" are removed

and the non-condensable gases are fed out of the condenser 48 back into the burner 36, the two-way valve 53 being moved to accomplish this connection. It should be noted however that it is not necessary to the invention that the non-condensable gases be so burned. However, burning the non-condensable gases has been found to be advantageous in the present embodiment and quite adequate to make the process self-sustaining. After the particles 11b have been completely converted to glowing particles of charcoal, the feed screw 15 forces them through the zone "C." In the zone "C" cooling is effected so that the glowing particles are cooled to or below the temperature at which self ignition in air occurs. Again the eccentric mounting of the feed screw 15 in the retort 13 is of assistance. The feed screw 15 agitates the particles of charcoal 11c and improves the cooling effect of the coil 37. After the particles of charcoal 11c reach the end of the retort 13 they fall into the storage bin 30 where they are cooled to ambient temperature and removed.

The automatic manner in which the apparatus controls the carbon content of the charcoal particles 11c may be seen from the following: It is known that the carbon content of charcoal formed from any given type of wood is fixed by the highest temperature to which the wood is subjected during processing. In the illustrated apparatus the highest temperature to which the wood is subjected is the temperature of the retort 13 and feed screw 15 adjacent the thermocouple 31. This temperature may be held very close to any desired temperature by adjustment of the controller 33 and the throttle valve 56. It remains only to ensure the heating of the particles 11b to that same temperature. That end is accomplished by controlling the motor 18 in response to the temperature detected by the thermocouple 19, once the temperature detected by the thermocouple 31 has reached its desired value. Thus, if the temperature at thermocouple 19 is low, as would be the case when the sawdust 11a contains a large amount of moisture, controller 21 in the illustrated structure operates so that the proportional timer 59 controls the motor 18, allowing the latter to rotate the feed screw 15 for relatively short time intervals. This means of course that a relatively long time is taken to move the particles 11b through the zone "B," ensuring the proper heating of each particle. On the other hand when the temperature at the thermocouple 19 is high, as when the moisture content of the sawdust 11a is low, the controller 21 operates to connect the proportional timer 58 to control the motor 18, allowing it to rotate the feed screw 15 for relatively long time intervals. This in turn means that a relatively short time is taken to move the particles 11b through the zone "B." It is then a simple matter so to adjust the controller 21 that the natural variations in the moisture content of the sawdust 11a makes no appreciable difference in the carbon content of the charcoal produced by the apparatus.

Equally as important as the apparatus's ability to automatically adjust itself to produce a charcoal of a given carbon content is its flexibility. Thus the specific temperature and speeds mentioned hereinbefore result in charcoal having a carbon content of about 95% when sawdust from hardwood is used. If charcoal having some lower carbon content is desired, it is necessary only to decrease the temperature in the zone "B," as by setting the throttle valve 56 and adjusting the temperature controller 33 so that the solenoid valve 54 closes at a lower temperature. In almost all cases it will also be feasible to increase the settings of the proportional timers 58, 59 so that the drive motor 18 is energized for longer periods. In other words, the carbon content of the product may be adjusted to any desired value by adjusting the temperature of the zone "B" or by changing the time taken to convert the sawdust to charcoal. Another aspect of the flexibility of the apparatus is that sawdust is not the

only kind of material that may be converted to charcoal in it; in fact sawdust is one of the more difficult materials to convert to charcoal. If larger pieces of wood, or even bark are fed into the apparatus, it is easier to produce charcoal because of the greater heat conductivity of such forms of wood.

Although the invention has been described in connection with one particular practical apparatus, it is evident that the invention may be equally well described in terms of the method exemplified by the disclosed apparatus. Thus, the inside of the retort constitutes a substantially oxygen-free atmosphere into which a finely divided material capable of being converted to charcoal by destructive distillation, particularly sawdust, is introduced. The sawdust is agitated and moved through the oxygen-deficient atmosphere, being first dried, then converted to charcoal by radiant energy and finally cooled to prevent self-ignition of the newly formed charcoal. In addition, the length of time that is taken to convert the sawdust to charcoal is closely controlled so that the carbon content of the charcoal produced is held within very close limits. Furthermore, the highest temperature to which the charcoal is subjected during its conversion is varied as desired to change the carbon content of the charcoal produced.

Because the drying, conversion and cooling steps are carried out sequentially as the sawdust and/or charcoal is moved through the oxygen-deficient atmosphere, it is relatively simple to extract the different gases that are evolved at different stages in the process as desired. Further, it is easy to extract the different gases separately or almost completely so and apply each to the purpose for which it is best suited. Thus, the water vapor and steam driven off from the sawdust during the drying step may be used to create a vapor barrier at the inlet end of the oxygen-free atmosphere, preventing the entrance of air thereto and dispensing with the necessity for providing complicated and expensive valving arrangements. The non-combustible gases evolved from the sawdust after substantially all the moisture has been driven off but before conversion has begun may be removed to be used to fill storage bins for the newly formed charcoal so that all danger of self-ignition is eliminated while the gases evolved during conversion of the sawdust to charcoal may be removed and processed as desired. Thus, even though the illustrated apparatus in Fig. 1 shows the gases evolved during conversion of the sawdust to charcoal being passed through a condenser in which the condensible and non-condensable portions of those gases are separated, with the non-condensable portions being burned to keep the burner supplied with fuel, such a use is not essential to the method. Economical considerations may make it advantageous to treat the non-condensable gases further according to known ways in order to obtain by-products such as methanol or acetic acid.

What is claimed is:

1. Apparatus for the destructive distillation of wood comprising in combination an elongated retort having an inlet and outlet and having a drying zone followed by a distilling zone, a burner for heating said retort and fuel control means therefor, a conveyor for agitating the wood and advancing it through both of said zones, first temperature sensing means adjacent the outlet of said distilling zone, second temperature sensing means adjacent the juncture of said zone, means responsive to said first temperature sensing means operable to start said conveyor and to operate said fuel control means to reduce the fuel to said burner after the wood adjacent to the outlet of said distilling zone is brought to a first predetermined temperature, and conveyor control means for controlling the rate of operation of said conveyor responsive to said second temperature sensing means, whereby the wood adjacent to the juncture of said zones is maintained substantially at a second predetermined temperature which is lower than said first predetermined temperature.

2. In the manufacture of charcoal by the destructive distillation of wood wherein wood particles are first dried and then heated to a temperature sufficient to initiate an exothermic destructive distillation reaction, the continuous method comprising first heating an elongated retort having a drying zone followed by a distilling zone while the wood is stationary in said zones until the wood adjacent to the outlet end of said distilling zone is at a first predetermined temperature above that attained by the exothermic reaction alone, then agitating and advancing the wood particles continuously through both of said zones at a rate controlled to maintain the temperature of the wood particles adjacent to the juncture of said zones at a second predetermined temperature which is above that at which exothermic destructive distillation is initiated and continuing the heating of said retort at an amount less than the first heating step to a temperature sufficient to maintain the wood particles adjacent to the outlet of said distilling zone at at least said first predetermined temperature.

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