

Jan. 8, 1952

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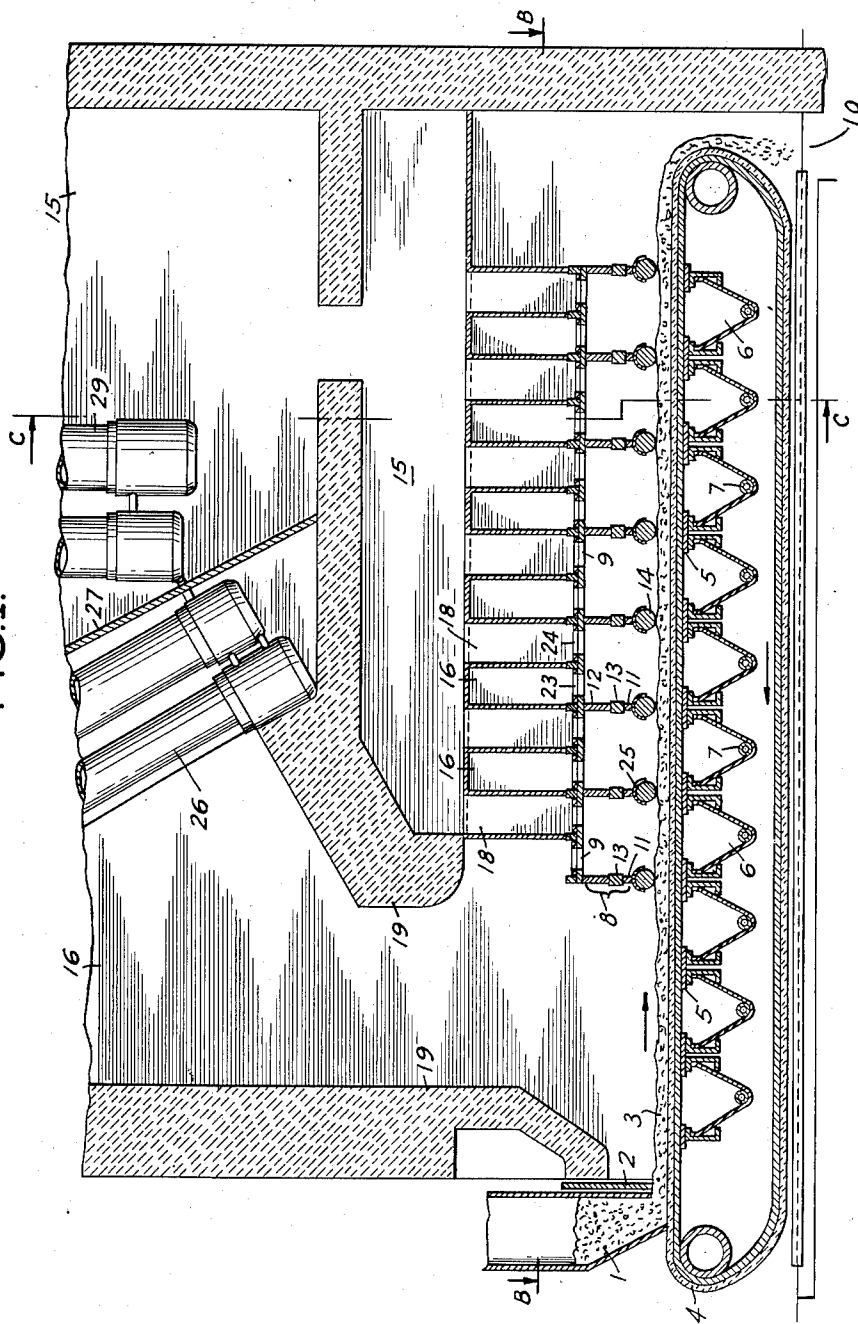
2,581,575

APPARATUS FOR THE CONTINUOUS PRODUCTION OF WATER GAS

Filed June 27, 1946

3 Sheets-Sheet 1

FIG. I.



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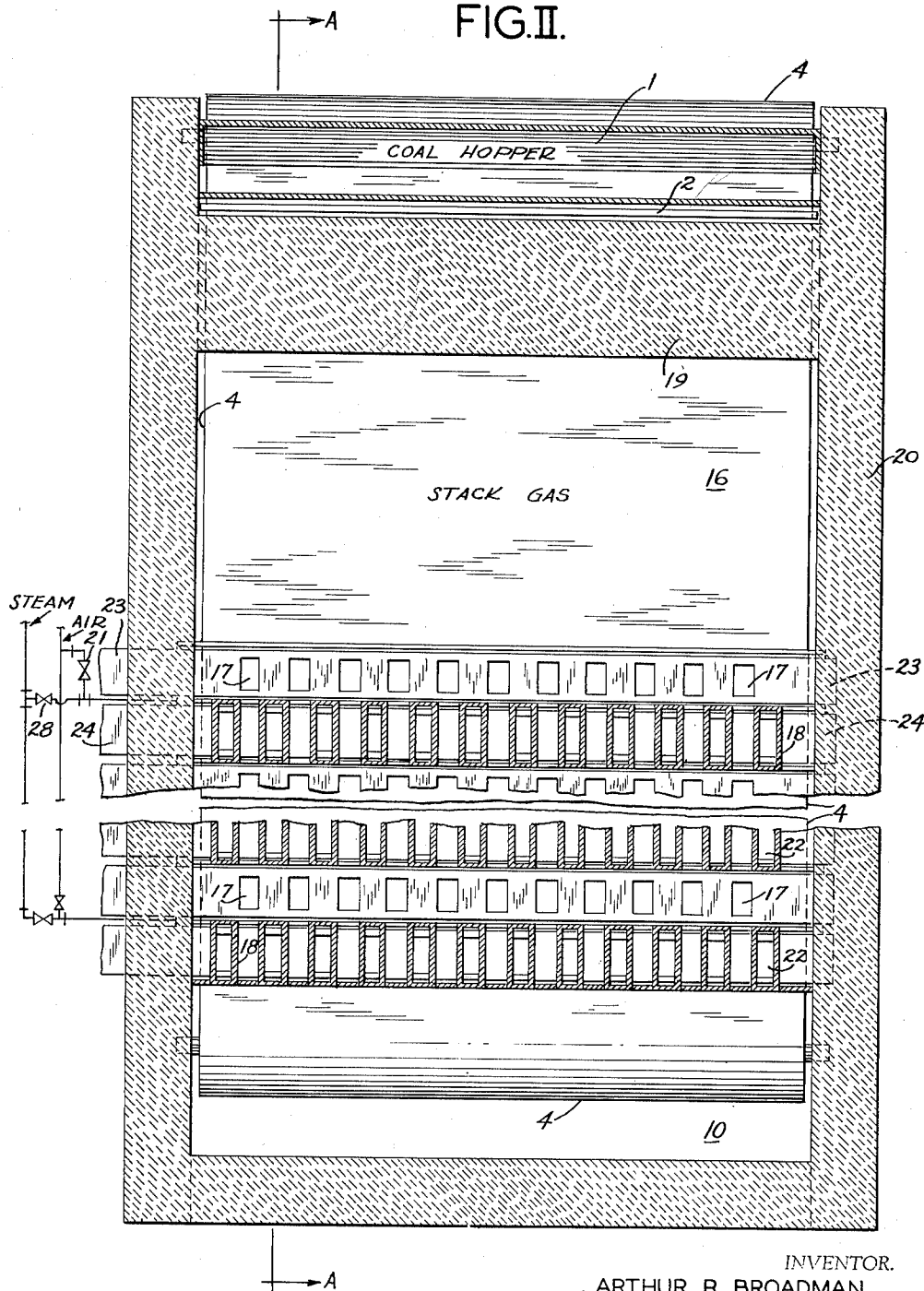
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Filed June 27, 1946

3 Sheets-Sheet 2

FIG. II.



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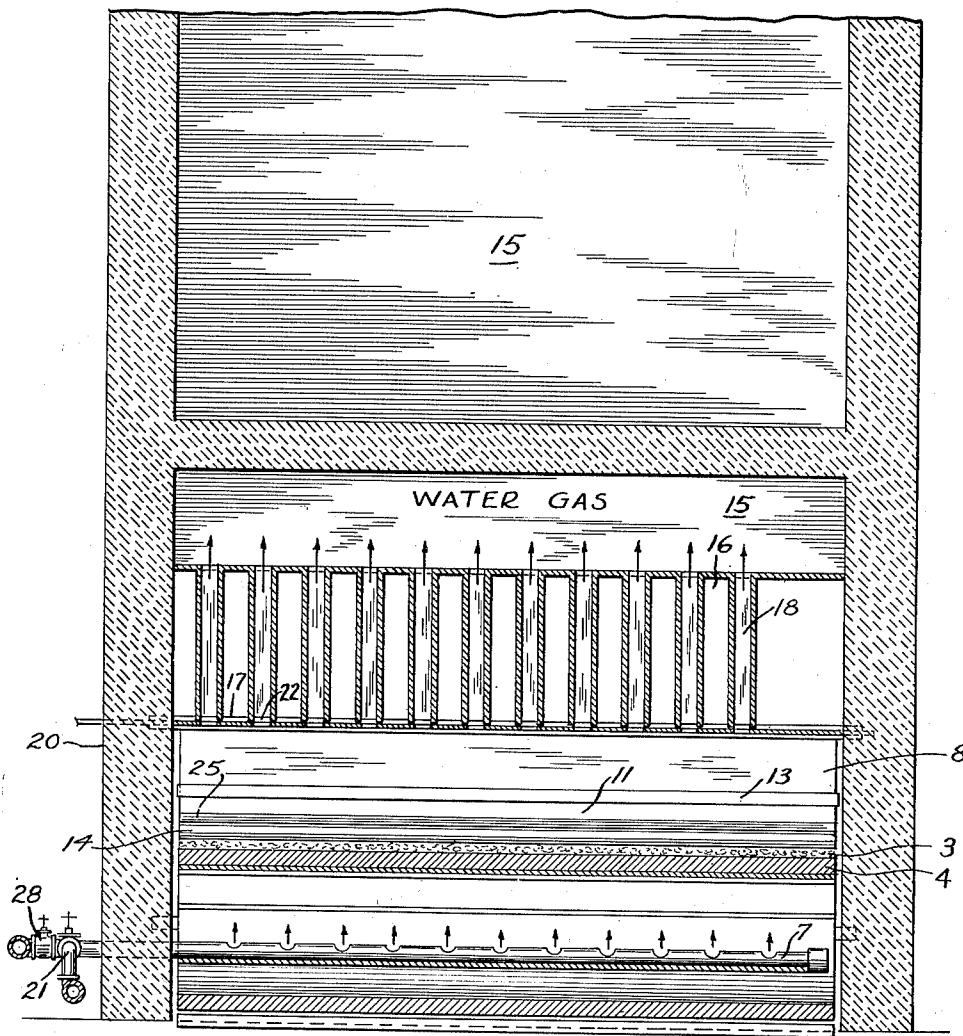
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Filed June 27, 1946

3 Sheets-Sheet 3

FIG. III.



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## UNITED STATES PATENT OFFICE

2,581,575

APPARATUS FOR THE CONTINUOUS  
PRODUCTION OF WATER GAS

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Application June 27, 1946, Serial No. 679,604

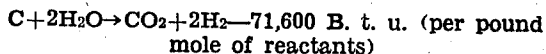
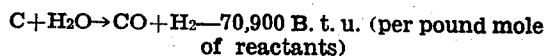
2 Claims. (Cl. 48-78)

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The present invention relates to the production of water gas by the reaction of steam on coal or other normally solid combustible carbonaceous materials and relates particularly to a process that is particularly adaptable to the production of water gas from fines or smaller sizes of anthracite coal or cokes. In one specific embodiment of the present invention, coal, coke or other solid carbonaceous material carried on a progressively moving or traveling grate is subjected continuously to a plurality of alternate blasts of air and steam.

The principal object of the present invention is to provide a process for the production of water gas from coal, coke and other solid combustible carbonaceous materials. A further object of the invention is to provide such a process which is adapted to the continuous production of water gas and which is particularly adapted to utilizing anthracite or coke fines or particles of small size that command a relatively low price or are at present normally discarded as waste. Other objects and advantages of the invention, some of which are referred to more specifically hereinafter, will be apparent to those skilled in the art to which the invention pertains.

The reactions by which water gas (which is a mixture of carbon monoxide, hydrogen and a smaller proportion of carbon dioxide) is formed from carbonaceous materials and steam, may be represented as follows:



As is shown, large quantities of heat are required to support either of these reactions, and these reactions require a high temperature level in order to proceed.

In conventional methods of producing water gas, anthracite, bituminous coal, coke or other solid carbonaceous material is charged to a stationary converter or generator to a depth of about 6 to 9 feet, in which it is ignited and subjected to a blast of air in order to bring the carbonaceous material to incandescence by combustion. The air blast is then discontinued and a blast of superheated steam is charged through the hot bed, producing water gas. The temperature drops during the steaming and is again brought up to a point favorable to the water-gas reaction by a subsequent air blast. The air and steam blasts are continued in a cyclic manner until the carbonaceous material is no longer suitable for further treatment, although it may still contain considerable unconsumed carbon. The water gas and the stock gases produced respectively during the air blasting and steam blasting are led off through separate ducts. The ash of the car-

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bonaceous material is subsequently discharged from the generator.

In order to maintain a high rate of water-gas production, large amounts of heat must be stored up during the air blasting. This requires a very thick bed of coal, and the temperature of the fuel must be raised quickly after each steaming. A rapid flow of air through the thick bed is required and this entails a great expenditure of power. Only the larger sizes of coal can be used, in order to minimize the pressure required to force the air or steam through the thick fuel bed and to maintain the proper fire conditions. These large sizes of coal are the highest priced grades and represent a large portion of the cost of the gas produced. The intermittent and alternating nature of the operations makes it necessary to have an elaborate and expensive system of timing devices, motor-controlled valves, high-capacity blowers and the like. The intermittency of the process also inherently results in high thermal losses and low production capacity. The use of relatively thick beds of fuel results in inefficient combustion of the coal, as is manifest by the high content of carbon monoxide in the stack gases produced during the air blasting. In the process herein described, a relatively thin bed of fuel is subjected to the air blast whereby high combustion efficiency is achieved and the stack gases are relatively free from carbon monoxide.

In accordance with the process of the present invention, the solid combustible carbonaceous material, which may be anthracite, bituminous or coke fines or larger particles of these or other solid combustible carbonaceous materials on an endless-chain or travelling grate, are charged in such manner as to form a relatively thin substantially uniform bed on the grate. As the layer or bed of particles on the grate is progressively advanced the carbonaceous material is ignited and combusted in a continuous blast of air. It is then subjected to alternate blasts of superheated steam and air and the products from each separate blast are collected separately in individual compartments or chambers of the apparatus or generator.

In this manner, water gas is produced continuously. In addition, the process of the present invention permits the use of the finer sizes of anthracite or bituminous coal, or coke "breeze," which command a considerably lower price than the large sizes of fuel required in conventional water-gas generators. Although the principle of such a continuous process utilizing a travelling grate is relatively simple, it has not heretofore been considered possible to conduct such a process advantageously.

In U. S. Patent No. 1,814,463 is described a process of carbonizing coal in a retort or furnace in which the coal is advanced by means of

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a travelling grate through heated zones having progressively increasing temperatures that are separated from each other by compartments. The zones are heated by gas burners placed in the retort or by external heating of the retort. No air or oxygen is used. It is stated in said patent that steam may be introduced into one of said zones having a temperature in excess of 600° C. in order to produce water gas. Such a furnace or retort differs from my apparatus, which has provision for a plurality of air blasts and a plurality of steam blasts and collection of the different gaseous products in each separate chamber or compartment. My apparatus differs also in purpose or function and in other essential respects, as pointed out more specifically herein. Furthermore, the principle of my process is entirely different from that described in the patent. My process is adaptable to a more economical conversion of the carbonaceous material into the maximum quantity of water gas and utilizable heat.

The drawings are a diagrammatic representation of one specific form of apparatus for conducting the process of the invention. Figure I is a side elevational view along the section AA on Figure II; Figure II is a top section along the section BB on Figure I; and Figure III is a front elevational view of the same apparatus through the section CC on Figure I.

Coal, coke, peat, lignite or other carbonaceous material, in the form of lumps or fines, is charged from the hopper or feed chute 1 through an adjustable horizontal gate 2 to control the depth of the bed 3 onto the travelling or conveying grate 4, which may be of conventional design. The depth of the bed 3 may vary from about 3 in. to about 18 in. or more, dependent upon the type of fuel used, the dimensions of the apparatus, and other characteristics referred to hereinafter.

The travelling grate 4 is supported on horizontal bearing beams 5, the upper surfaces of which may be of suitable iron or steel alloy composition. These bearing beams are preferably wider than would be used in a conventional travelling grate furnace, in order to prevent or minimize the passage of any gases from one portion or section of the grate to an adjacent portion and to confine the fluid or gas blasts in each chamber to that particular portion or section of the coal bed. Each chamber consists of a transverse wind box 6 provided with a transverse fluid or gas ejector or sparger 7 underneath the travelling grate. Above the travelling grate 4, forming the lateral boundaries of the chamber, are transverse vertical barriers 8 extending downward from a horizontal ceiling or ceiling members 9 to lower segments 11. These lower segments 11 are connected with the upper segments 12 by means of slidable joints 13. The bottoms of the lower segments 11 of the transverse barriers 8 are provided with rollers 14 that rest on the surface of the coal bed 3.

Each chamber under the gasification arch is in communication with a water-gas flue 15 and a stack-gas flue 16. The stack gas from each chamber flows or passes to the stack-gas flue 16 through a plurality of openings or ports 17 (see Figure II). The water gas from each chamber flows or passes to the water-gas flue 15 through a plurality of vertical connecting ducts 18 formed of any suitable confining materials, such as steel or steel alloys containing chromium and/or nickel.

The coal which is deposited on the travelling

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grate 4 as a layer or bed is carried by the moving or travelling grate 4 over a plurality of wind boxes 6 where primary heated air is blasted upward through the layer or bed of coal 3 on the grate 4. The layer or bed of coal on the grate is brought to ignition temperature by means of heat radiation from the ignition arch 19 and from the brick side walls 20 of the furnace. The blast of primary air supplies necessary oxygen for combustion, which further raises the temperature of the coal bed 3 as it travels on the grate 4. The air blasts in the wind boxes 6, which are preferably continuous blasts, are so controlled and regulated by valves 21 as to bring the bed of coal to a suitable or the desired higher temperature. This temperature is generally between 2000° F. and 2500° F.

The heated bed of coal is progressively advanced and carried by the grate 4 to the first of the chambers under the gasification arch. In this first chamber the bed of coal is subjected to an upward blast of superheated steam which is ejected from the sparger or ejector 7 in the first wind box 6 while the ports or openings 22 to the vertical ducts 18 leading into the water-gas flue 15 are in open position. The water gas that is thus formed passes upward into the water-gas flue 15 and may be passed through a waste-heat boiler 29 before it is collected or stored in a suitable tank or gas holder. The openings, apertures or ports 17 in the ceiling leading to the stack-gas flue 16 are maintained in closed position, but if it should be desired to treat the bed in this chamber with a blast of air, these ports 17 would be opened and the water-gas ports 22 would be closed. The bed of coal is cooled as a result of the water-gas reaction; the amount of steam which will react in the bed is dependent upon the temperature of the bed. Therefore, the amount of steam blown through the bed should be controlled so that the temperature of the bed at the exit end of the chamber does not fall below the point at which an economical amount of steam will react, or an excessive amount of carbon dioxide will be formed. This temperature will vary slightly with the type of carbonaceous material being used, but will generally range from approximately 1300° F. to approximately 1500° F.

The bed of coal is then progressively advanced and carried under the next vertical barrier 8 to the section of the grate over the next wind box 6, where it is subjected to an upward blast of air or other oxygen-containing gas ejected from the sparger 7 in said wind box. The resulting combustion of the coal raises the temperature of the remaining uncombusted coal and ash on the grate. The stack gases produced are educted or vented from this chamber through the openings or ports 17 in the ceiling 9 that lead to the stack-gas flue 16. The openings or ports 22 in the ceiling that lead to the water-gas flue 15 are kept closed.

This alternate subsection of the coal to steam and air blasts from the successive wind boxes 6 is continued as the coal advances progressively through the furnace. The number of chambers and wind boxes will be dependent upon various factors, such as the type of carbonaceous fuel being treated, the initial thickness of the bed which it is desired to process, the speed of the travelling grate, the completeness of the combustion of the fuel desired, the temperatures of the steam and air, etc. However, in each case, where the bed is blasted with air those open-

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ings or ports 17 leading to the stack-gas flue 16 would be opened, those openings 22 leading to the water-gas flue 15 would be closed. Where the bed is treated with steam, the openings or ports are respectively open and closed in the opposite arrangement.

For purposes of illustration the process and operation of the particular apparatus represented in the drawings has been described with reference only to alternate steam and air blasts. However, it may be desirable to use two or more successive sections of the travelling grate as oxidizing zones and to blast air through the coal bed in these sections before blasting the bed with steam in a successive section.

A feature of the apparatus represented in the drawings is the means by which the chambers may be placed into communication with either the stack-gas flue 16 or the water-gas flue 15 and thus permit the various chambers to be used alternatively as oxidizing and heating chambers or as water-gas-producing chambers. This makes it possible to treat the coal bed with air or steam in any desired succession or order.

These means for changing the communication of the chambers with either of the flues, which are represented in the drawings, comprise a ceiling 9 having two transverse rows of apertures or openings 17 and 22 therein, one row of such apertures 17 communicating with the stack-gas flue 16 and the other row of apertures 22 communicating through the vertical ducts 18 with the water-gas flue 15, slidable transverse plates 23 and 24 having a set of openings or apertures 17 and 22, respectively corresponding with the openings or apertures 17 and 22 in the ceiling 9, and one set of vertical ducts 18 connecting one row of apertures 22 with the water-gas flue 15. The ceiling 9 is continuous over all the sections or chambers of the furnace and each section is provided with two separate transverse plates 23 and 24 and one row of vertical ducts 18, as shown in the drawing.

To place any section or chamber into communication with the water-gas flue 15, the slidable transverse plate 24 associated with the water-gas ducts 18 is moved so that the openings 22 in said plate come into register with the corresponding openings or apertures 22 in the ceiling 9, while the other slidable transverse plate 23, which is associated with the stack-gas flue 16, is moved so that the openings 17 in the ceiling 9 thereunder are closed. If it is desired to place the chamber or section into communication with the stack-gas flue 16, the two slidable plates 23 and 24 connected with said chamber are moved counterrivewise. Means may be provided so that the two slidable plates of each chamber are moved simultaneously in opposition to each other so that by one motion the alignment or register of the holes is such that one set is closed while the other set is opened.

Normally, when operations with a particular carbonaceous material have been started, it is seldom necessary to change the chamber from a steam-blasting to an air-blasting chamber, or vice versa, so the slidable plates 23 and 24 are mainly used at the start to establish proper operating conditions. However, when changes occur in the character of the carbonaceous material, and it is necessary to change the character of the chamber from a steam-blast to an air-blast chamber or vice versa, and it is necessary to do so without increasing substantially the nitrogen

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content of the product water gas, the slidable plates 23 and 24 should be operated so that communication of a chamber with the water-gas flue 15 is not established until after steam has been turned into the bed of carbonaceous material for a sufficient period to insure purging of the stack gases from the particular chamber.

Although it is possible to construct and operate successfully an apparatus or furnace without the foregoing means for changing the communication of the chambers with the flues, such construction is not recommended. Other means of effecting the same result may be adopted but all of these lack the sheer simplicity and reliability that characterizes my particular construction.

As the bed of coal advances progressively through the furnace the thickness of the layer of coal will decrease because of the combustion and reaction of the coal. To maintain the separation of the fluid contents of the separate chambers from each other the rollers 14 are preferably constructed so that they are vertically movable as represented in Figure 1, being provided with slots or chambers 13 into which the lower portions or extremities 11 of the stationary barriers 8 fit. Furthermore, in order to minimize the passage of gases from one chamber to another, the upper halves of the rollers 14 are covered with a skirt 25 curved to conform to the rollers and fit within about  $\frac{1}{8}$  inch of the roller surface. This lower section 11 of the barrier 8 should be as short as possible, in order to minimize the vertical distance at the walls 20 where there will be only a close fit between the edge of the movable barrier 11 and the wall 20. The edges of the stationary portion 12 of the barrier 8 form a tight connection with the furnace walls 20. The rollers 14 serve another purpose in that they press the carbonaceous material 3 into a denser and more uniform bed, thus eliminating blow-holes, which would lower the quality of the water gas, decrease the efficiency of steam utilization and lower production capacity. Another function of the rollers 14 is to exert a rolling and squeezing force upon the bed, which minimizes the amount of gas that remains in the voids of the bed and that would be carried in the bed to the next chamber. This is particularly important in going from an air-blast chamber into a steam-blast chamber, especially when it is desirable to maintain the nitrogen content of the water gas in said chamber at a minimum. Other conventional devices for accomplishing this purpose may be adopted, if desired.

As the bed of coal advances further through the chambers of the furnace, the carbon of the coal will be consumed progressively until it is completely exhausted or the quantity remaining will not suffice to support combustion when subjected to air blasting. Further processing is discontinued and the residue is carried by the grate 4 to the end of the upper travel of the grate where it is discharged into an ash receiver 10. The rate of recovery of temperature in the air chambers will decrease as the coal travels toward the rear of the furnace so that the amount of steam used in the steam-blast chambers should be decreased progressively from the front to the rear of the furnace. The amount of air should be similarly decreased in order that the lighter bed at the rear of the furnace should not be blown from the grate. It is obvious that the greater part of the water gas will be produced at the front end of

the grate. However, it has been observed that the ash appears to exert an activating or catalytic effect upon the water-gas reaction so that the formation of ash exerts an influence tending, to some extent, to compensate for the slowing of the reaction due to the diminishing carbon content.

Due to the relatively thin beds employed in this process the pressures at which the steam and air blasts are introduced into the wind boxes 6 are very low as compared with those inside conventional water-gas generators. The actual pressures employed are of the same order as those used in combustions on conventional travelling grates and vary with the thickness of the bed and the type of fuel comprising the bed.

In order to minimize the possibility of stack gas contaminating water gas by leakage from an air-blast chamber to a steam-blast chamber, the entire stack-gas-flue system 16 inherently including the air-blast chambers is maintained at a very slightly lower pressure than the water-gas-flue 15 and steam-blast chambers.

It is desirable and extremely simple to utilize the heat contained in the hot stack gases produced continuously by leading them into a conventional boiler 26. Also it is possible to utilize similarly the heat of the hot water gas produced continuously by having it heat the same boiler, but maintaining the water gas separate from the stack gases by means of walls or baffles 27. By such an arrangement, the steam required for the production of water gas may be produced by the process itself, together with about 50% steam which may be used for other purposes.

In the apparatus illustrated in the drawings, the wind boxes 6 are each provided with one set of spargers or ejectors 7 through which may be injected air or steam by proper manipulation of the valves 21 and 28, respectively, in the air and steam lines. This is the preferred arrangement although other conventional arrangements may be used.

In the apparatus or furnace described and illustrated in the drawings the air and steam blasts are directed from beneath the layer or bed of coal 3, but the furnace may be altered or changed so that either or both air and steam blasts are directed from above onto the surface of the layer or bed of coal and the effluent gases collected beneath the layer or bed of coal.

Travelling or chain grates are described in "Fuels and Their Combustion," by Robert T. Haslam and Robert P. Russell, published by McGraw-Hill Book Co., Inc., New York, 1926, pages 386 to 391. The grates contemplated for use in the apparatus of the present invention involve no substantial departure from conventional grates described in said book and elsewhere and the selection of a particular grate will be governed largely by individual preference and requirement.

Although in the foregoing description, anthracite fines have been referred to rather extensively, it is to be understood that culm and silt coal, coke breeze or fines, bituminous fines, and lignite, petroleum coke and similar combustible carbonaceous materials may be used in sizes ranging from the smallest fines to buckwheat #4 or larger lumps, dependent not upon technological considerations but upon economies.

It is to be understood that the drawings are

a mere diagrammatic representation of one specific form of apparatus and that the various component parts may differ greatly in size and proportions from the dimensions shown. For example, the ceilings of the gas-generating chambers or sections may be much lower than thereon represented and the walls thereof may be much nearer together or further apart than shown.

Inasmuch as the foregoing description comprises preferred embodiments of the invention, it is to be understood that the invention is not limited thereto and that modifications and variations may be made therein without departing substantially from the invention, which is to be limited solely by the appended claims.

#### I claim:

1. An apparatus for the continuous production of water gas from a solid combustible carbonaceous material, which comprises a plurality of chambers through which passes a continuous travelling grate, each of said chambers communicating with a stack-gas flue and a water-gas flue, means on each of said chambers for closing the communication of said chamber with each of said two flues, means for charging the carbonaceous material to the travelling grate as a substantially uniform layer thereon, means for igniting the carbonaceous material on the travelling grate and means in each of the chambers for blasting fluids through the layer of carbonaceous material while it progressively passes through said chamber on the travelling grate.

2. An apparatus for the continuous production of water gas by the action of steam on a solid combustible carbonaceous material, which comprises a plurality of gas-generating chambers each of which is in communication with a water-gas flue and a stack-gas flue through a series of openings in the ceiling thereof, slidable plates provided with a series of openings adapted to register with the openings of the respective ceilings and so arranged and constructed with respect to the openings in the ceiling that communication may be made or broken with either of the said flues, an ignition arch preceding the first of the said gas-generating chambers, a travelling grate which passes the said ignition arch and then through each of said gas-generating chambers, a hopper and gate so constructed and arranged as to charge the carbonaceous material as a bed having a substantially uniform thickness upon the travelling grate, and a series of spargers below the travelling grate so constructed and arranged as to discharge fluids through the bed of carbonaceous material on the travelling grate.

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