

Dec. 4, 1956

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CONTINUOUS PROCESS FOR DRYING, PREHEATING, AND
DEVOLATILIZATION OF CARBONACEOUS MATERIALS

Filed Aug. 12, 1952

4 Sheets-Sheet 1

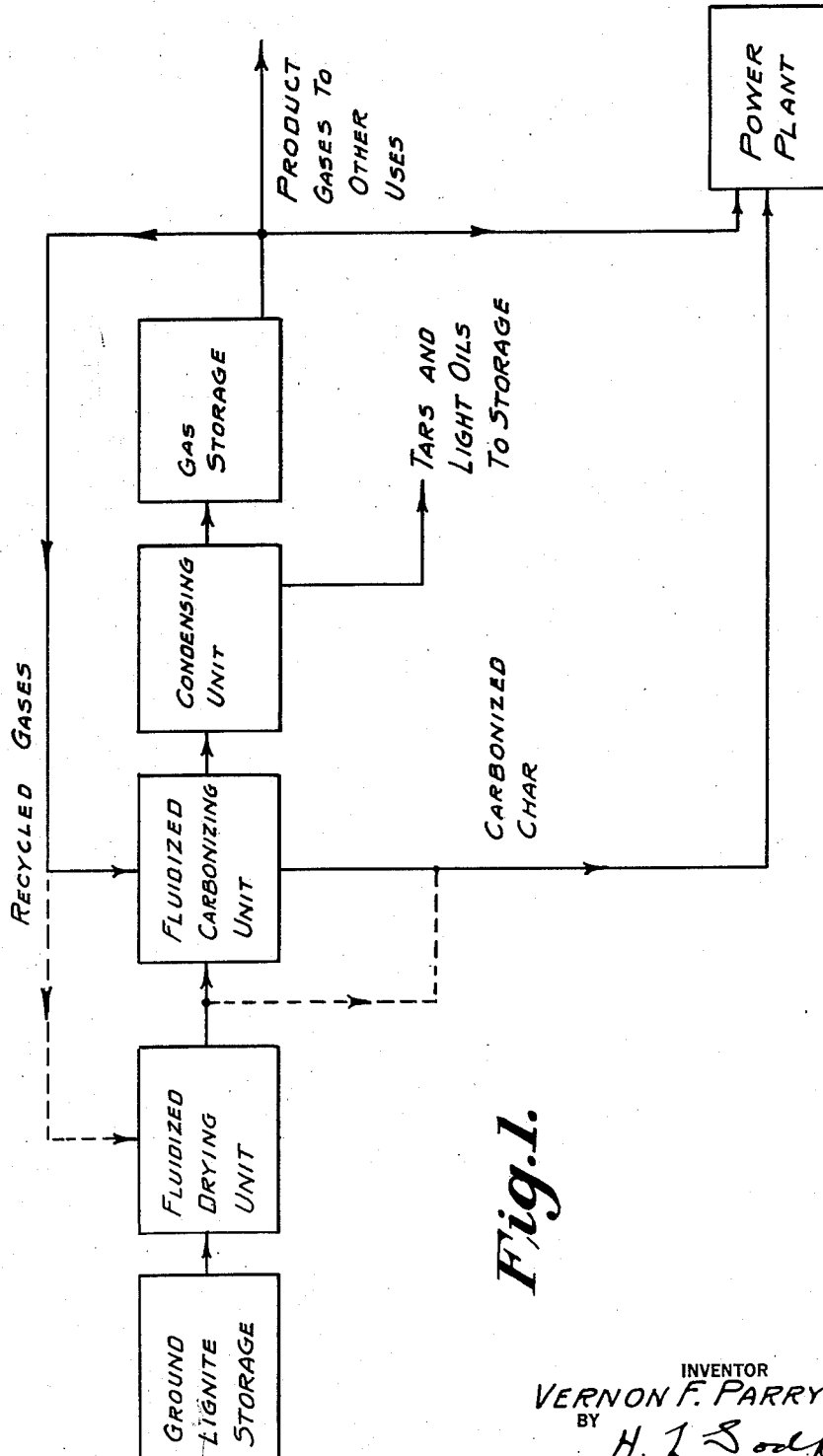


Fig. 1.

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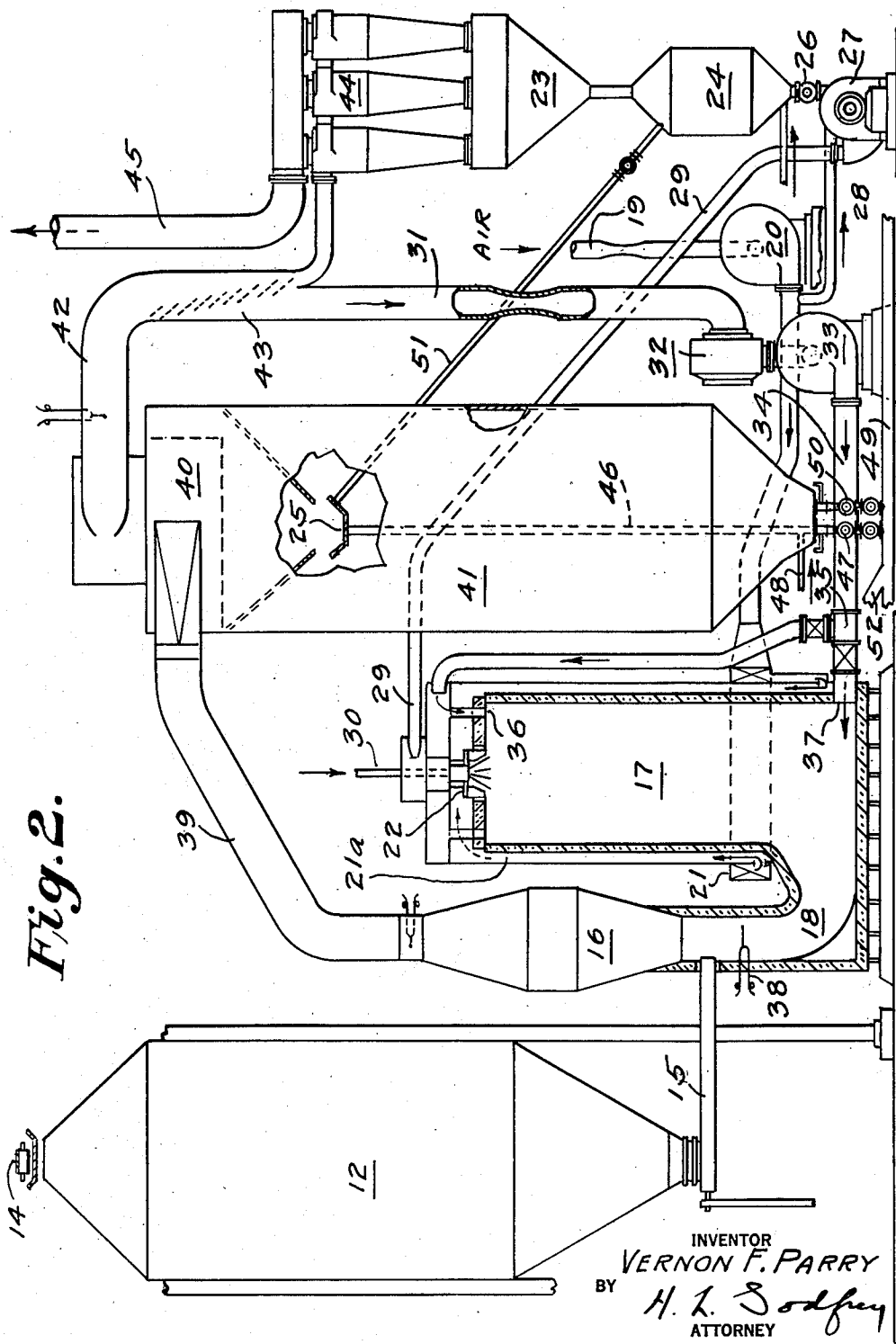
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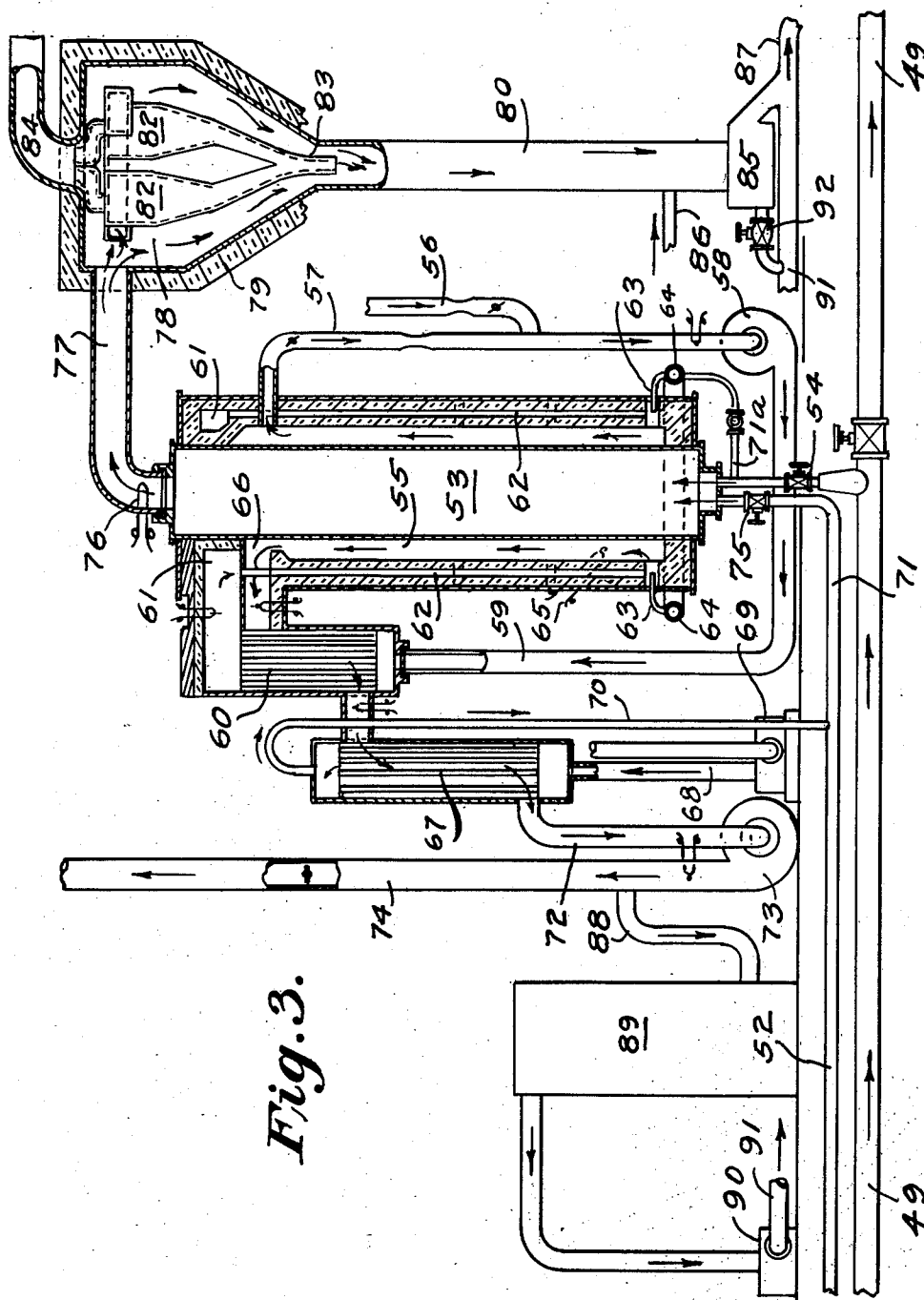


Fig. 3.

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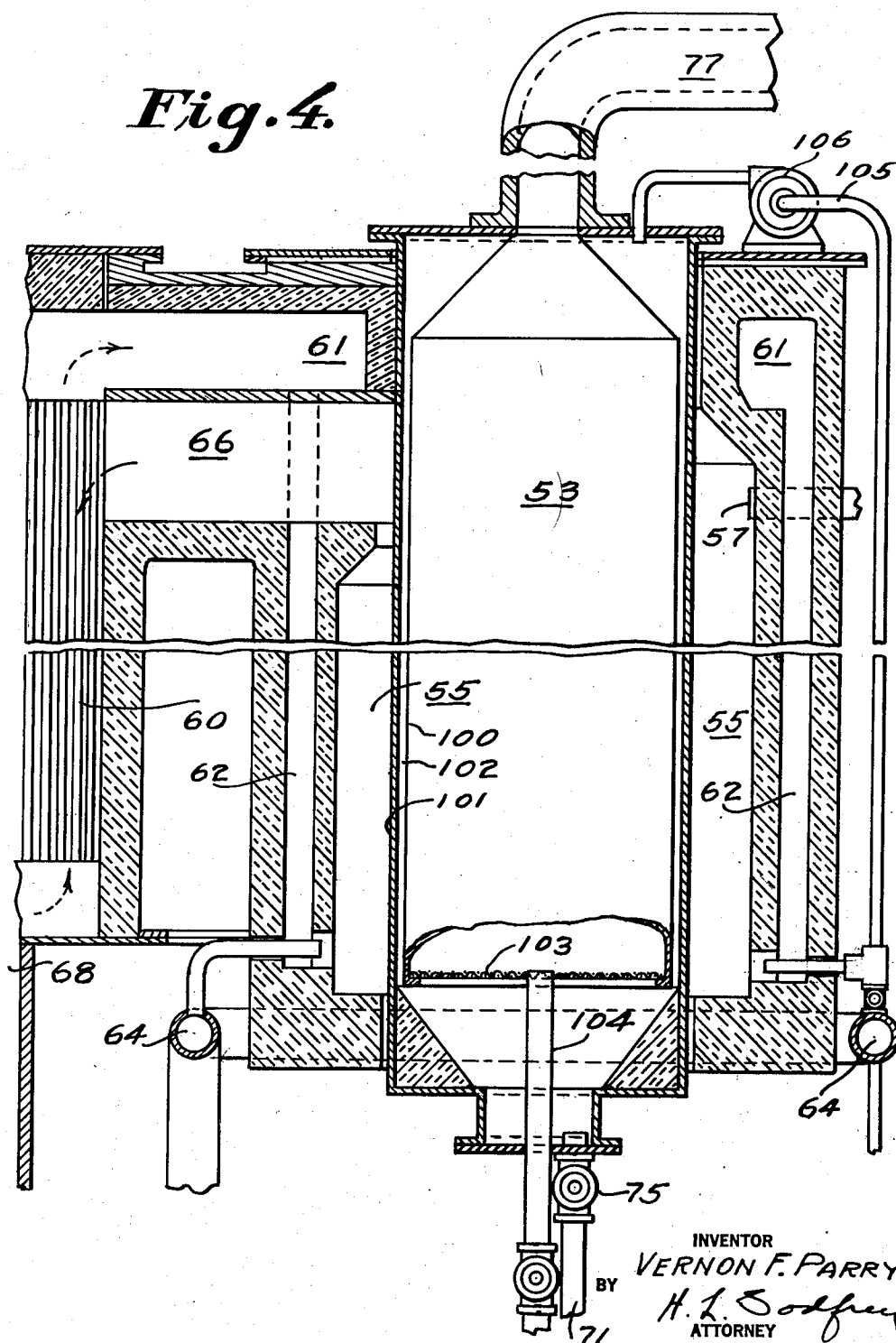
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Fig. 4.



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CONTINUOUS PROCESS FOR DRYING, PREHEATING, AND DEVOLATILIZATION OF CARBONACEOUS MATERIALS

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Application August 12, 1952, Serial No. 304,051

7 Claims. (Cl. 202—27)

(Granted under Title 35, U. S. Code (1952), sec. 266)

This invention relates to the art of processing low rank fuels and more particularly to treatments of lignite and non-coking coals, or the like.

Low rank fuels are plentiful in many localities, but due to present day cost and demand factors, are not worked commercially in any great quantity because of lack of sizeable markets close to the producing areas. Such deposits, when worked commercially, are first mined and the recovered mineral is then subjected, at the mine or at some nearby site, to a rough preparation of the lignite or coal to remove non-combustible matter with which it is associated in its natural formation and to size the product. At the present time lignite is neither washed nor dried before use.

While the cleaned coal makes a satisfactory fuel for most industrial or domestic uses, it is characterized by high moisture content and contains some matter which is more valuable as an extracted product than as a fuel constituent. Included in this category are certain tars and similar constituents, which, when separated, have value other than as fuels. For example, a lignite from Milam County, Texas, analyzed 37.6% moisture; 27.2% volatile matter; 27.1% fixed carbon; and 8.1% ash. Chemical analysis of this same lignite was as follows: hydrogen 7.2%; carbon 40.2%; nitrogen 0.8%; oxygen 42.6%; and sulfur 1.1%. From this lignite 15 gallons of tar and 100 gallons of water can be extracted from a ton of raw fuel by drying and low-temperature distillation.

At-the-mine lignite of this character in most United States deposits has little present-day demand as a fuel, but may be processed according to the present invention to produce a high heat value char, which is a satisfactory composition for power plant fuel, and is a good raw material for gasification or for briquetting, and in addition, substantial quantities of crude coal tar and similar distillation products are obtained which have a substantial market value.

It is an object of the present invention to provide a simple, economical and efficient process for the treatment of low rank fuels for the production of a plurality of valuable final products, one of which is suited for use as a power plant fuel, and the other of which is suited for other industrial uses.

Another object of the invention is to provide a process which converts low rank fuels into other fuels of higher B. T. U. content while producing by-products of a value greater than the cost of such conversion.

A further object of the invention is to provide a process for the treatment of low-rank fuels which utilizes waste products of the fuel conversion to effect a substantial part of the conversion.

Other objects reside in novel combinations and arrangements of parts or equipment utilized in performing the process, all of which will be fully described in the course of the following description and accompanying drawings, in which:

Fig. 1 is a flow diagram showing the general movement of materials through a typical arrangement of apparatus units in accordance with the process of this invention;

Fig. 2 is side elevation, partially in section and par-

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tially diagrammatic, illustrating the equipment employed in the drying stage shown in Fig. 1;

Fig. 3 is a side elevation, partially in section and partially diagrammatic, illustrating one embodiment of the equipment employed in the carbonization stage shown in Fig. 1.

Fig. 4 is an enlarged vertical sectional view illustrating a modification of the carbonization chamber shown in Fig. 3.

As shown in the flow sheet of Fig. 1, the present invention, in its basic concept, resides in the discovery that low rank fuels such as lignite, after being suitably reduced to a fine state of division, may be subjected to rapid drying in the entrained state, for the removal of internal moisture, and after drying may be subjected to a carbonizing treatment in the entrained state for the production of a char of high heat value as one end product, crude tar as a second end product, and fuel gas as a third product usually used in the process, with the total market value of these products exceeding the cost of the lignite plus processing costs.

The problem of removing surface moisture from fine coal is principally one of heat exchange and dispersion of the coal particles so that heat can reach the moisture to permit evaporation. If enough heat can reach the surface of the particles at temperatures higher than 250° F., moisture evaporates almost instantly, and the factors of time and size are of secondary importance compared with the factors of heat balance and dispersion of the coal. The problem of removing inherent moisture from low rank coals is similar to the problem of removing surface moisture, but a longer time is required because the moisture is associated with the coal inside each particle. Hence, when low rank coals are dried, in the entrained state it is necessary to provide control of time of contact. This is done by adjusting the superficial velocity which controls the density or dispersion of the particles. The density of a solids-gas entrained system suitable for drying low rank coals appears to range from about 5 up to about 15 pounds per cu. ft. and the superficial velocity ranges from 5 to 20 feet per second.

In the drying stage hot gas under moderate pressure is generated in a combustion chamber by the combustion of pulverized coal, oil or gas. The temperature of the hot gases issuing from the burner is regulated by recirculating inert products of combustion to reduce the free-oxygen content and to produce a temperature suitable for drying the coal. This hot gas is jetted at velocities of about 80 feet per second into a drying column or heat-transfer zone where it contacts the fine coal and creates an entrained mixture of gas and coal in which heat exchange occurs rapidly to evaporate the moisture.

The mixture of hot gases and fine coal moves upwardly in an entrained condition to suitable cyclone separators, where the dried coal is deposited and the moisture vapor is discharged. During this stage, heat is transferred from the hot gas to the coal and moisture evaporates. Some of the discharged gases are recirculated to control the temperature and velocity of the gases in the drying column.

This process causes extremely rapid rates of heat interchange between the hot gases and coal particles and results in maximum thermal efficiency. The time required to pass the coal through the drying system ranges from about 20 to 230 sec. depending upon the size of the coal treated.

Features of the drying procedure and system described and illustrated herein have been claimed in my co-pending application Serial No. 111,752 of August 22, 1949, for Continuous Processing for Devolatilization of Carbonaceous Materials and Apparatus Therefor, now U. S. Patent No. 2,666,269, issued January 19, 1954.

The entrained technique can also be applied in the heating of solids in suspension quickly and uniformly through the carbonizing stage to remove valuable tars and gases. After drying, hot gases are used to pick up crushed solids and hold them in suspension in a reaction chamber until they are heated to the desired temperatures which range from 850° to 1000° F. when recovering maximum yields of tar products. In the course of being heated to these temperatures the solids undergo thermal decomposition and the reactions expected of the material at such temperature. The hot gases may be either air or hot products of combustion, or they may be recirculated coal gas heated indirectly in the carbonizing unit, if a low oxygen gas is required and undiluted make gas is recovered.

Carbonization by the entrained technique includes use of recirculated gas generated from the coal, or it may employ products of combustion formed from combustion of air and carbon inside the reactor as the suspension medium. When recirculated gas is used, cleaned make gas is returned from the condensing system and is heated indirectly to the desired temperature. This gas carries the coal through the process and supplies part of the heat of carbonization transferred directly through the walls of the reactor, and with the remainder supplied by air or oxygen introduction to effect internal heating in the reactor. The mixture of gas, char, tar and light oils that leaves the reactor is passed through a hot separator to remove the char, then through suitable heat exchangers and a condensing system. The tar and light oil are removed and some of the gas is returned to the system to entrain additional solids. The circulated load of gas remains constant and after equilibrium is reached in the operation of the carbonizer, all of the gas produced from the coal is available for heating the process or for sale if desired. The carbonizing reactor can be heated with low B. t. u. gas if necessary.

One of the essential features in the success of the operation is to attain a rapid heat exchange and optimum temperature at the carbonizing stage. To this end, large reactors with annular type combustion chambers are used. They are of advantage because the luminous zone of the combustion chamber extends over the full length of the heat transfer surface, taking advantage of the extremely high radiation from the luminous gases and particles. Heat not directly absorbed by the encompassing entraining gas radiates to the reactor shell since this shell is at the lowest temperature in the system, and passes directly through the wall and is picked up by the turbulent mixture of coal and gas inside the reactor. The solids carried in suspension inside the reactor chamber practically destroy the gas film that tends to form on the surface and thus permits extremely high heat transfer rates. As the gases move up the reactor carrying the coal with them a churning, turbulent condition is found, which breaks the gas film.

With this understanding of the problems involved in performing the process constituting the present invention reference will now be made to a typical operation as performed in the apparatus illustrated in Figs. 2 through 4 of the accompanying drawings.

As shown in Fig. 2, a crushed low rank fuel such as Texas lignite, for example, is delivered into a storage receptacle 12 by a belt conveyor 14. While the present invention may be practiced on fuels within the size range $\frac{3}{4}$ " to 0, it is preferable to treat a fuel within the size range $\frac{3}{8}$ " to 0, which reduction may be performed in any suitable apparatus, not shown. The crushed lignite, containing about 36 percent inherent moisture is fed from receptacle 12 to a conveyor 15, conveniently of the scroll type, by which it is delivered into a drier column 16. A combustion chamber or furnace 17 for generating hot gases is connected with the drier unit 16 by means of a flue 18.

The fine lignite is picked up by a rising stream of hot gases circulated as follows:

Primary air to support combustion in chamber 17 is drawn into an inlet 19 and through a forced draft fan 20 where it is pressurized to approximately 2 pounds pressure. The pressurized air moves to a plenum chamber 21 on the furnace. The air then moves upwardly through duct 21a to the burner 22.

Dried lignite for combustion may be obtained from the separating system following the drying column as from bin 23, from which it is moved into a reservoir or supply chamber 24. Any extra fuel needed is moved from a hopper 25 to the reservoir 24. Fine dust is then picked up by a coal feeder 26 which provides pressurized feeding to a pulverizer 27. The pulverizer 27 receives pressurized air from the forced draft fan 20 through dust 28, mixes it with the pulverized lignite, transports it through the line 29 into the burner 22. The mixture of air and fine lignite fed through burner 22 burns in the combustion chamber 17. Oil or gas introduced through line 30 may be used for starting the burner.

Alternatively, the burner may be fired with recycled gas produced at a point later in the system, or with pulverized carbonized char from the carbonizing unit.

The ratio of air and fuel is maintained to provide maximum combustion, approximately 30 percent excess air above the theoretical requirement provides maximum combustion. The combustion produced in furnace 17 is moderated by recirculated gas drawn from the separating system through line 31. The recirculated gases containing about 50 percent moisture vapor are pressurized through fans 32 and 33 and are moved into the furnace through line 34. The flow of these gases is split at T 35, part of them going to the top of combustion chamber through ports 36. These gases travel along the furnace walls and moderate the temperature. The balance of the recirculated gas enters the bottom of furnace 17 through port 37 and mixes with the primary products of combustion. The temperature of the final mixed gases, indicated by thermocouple 38, determines the amount of recirculated gas. These hot gases at temperatures of not exceeding 2100° F., travel at high velocity at the point of entrainment and pick up the fine raw lignite from conveyor 15 and carry the fuel into the drying column 16. In this section the sensible heat in the gases issuing from the furnace is transferred to the raw lignite and evaporates the moisture.

The drying section is constructed to allow a relatively low velocity of approximately 10 to 15 feet per second and the volume of this drying section permits a time of contact sufficient to exchange the heat and heat the coal to approximately 300° F. The mixture of dried particles, moisture vapor and cooled products of combustion is then increased in velocity through duct 39 which is designed for a superficial velocity of 75 to 100 feet per second. The mixture then moves to the primary separator 40 in the top of the collecting bin 41. In the primary separator, the dried fuel products are separated from moisture vapor and spent gases.

The dried fuel descends to hopper 25. The moisture vapor and spent gases containing some fine particles travel through duct 42 into a baffle type separator 43. The baffles reverse the direction of flow of the gases through the duct and dust particles descend into dust separators 44. The fine dust separated in the cyclones 44 moves into bin 23 to supply part of the fuel for the process. The waste gases containing about 55 percent moisture move to the stack through line 45 and are wasted.

The dried fuel feeding into hopper 25 moves in two directions. First, it will move through column 46 into a feeder 47. The fuel in this column is pressurized by introduction of pressurized gases from line 48. This allows the feeder 47 to operate readily to feed the dry coal to transport line 49. Part of the dried fuel may

pass into the collecting bin 41 when the hopper 25 is full. As the collecting bin fills and fuel is needed from the bin, it is transferred to transport line 49 through a second feeder 50. Dried fuel may also be withdrawn from hopper 25 by line 51 to supply fuel to reservoir 24.

In performing the second stage of the treatment, namely, the carbonization of the dried fuel, it has been determined experimentally that it is necessary to invest about 415 B. t. u. per pound of dried lignite to raise its temperature to 900° F. and to distill the volatile products. The heat required for carbonization can be supplied more efficiently in an externally heated retorting system where about half the heat for carbonization is transferred through the walls of the retort and the additional heat is supplied by partial combustion of the char or recirculated gas with the air introduced in the fuel mixture.

Finally, it should be understood that to be effective for its intended purpose, the carbonization stage must produce a temperature rise of from approximately 250° F. to 900° F. within a relatively short time interval, usually termed residence time. For this reason, the carbonizer and recuperator unit now to be described is particularly suited for use in this treatment.

Dried fuel from the column 46 or from the collecting bin 41 is moved pneumatically through line 49 with preheated air which may be supplied by line 52. As shown in Fig. 3, this mixture enters reaction vessel 53 through a valve 54. In the reaction vessel 53, the fuel is heated to approximately 900° F. to form char, tar and process gases.

In the preferred embodiment, shown in Fig. 3, the vertical reactor 53 is a single walled vessel of alloy heat resistant steel. This vessel is heated externally by the combustion of process gases and recirculated products of combustion in combustion space or zone 55. The features of the combustion chamber are generally similar to those shown in Patent No. 2,518,490. Air is drawn into the system through line 56 and is mixed with hot recirculated products of combustion travelling through line 57. This mixture is pressurized in a blower 58 and is moved through line 59 to a recuperator 60 where it is preheated and enters plenum chamber 61. From this plenum chamber a plurality of ducts 62 lead to tangential burners 63. Each burner is served by one duct. The preheated end products of combustion join the process gas entering the system through header 64, which may be supplied by recirculated coal gas from the condensing system. This mixture of air and gas burns around the outer wall of reactor 53 under controlled temperatures, indicated by thermocouple 65.

The ratio of air, products of combustion and process gas is adjusted to allow the desired temperature while using a minimum of excess air (not exceeding 5 percent is suitable for this combustion). Heat is transferred to the fuel inside the reaction vessel by radiation from the flame of direct combustion and by convection. This provides maximum rates of heat transfer. The products of combustion leave the system through flue 66 and pass through the recuperator 60 where the air and products of combustion are preheated. The partially cooled products of combustion then pass into a second recuperator 67 which is used to preheat air introduced through line 68 by means of fan 69. This preheated air passes through line 70 into line 52 which provides air for dried fuel transport and for reaction with the fuel inside reaction vessel 53. Preheated air in addition to that required for fuel transport may be introduced into the reaction vessel 53 through line 71. Process gas may also be introduced into the reaction vessel 53 as by line 71a.

The cooled combustion gases from recuperator 67 are drawn through line 72 by an exhaust fan 73. This fan can be regulated to provide zero or atmospheric pressure around the reaction vessel. Waste gases are vented to stack 74.

The dried coal entering the reactor through line 49 under control of valve 54 is mixed with the preheated transport air which is further heated to reaction temperature inside the reaction chamber. Additional air for this reaction also enters the reactor through line 71 controlled by valve 75. The mixture of air and dried coal is heated in the externally heated reaction vessel by transfer of heat through the walls of the reaction vessel to a point where the air supplied enters into reaction with the coal. The air thus supplies internal heat. The amount of air mixed with the coal is adjusted to provide a final reaction temperature measured by a thermocouple at point 76 of about 900° F. At this temperature, the maximum yield of crude primary tar is formed, provided the lignite particles are retained in the reaction vessel for a suitable period. This time is approximately 10 to 15 minutes. The time of residence in the vessel is predetermined by the reaction and the temperature of the vessel is adjusted to the rate of movement of the gases for reaction purposes. The optimum superficial velocity is in the range of 3 to 6 feet per second.

The products of carbonization forming in the reactor are moved upward by the pressure of the contained gases and move from the system through duct 77 to a primary separator 78. This separator is insulated as shown at 79 to prevent cooling and condensation of the vapors. At this point, the carbonized residue or char separates from the vapors and moves into a feeding column 80. The char not separated by the initial cyclone action is then passed through high velocity cyclones 82 which strip the finer char particles from the vapors or gases. These fine particles then descend by gravity through lines 83 which are submerged in the column of char in column 80. The cleaned vapors and gases then leave the system through line 84 running to a condensing plant of any conventional type, the details of which are not shown.

The carbonized char, now at a temperature of 900° F., moves through column 80 to a feeder 85. Entraining gas may be introduced into the column 80 by means of line 86. In the arrangement shown, the function of this feeder is to pressurize the char to allow it to be transported to the boiler plant (Fig. 1) through line 87 which joins an extension of transport line 49 from the drying unit. The hot char is moved pneumatically from the feeder 85 with inert products of combustion withdrawn from the stack 74 through line 88. These gases pass through a scrubber 89, before entering compressor 90. These inert gases then move to the feeder 85 through line 91 and are regulated by valve 92. The hot char which may be mixed with entrained dried fuel in the line 49 is now transported to the power plant as shown in Fig. 1 where it may be burned in suitable apparatus.

As shown in the flowsheet of Fig. 1, the gases from the condensing unit pass to a storage chamber from which they may be withdrawn to provide part of the power plant fuel. Part of the gases produced may be recycled to provide the gases for combustion in the carbonizing units either within or around the reaction chamber, for combustion in the furnace of the drying unit, or for both purposes. The product gases may also be used for other purposes either within or outside of the system shown. In the preferred practice a constant recycle gas rate is used, thus providing a constant supply of product gas for power plant and other uses.

An alternative form of carbonizer structure is shown in Fig. 4. In accordance with this modification, a double-walled reactor is employed. The vertical reactor is provided with an inner wall 100 and an outer wall 101, both constructed of material of good conductivity such as alloy heat-resistant steel, and which define an annulus 102. The bottom of the inner shell is provided with a grid or screen 103 through which inlet line 104 from the dried fuel transport line extends.

In operation of the double-walled carbonizer shown in Fig. 4, recirculated gas from manifold 64 is introduced

at the top of the carbonizer by means of line 105 and pump 106 and while passing downwardly through annulus 102 is heated by heat exchange with the combustion in chamber 55, after which it enters through grid 103 into the interior of carbonizer 53. Within the carbonizer, the dried fuel-air mixture introduced by line 104 and the hot recirculating gas are subjected to further heating resulting from the heat exchange from combustion chamber 55, radiant heating from the surface of shell 100, and a partial combustion occurring within said mixture. As the amount of air so introduced is substantially less than required for complete combustion, the partial combustion serves as the means for attaining the desired temperature rise in the optimum residence time and without undue decomposition of the tarry constituents.

In preferred practice, the carbonizer vessel 53 will have a length-to-diameter ratio of about 5.1, and will have a combustion zone located substantially about the entire extent of the wall 101. Combustion is conducted under conditions that allow rates of heat transfer of approximately 10,000 to 15,000 B. t. u./sq. ft. hr. when developing a furnace temperature of about 1900° F.

In the treatment of a Texas lignite, for example, the flow of gases at the base is adjusted to allow a superficial velocity of 2.0 to 3.5 feet per second, which carries the fuel particles upwardly in an entrained stream. The entering recirculated gas which has passed downwardly through the annulus 102 may ignite with part of the air entering with the fuel, and thus provides the controlled combustion. Heat resulting from combustion of the char or gas with the air combines with heat transferred through the shell 100 to heat the fuel particles to a temperature of approximately 900° F.

The external heat initiates low temperature combustion of the air near the base of the carbonizer and combustion is completed rapidly so the lignite particles have several minutes to reach the carbonizing temperature. The residence time of the fuel particles in the reactor is controlled by the rate at which the entrained fuel is charged and the superficial velocity of the gases moving up the column. A change in this velocity and fuel charging rate are adjusted to provide a residence time of 10 to 15 minutes, which completes the carbonization with maximum tar yield.

After completion of the carbonizing action as just described, the char residue tars and light oils pass through the line 77 into the primary separator, the functioning of which has already been described. Thus, it will be seen that the two stage treatment of the fuel in an entrained state is capable of functioning efficiently in continuous operation.

It should be understood that the drawings are intended to disclose typical arrangements for performing the process of the present invention and various arrangements may be resorted to in effecting the two stage processing previously described. As an example, the preferred arrangement for controlling fuel discharge from standpipe 46 and bin 41 of the drying unit is to maintain sufficient pressure at the base of standpipe 46 by gas introduction through gas inlet 48 to maintain an entrained condition in standpipe 46 and at the same time provide a pressure at feeding device 47 which balances the pressure in line 49. Any drop in pressure below normal in standpipe 46 will activate feeder 50 to discharge fuel directly from bin 41 into line 49. For this reason, feeder 50 is gas-tight.

At the present time, the value of the tar content extracted by the present process varies between eight cents and ten cents a gallon. On the basis of the comparative testing so far undertaken, it has been determined that if Texas lignite is utilized as a fuel with only conventional screening and grading operations performed prior to its use as fuel, the actual fuel cost of a given operation on a heat value basis is substantially twice that of the char product by the present process after credit is taken for the market of the extracted products. As a consequence, it

now appears that low ranking fuels can be processed by the present method and utilized as power plant fuel on a cost basis competitive with other fuels, such as oil and natural gas.

The term "low rank fuels" as used in the present specification is intended to designate fuel such as lignite or pure coal having more than 11 percent oxygen on a moisture or ash-free basis. While the present invention has been shown as having particular application to the treatment of low ranking fuels, because of the economical factors favoring such treatment on the present market, it should be understood that the same procedure may be used with high ranking fuels, possibly requiring some blending of char produced in the operation with the dried fuel feed to the carbonizer stage in order to maintain the desired fluid condition.

The carbonization stage as referred to in the specification is intended to designate the lower range of temperatures, whereby bituminous materials decompose by thermal treatment. "Gaseous medium" as used in the specification means any form of gas, alone or blended, as well as vapors evolved in the various stages of the process.

What is claimed is:

1. The process of drying, preheating and devolatilizing carbonaceous materials which comprises passing finely divided carbonaceous low rank coal particles entrained in a stream of hot gases flowing upwardly at relatively low velocity through the bottom of and upwardly through a drying and preheating zone, where the sensible heat in the gases is transferred to the carbonaceous particles and evaporates the moisture therefrom, and the particles are preheated to about 250°-300° F., passing said stream at increased velocity from said drying and preheating zone to a separating zone and there separating the dried carbonaceous particles from the moisture vapor and spent gases of said stream, passing the dried heated particles entrained in air upwardly through the bottom of and upwardly through a reaction zone while suddenly raising the temperature of the particles in said zone to a temperature in the range of about 850° to 1000° F. to form char, tar and process gases and withdrawing said char, tar and process gases through the top of said reaction zone.

2. The process as set forth in claim 1 in which the particles are within the size range $\frac{3}{4}$ " to 0.

3. The process as set forth in claim 1 in which the superficial velocity of the stream as it passes through the drying and preheating zone is within the range of from 5 to 20 feet per second.

4. The process as set forth in claim 1 in which the superficial velocity of the stream between the preheating zone and the separating zone is increased to about 75 to 100 feet per second.

5. The process as set forth in claim 1 in which the residence time of the particles in the reaction zone is from about 10 to 15 minutes.

6. The process as set forth in claim 1 in which the velocity of travel of the particles through the reaction zone ranges from about 3 to 6 feet a second.

7. The process as set forth in claim 1 which includes the step of passing the particles into and out of a storage zone intermediate the drying and preheating zone and the reaction zone for accumulating a supply of dried particles for distribution and delivering particles from said supply to the reaction zone.

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