

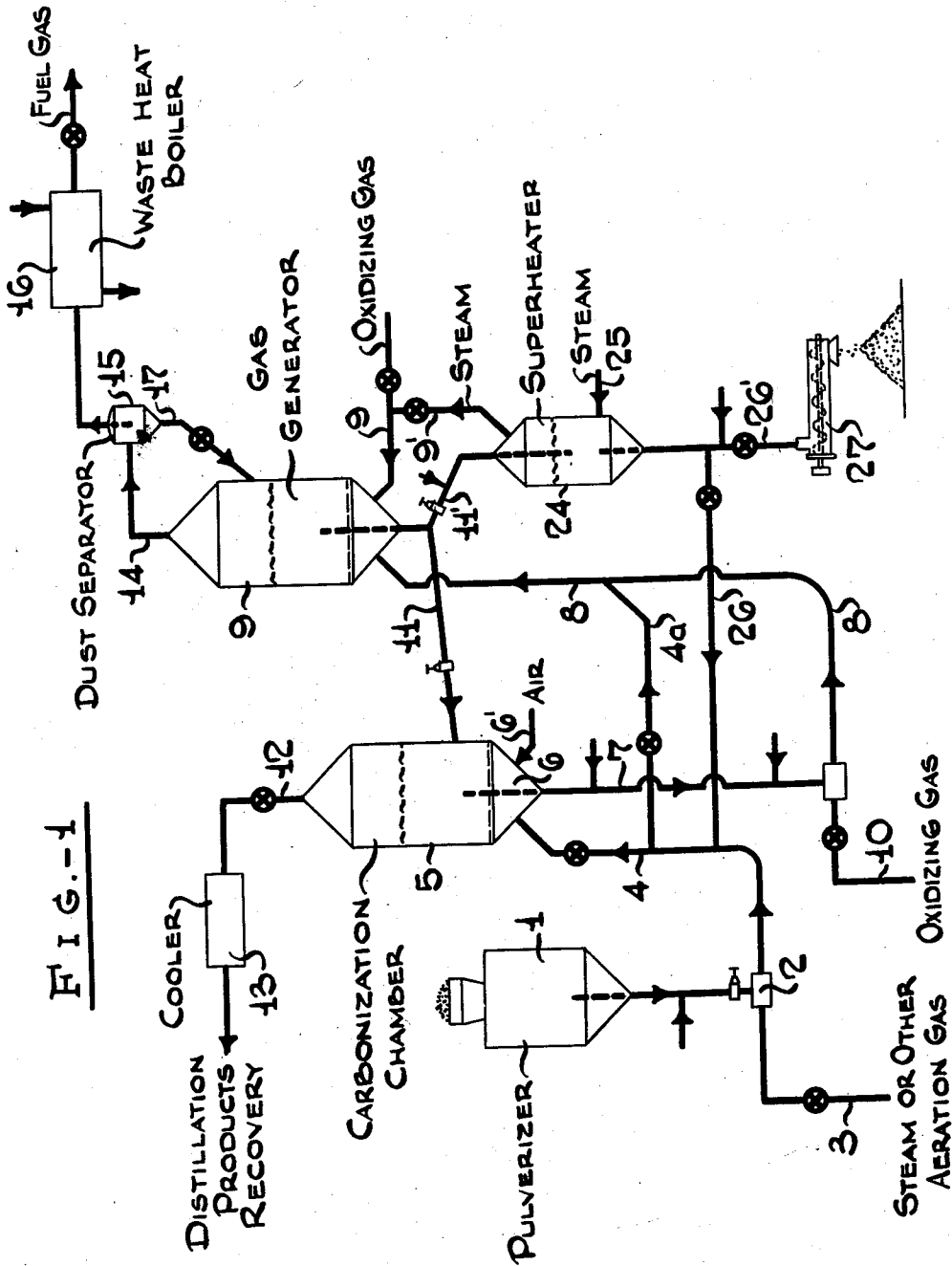
Dec. 18, 1951

B. E. ROETHELI
METHOD FOR HANDLING FUELS

2,579,398

Filed Aug. 8, 1945

5 Sheets-Sheet 1



Bruno E. Roetheli Inventor
By P. J. Young Attorney

Dec. 18, 1951

B. E. ROETHELI
METHOD FOR HANDLING FUELS

2,579,398

Filed Aug. 8, 1945

5 Sheets-Sheet 2

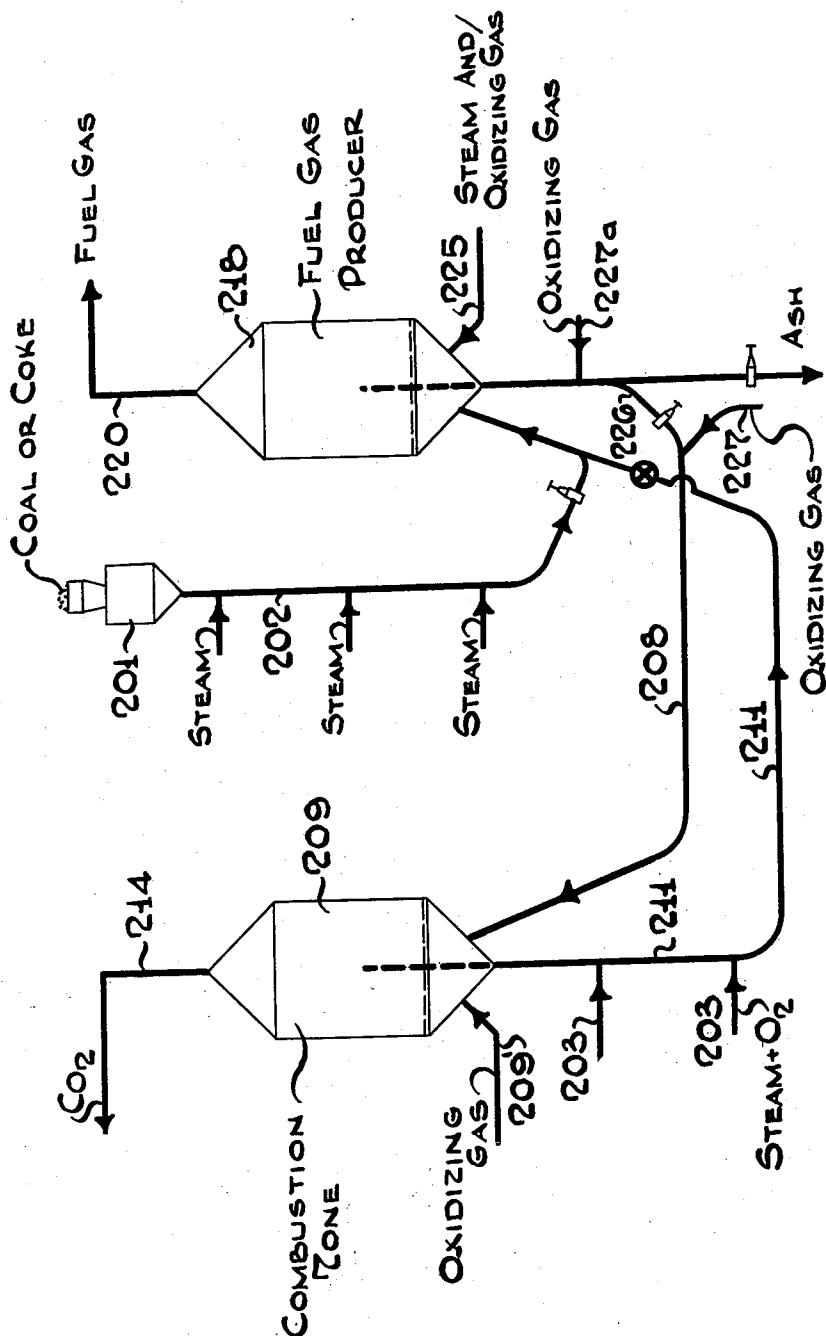


FIG. - 2

Bruno E. Roetheli Inventor
By P. H. Young Attorney

Dec. 18, 1951

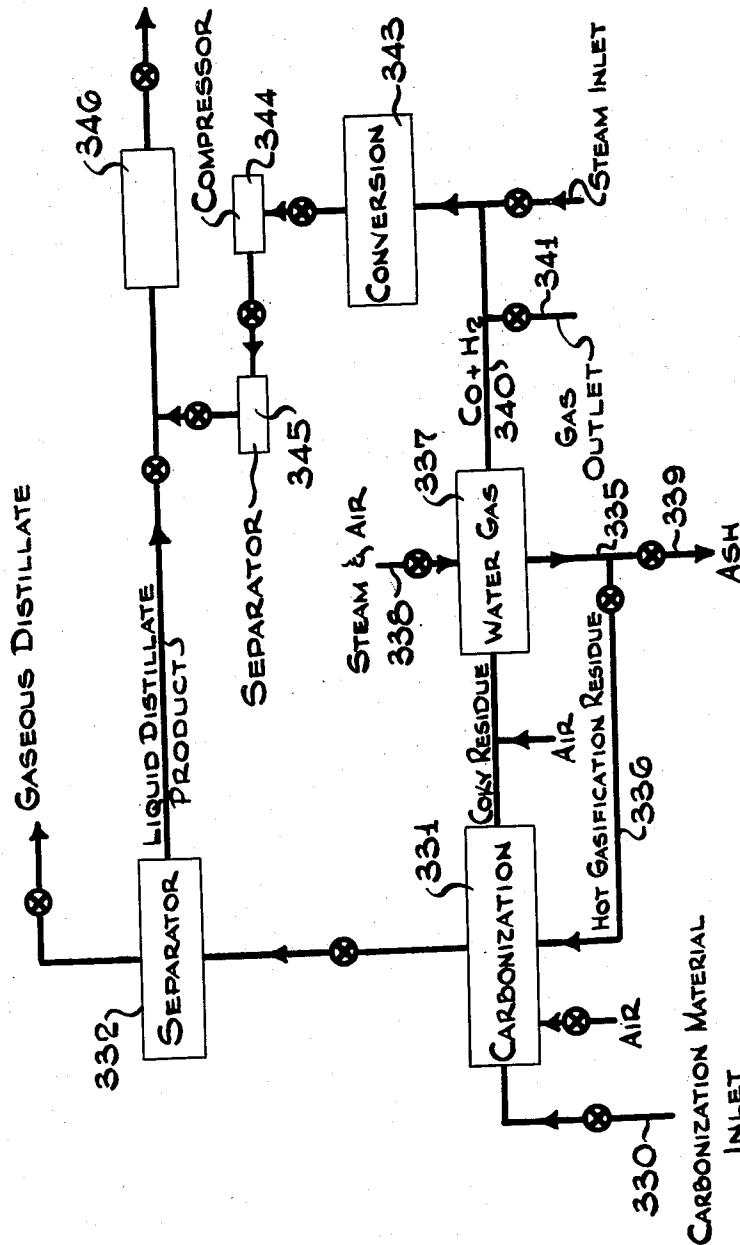
B. E. ROETHELI
METHOD FOR HANDLING FUELS

2,579,398

Filed Aug. 8, 1945

5 Sheets-Sheet 3

FIG. - 3



Bruno E. Roetheli Inventor

By J. L. Young Attorney

Dec. 18, 1951

B. E. ROETHELI

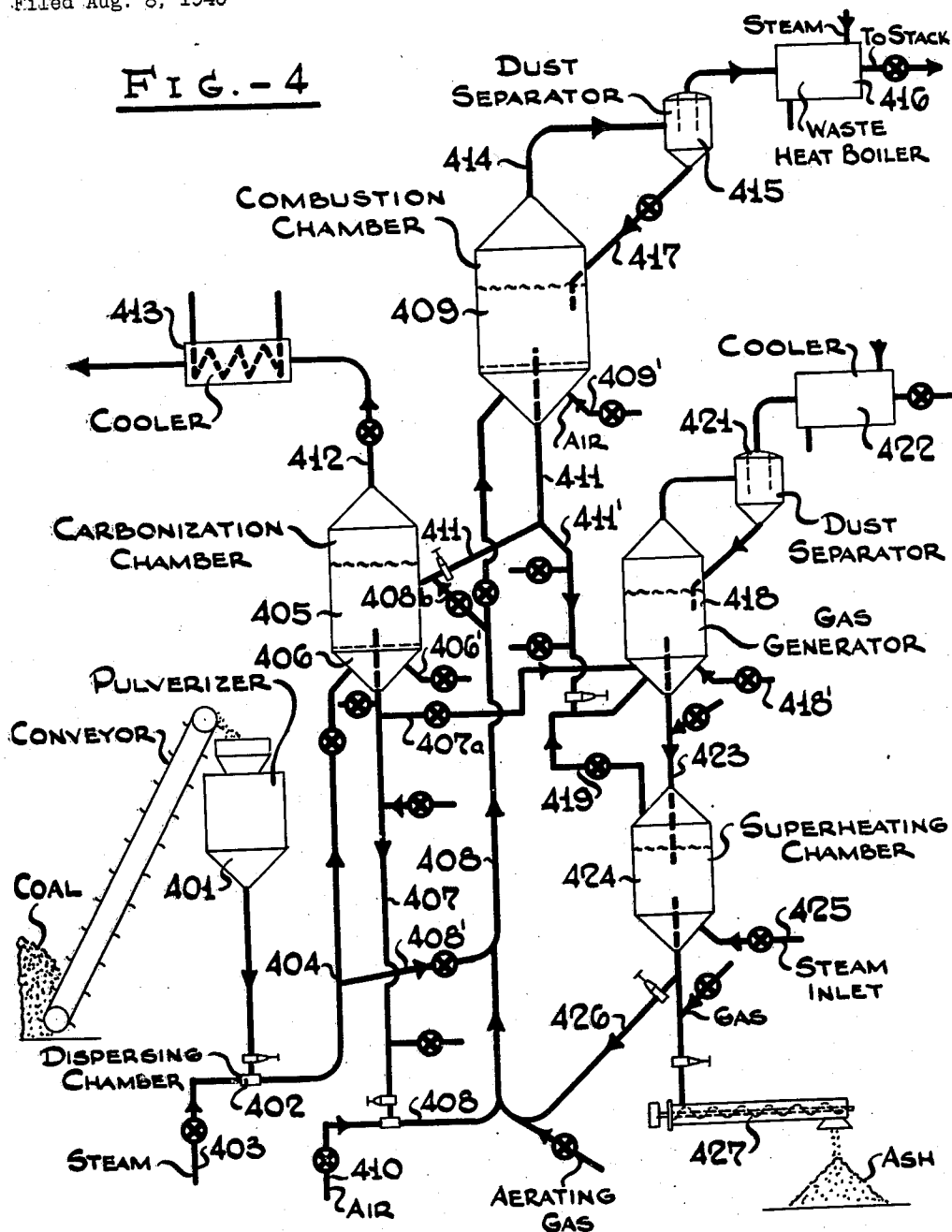
2,579,398

METHOD FOR HANDLING FUELS

Filed Aug. 8, 1945

5 Sheets-Sheet 4

FIG.-4



Bruno E. Roetheli Inventor

By P. H. Young Attorney

Dec. 18, 1951

B. E. ROETHELI
METHOD FOR HANDLING FUELS

2,579,398

Filed Aug. 8, 1945

5 Sheets-Sheet 5

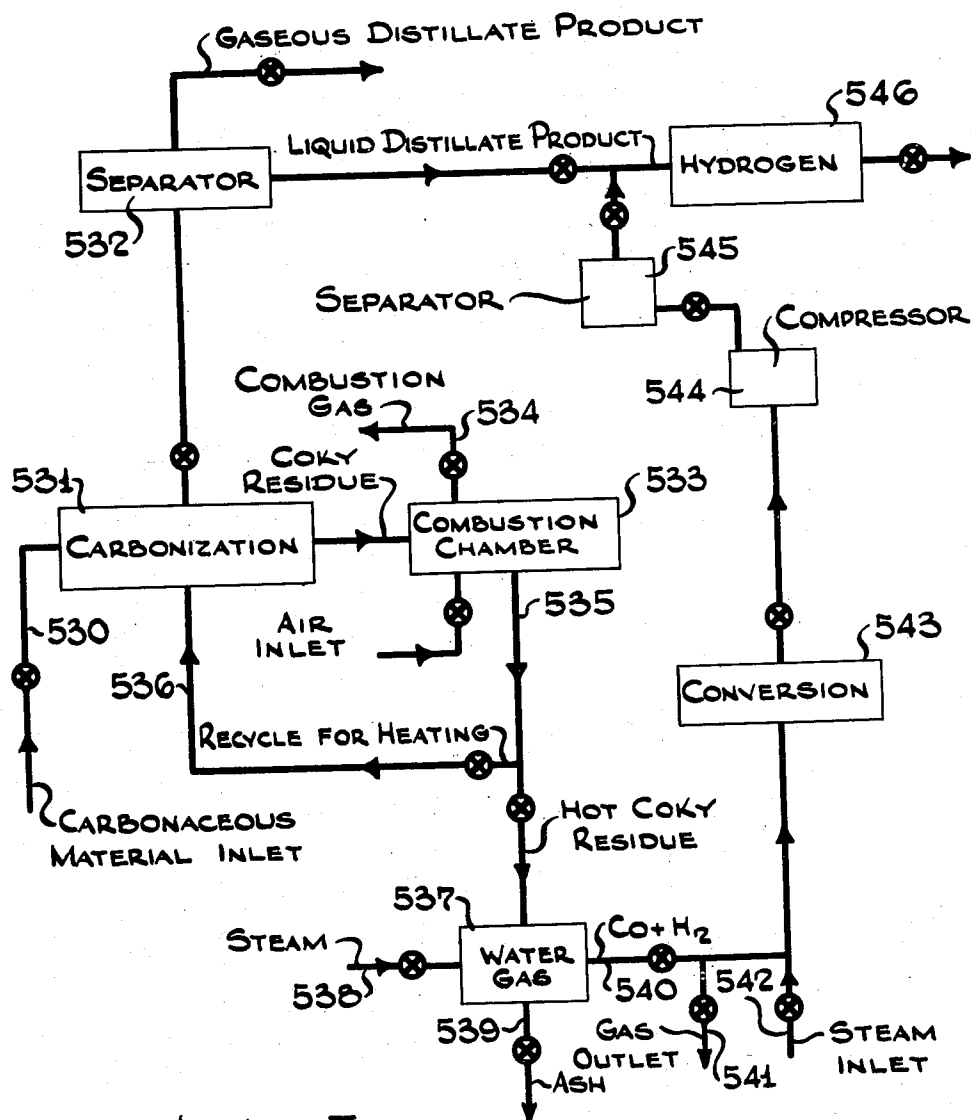


FIG. - 5

Bruno E. Roetheli Inventor

By P. H. Young Attorney

UNITED STATES PATENT OFFICE

2,579,398

METHOD FOR HANDLING FUELS

Bruno E. Roetheli, Cranford, N. J., assignor to
Standard Oil Development Company, a corporation of Delaware

Application August 8, 1945, Serial No. 609,662

9 Claims. (Cl. 48-202)

1

The present invention relates to an improved process for the efficient utilization of carbonaceous solid material, such as coal, coke, peat, tar sands, oil shales, and the like, and more specifically to a process for converting such materials into more valuable products including fuel gases.

It has been long known and appreciated that solid fuel materials, such as coke, coal, and the like, could be converted into more valuable gaseous fuels which can be more efficiently used in this form. Producer and water gas processes are familiar to all, but neither of these processes is entirely satisfactory because the first mentioned produces a low calorific fuel, and because the second has heretofore required a discontinuous type of operation. Low temperature carbonization is also known to have many advantages, but it is difficult to carry out mechanically. The present process may be used for producing in a continuous manner valuable fuel gas of high calorific value, including gas mixtures useful in the production of synthetic hydrocarbons by the catalytic conversion of carbon monoxide with hydrogen, and it can be employed for carrying out the carbonization of coal at the same time in a mechanically efficient manner.

This application is a continuation-in-part of my application Serial No. 487,187, filed May 15, 1943. My invention deals broadly with a continuous process for converting solid carbonaceous materials containing distillable constituents into valuable volatile fuels such as carbonization products and fuel gas by passing a fluidized stream of finely divided starting material through suitable conversion zones, such as carbonization and/or gasification zones, and using heat of combustion to supply the heat required in the conversion zones.

It is an object of my present invention to provide means by which the heat required in the carbonization and/or gasification zones is generated by the combustion of portions of the carbonaceous materials and supplied to these zones either by the circulation of fluidized solids highly heated by the heat of combustion or directly by partial combustion in the zones to be heated, or both.

My new process affords substantial savings in capital investment and operating cost, as well as full and easy adaptability to changes in the character of the starting materials and/or the properties of the desired products. These and other advantages will be fully understood from the following description and the drawing.

The drawing in Fig. 1 is a semi-diagrammatic

2

view in sectional elevation of an apparatus for carrying out the present process and indicates the flow of the materials.

Fig. 2 is a semi-diagrammatic view in sectional elevation of an apparatus for carrying out the present process when applied to the production of fuel gas only.

Fig. 3 is a diagrammatic flow plan showing a modification of the plan of Fig. 1.

Fig. 4 is a semi-diagrammatic view in sectional elevation of an apparatus for carrying out the present process in separate carbonization, gasification and combustion zones.

Fig. 5 is a diagrammatic flow plan showing a modification of the plan of Fig. 4.

Referring to Fig. 1, numeral 1 denotes the crusher or pulverizer which is employed to reduce a solid carbonaceous fuel to a finely divided form, for example, preferably of the order of below 50 mesh, or even less than 100 mesh, although even small lumps, say $\frac{1}{4}$ to $\frac{1}{2}$ " size, may be used. For the purposes of the following description, the material will be referred to as carbonization coal, but it will be understood that other materials can be used. The finely ground coal drops from the crusher into a dispersing chamber 2, wherein it is thoroughly dispersed in a stream of an "aeration" gas, such as superheated steam, nitrogen, combustion gases, etc., which is added by pipe 3. The coal in the dispersion is said to be in a "fluidized" form because in this form it is capable of flowing through pipes, valves, ducts and such equipment much like a liquid, showing both static and dynamic heads. The fluidized stream is passed through pipe 4 into the lower portion of a carbonization chamber 5 which is in the form of a cylinder fitted at its lower end with a conical base 6 to which an oxidizing gas, such as air and/or oxygen, may be admitted through line 6'. A grid or screen is located in the lower portion of the chamber conveniently at the place where the cone and cylinder unite.

An elongated vertical pipe 7, preferably opening above the grid or screen, is provided to carry a fluidized stream of solids from the carbonization chamber 5 and the stream is then conducted by the vertical pipe 8 into a gasification chamber 9, which is similar to chamber 5. An oxidizing gas, such as air and/or oxygen, is added to the withdrawn stream of the fluidized solid at 10 and causes the flow of the stream, as will be explained below, up into the chamber 9 where steam is added through line 9' and rapid gasification takes place to form carbon oxides and hydrogen. The heat required for the endothermic gasification re-

3

action with steam is supplied by the combustion of a portion of the carbonaceous solids in chamber 9 by the oxidizing gas admitted through line 10. Additional air and/or oxygen may be added to the chamber through pipe 9' as indicated in the drawing. The total supply of oxidizing gas is carefully controlled to generate sufficient heat by combustion to satisfy the heat requirements of the process.

A discharge pipe 11 takes a stream of the fluidized solid material from the gasification chamber 9 and discharges it into chamber 5 so that the highly heated material from the gasification chamber 9, which is at a temperature of, say, 1400° to 2500° F., is continuously recycled to the carbonization chamber 5. This chamber is at the usual carbonizing temperature of, say, 1000° to 2200° F. and the preheat and heat of carbonization may thus be substantially completely furnished by heat supplied from the gasification chamber.

Vapors are withdrawn from the carbonization chamber 5 by a pipe 12 through cooler 13 and than to any suitable means for recovery of the coal distillation products. Cooler 13 may be of the indirect type shown or the direct type, as desired. The recovery system (not shown) need not be described in detail because such systems are well known in the art, but should provide means for segregating the dust, tar, light oils, ammonia and fuel gas.

Fuel gases, such as water gas, are taken from the chamber 9 by a pipe 14 which leads to a dust separator 15 and to a waste heat boiler 16 for steam generation. The separated dust may be returned to the chamber 9 by a pipe 17. The gas may be treated in any usual manner for the removal of sulfur or other impurities, in equipment not shown, making it suitable for use as city gas or otherwise. If desired, the whole or a portion of the gas resulting from coal carbonization may be admixed with the water gas.

A fluidized stream of solids which is now largely free from carbon is withdrawn by pipe 11' from the gas generator 9 and can be discharged into the chamber 24 which is blown with steam admitted by pipe 25. Steam is then withdrawn by pipe 9' in a highly heated condition useful for the generation of the water gas. A portion of the fluidized solid is taken from the superheating chamber 24 by a pipe 26 and may be returned to pipe 4 to add preheat to the charge of chamber 5. Another portion is discharged through 26' at 27 to prevent accumulation of non-carbonaceous materials in the system.

The system described above is a very flexible one, capable of many modes of operation. In it there are two main chambers or zones; the first for carbonization, and the second for combustion and water gas generation. The gasification zone is operated at the most elevated temperature and high temperature heat is generated therein by combustion which is utilized for the carbonization and gas generation, which processes require lower temperatures. Excess heat generated in the gas generation chamber is carried from this chamber to the carbonization chamber by the continuously flowing streams of fluidized solid. Thus the process is made fully continuous.

If it is desired to conduct the gas generation reaction at lower temperatures, for instance in order to modify the composition of the fuel gases produced, or if it is desired to reduce the amounts of hot solids recirculated from the gas generation chamber 9 through lines 11 and/or 26 to carbon-

4

ization chamber 5, with the result that the heat supplied by the recirculated solids is insufficient to satisfy completely the heat requirements of the carbonization zone, an oxidizing gas, such as and/or oxygen, may be introduced through line 6' into the lower cone 6 of carbonization chamber 5. The amount of oxidizing gas thus introduced is carefully controlled to supply just sufficient heat by combustion of carbonaceous material to supplement the heat supplied by the recirculated solids so as to maintain the desired carbonization temperature.

If coal is used as the raw material, it is preferably fed directly to the carbonization chamber and heat for the carbonization is supplied by a stream of highly heated solids flowing continuously from the gasification chamber through the pipe 11 and discharging into the chamber 5. The temperature is capable of very careful regulation and control, and is distributed rapidly through the fluidized mass in the carbonization chamber because of the high degree of agitation maintained therein. Chamber 5 is sufficiently large to permit complete carbonization and the solids removed by pipe 7 are substantially free of volatile materials and are capable of rapid gasification with steam and air in the gas generation chamber 9. If desired, an inert material such as sand may be added to the coal and circulated through the chambers 5 and 9 and the associated pipes 7, 8 and 11, so as to provide a larger volume of heat-carrying solid material, but this is ordinarily not required as the ash content of the coal may be allowed to accumulate and thus furnish any desired amount of inert solid. High ash coals may thus be employed in the process.

It is important in this operation not to reach a temperature such that the solid is caused to sinter or melt, and if the ash content of the coal employed has a tendency in this direction, other materials such as alumina, lime, magnesia, coal having an ash of higher fusion point, and the like, may be added to raise the melting point of the ash so that the operation may be conducted efficiently, even where the ash is of relatively low melting point. The choice and quantity of these ash-modifying materials depend on the character of the low fusion point ash.

It is desirable in most cases to operate the water gas generator along with the carbonizer as described. In most cases there is heat available in the combustion of the solid inviolate portion of the coal in excess of that required for the carbonization reaction and the gas produced with the excess carbon in this manner is therefore of low cost.

If it is desired to convert the carbonaceous starting material predominantly into fuel gas, my process may be operated in a cycle comprising a combustion zone and a gasification zone with the feed of the starting material to the gasification zone, as will be more clearly understood from the following description in connection with Fig. 2 of the drawing.

According to this modification, as shown in Fig. 2, solid carbonaceous material, such as coal, shale, tar sands, and the like, or solid carbonization products thereof in finely divided form, is fed from hopper 201 into line 202 where it is fluidized with steam or a similar aerating gas as outlined before. The fluidized material is introduced into line 211 wherein it is mixed with hot residue having a temperature of about 1600° F. or higher, withdrawn from combustion zone 209 and fluidized with steam and/or an oxidiz-

ing gas, such as air or oxygen, as will appear more clearly hereinafter. The mixture now having a somewhat reduced temperature enters gasification zone 218 wherein it is maintained in a fluidized state at temperatures of about 1400° to 2200° F. to cause reaction between the carbonaceous material and steam to form water gas. The heat required for the reaction is furnished substantially by the heat of the hot residue recycled from combustion zone 209. Any additional heat required may be supplied by partial combustion of carbonaceous material with the aid of an oxidizing gas, such as air or oxygen, supplied as carrier gas through line 211 or separately through line 225. If desired, additional steam may be added through line 225; this steam and/or oxidizing gas may be superheated with the aid of waste heat recovered from products from zone 209 or 218 in a manner known per se. Fuel gas, such as water gas, is withdrawn through line 220 and further treated as outlined in connection with line 14 of Fig. 1.

Fluidized carbonaceous residue is withdrawn through line 226 further fluidized with an oxidizing gas, preferably air, introduced through lines 227 and 227-a and carried under the pressure of standpipe 226 and the gas pressure in 227 into combustion zone 209 wherein it is maintained in a fluidized condition and subjected to at least partial combustion at temperatures of about 1600° to 2400° F. Additional air or other oxidizing gas may be supplied for this purpose through line 209'. Solid combustion residue, which may be practically carbon-free ashes, is withdrawn from chamber 209 through standpipe 211 aerated through lines 203 and 203-a with steam and/or an oxidizing gas and fed to the gasification chamber 218, as outlined above.

Where carbonizable starting materials, such as coal, are used in this embodiment of my invention, the reaction in chamber 218 may be conducted alternatively or alternately as a carbonization reaction as outlined in connection with chamber 5 of Fig. 1. In this case solid fluidized carbonization residue from chamber 218 may be fed to the combustion zone 209 and the process further carried out as described above.

In Fig. 3 there is a flow plan illustrating a method which is particularly applicable to the working up of solid carbonaceous materials, such as are disclosed in Fig. 1, particularly coal, peat, shale, tar sands and the like. The apparatus employed is closely similar to that shown in Fig. 1, but the flow plan herein contained is more complete in some respects.

The raw material in finely divided form enters at 330, passing directly to the low temperature carbonization step indicated at 331. Distillation products are removed from 331 and are separated into gaseous and liquid products in the separation equipment indicated generally at 332.

The coky residue produced as a result of the carbonization is conducted to the gas generation stage of the process indicated at 337 where steam and air are also introduced. The gases are taken off at 340 and the hot residue at 335. A portion of this residue is returned to the carbonization stage 331 as indicated by the line 336 in order to carry heat for carbonization, as explained previously. Ash constituents of the original fuel are collected and drawn off at 339. The gas, which is largely CO and hydrogen is taken off at 340 and a portion of this may be drawn off for heating or other purposes at 341. To the

remainder of the gas an additional quantity of steam is added at 342 and the mixture is passed through a catalytic conversion step 343 wherein carbon monoxide is converted with steam to carbon dioxide.

The gas which remains is compressed at 344 and carbon dioxide is separated at 345. The remaining gas, which is substantially pure hydrogen, is then employed for the hydrogenation of the liquid distillation products produced from the original carbonization. This is accomplished in the hydrogenation step indicated at 346.

It will be understood that the carbonization and the water-gas generation stages are conducted just as indicated in the previous description of Fig. 1, that is to say while the solid material is in a fluidized condition. The conversion of the CO to CO₂ and hydrogen by means of steam is preferably effected catalytically, using as a catalyst iron oxide or iron oxide promoted with chromium and similar materials which are well known in the art. The conversion is effected at a temperature of the order of 850° F. and low pressure is ordinarily employed.

The hydrogenation step may be any one of a number of different types which are well known in the art. For example, it may be carried out under mild hydrogenation conditions, that is to say at relatively low temperatures and pressures so that the hydrogen does little more than to effect a purification by removal of sulfur, nitrogen and similar elements. On the other hand, the hydrogenation may be carried out under destructive conditions, that is to say at pressures above 20 atmospheres and preferably at about 200 atmospheres and at temperatures say from 700° to 1100° F. In this way the tarry materials are converted fully into lower boiling liquids rich in hydrogen. In these various hydrogenation procedures, the preferred catalysts are of the sulfur immune type, especially those containing metals, oxides or sulfides of the 6th group of the periodic table, either alone or in admixture with each other or with difficultly reducible oxides, such as alumina, zirconia, magnesia or lime. More readily reducible oxides, such as zinc oxide, can also be added to the catalyst mixtures.

In the modification of my process illustrated in Fig. 4 the heat required in the carbonization and gasification zones, described in connection with Fig. 1, may be generated in a separate combustion zone. Referring now to Fig. 4, numeral 401 denotes the crusher or pulverizer for the solid carbonaceous fuel. The finely ground coal drops from the crusher into dispersing chamber 402, wherein it is thoroughly dispersed in a stream of steam, which is added by pipe 403. The coal in the dispersion is in a "fluidized" form and is passed through pipe 404 into the lower portion of a carbonization chamber 405 which is similar in construction and operation to chamber 5 of Fig. 1.

An elongated vertical pipe 407, preferably opening above the grid or screen, is provided to carry a fluidized stream of solids from the carbonization chamber 405 and the stream is then conducted by the vertical pipe 408 into a combustion chamber 409, which is similar to chamber 405. Air is added to the withdrawn stream of the fluidized solid at 410 and causes the flow of the stream, as will be explained below, up in the chamber 409 where rapid combustion takes place. Additional air may be added to the chamber by pipe 409'.

A discharge pipe 411 takes a stream of the

7

fluidized solid material from the combustion chamber 409 and discharges it into chamber 405 so that the highly heated material from the combustion chamber 409, having a temperature of say 1600° to 2400° F., is continuously recycled to the carbonization chamber 405, maintained at about 1000° to 2200° F. The preheat and heat of carbonization is thus substantially completely furnished by heat supplied from the combustion chamber.

Product vapors are withdrawn from the carbonization chamber 405 by a pipe 412 cooled at 413 and thence passed to any suitable system for the recovery of coal distillation products.

Combustion gases are taken from the chamber 409 by a pipe 414 which leads to a dust separator 415 and to a waste heat boiler 416 for the steam generation. The separated dust may be returned to the chamber 409 by a pipe 417.

Pipe 411', which is shown as a branch of pipe 411, is provided to draw off a portion of the highly heated fluidized contents of chamber 409 and to conduct it to a gas generator 418. This generator is shown as a vertical cylindrical vessel with a conical base, similar to chambers 405 and 409 described above, and it is preferably provided with a screen at its lower portion to act as a distributor. The fluidized solid stream is discharged into the chamber, preferably below the screen as described above, and steam preferably superheated is added by a pipe 419. The generator is maintained at a temperature between about 1400° and 2500° F., suitable for the rapid reaction of carbon and steam to produce water gas.

Gas is withdrawn continuously by a pipe 420 to a dust separator 421 and to a cooler 422. Thereafter the gas may be treated as indicated in connection with Fig. 1.

A fluidized stream of solids which is now largely free from carbon is withdrawn by pipe 423 from the gas generator 418 and can be discharged into the chamber 424 which is blown with steam admitted by pipe 425 and is then withdrawn by pipe 419 in a highly heated condition desirable for the generation of the water gas. A portion of the fluidized solid is taken from the superheating chamber 424 by a pipe 426 and may be returned to pipe 408 for recirculation to the combustion chamber 409. A small portion is discharged at 427 to prevent accumulation of inert solids in the system.

In the system last described there are three main chambers or zones: the first for carbonization, the second for combustion and the third for water gas generation, but all three need not be used simultaneously. In any case, the combustion zone is operated at the most elevated temperature and is used to generate high temperature heat which is utilized for fluid fuel production either by the carbonization of carbonaceous materials or by gas generation, which processes are operated at lower temperatures. Heat is carried from the combustion chamber to the carbonization and/or gas generation chambers by the continuously flowing streams of fluidized solid. Thus the process is made fully continuous.

If coal is used as the raw material, it is preferably fed directly to the carbonization chamber and heat for the carbonization is supplied by a stream of highly heated carbon flowing continuously from the combustion chamber through the pipe 411 and discharging into the chamber 405. The solids removed by pipe 407 are substan-

8

tially free of volatile materials and are capable of rapid combustion with air in the combustion chamber 409. The process may be operated without the water gas generation step by closing a valve in pipe 411'. If desired, an inert material such as sand may be added to the coal and circulated through the chambers 405 and 409 and the associated pipes 407, 408 and 411, so as to provide a larger volume of heat-carrying solid material, but instead the ash content of the coal may be allowed to accumulate and thus furnish any desired amount of inert solid.

If the process is operated using coke instead of a carbonization coal as the raw material, there is no carbonization and the coke dust is fed directly into pipe 408 and the valves in pipes 404 and 411 will be closed. In this case the fluidized stream of coke is supplied to pipe 408 through the pipe 406' into chamber 409, thence by pipe 411' into chambers 418 and 424. The same modification may be applied to the direct gasification of suitable coals or the like. The addition of an inert heat carrier is of particular value in this operation, especially in starting up. At such time oil is introduced and burned in 409 until the ignition temperature of the coke is reached.

According to a further embodiment of my invention, the process described in connection with Fig. 4 may be modified by introducing an oxidizing gas, such as air or oxygen, into either or both of chambers 405 and 418 in carefully controlled amounts to supply any additional or supplemental heat desired in these chambers by combustion of a portion of the carbonaceous material contained therein. By this means temperature variations due to varying conditions in combustion zone 409 or to changes in the composition of the carbonaceous starting material may be compensated for. Furthermore, the composition of the fuel gas and distillation products may be varied so as to produce more or more highly oxygenated distillation and gasification products. The introduction of the oxidizing gas may take place through 406' and 418' in a manner similar to that described in connection with lines 8' and 9' in Fig. 1.

When an oxidizing gas is thus supplied to gasification zone 418 solid carbonization residue from coking zone 405 may be fed through line 407a directly into gasification zone 418 and gasified therein until the solids contain only a low percentage of carbonaceous constituents. Low carbon residue from gasification zone 418 may then be fed to combustion zone 409 and from there to coking zone 405 and gasification zone 418 in parallel to supply heat as described above in connection with Fig. 4. In this case, it is ordinarily necessary to return a major proportion, for instance about 90%, of the residue from combustion zone 409 to the gasification zone 418 and a minor proportion, for instance about 10%, to the carbonization zone 405.

An optional alternative of this modification provides for series flow of the combustion residue from combustion zone 409 through gasification zone 418 and from there through lines 408, 408b and 411 to the carbonization zone 405 as it may be easily accomplished by a suitable manipulation of the valves indicated in Fig. 4.

In Fig. 5 there is a flow plan similar to that of Fig. 3, illustrating a method which is particularly applicable to the working up of solid carbonaceous fuel materials such as are disclosed in Fig. 4, particularly coal, peat, shale, tar sands, and the like. The apparatus is similar to that

shown in Fig. 4, supplemented by some details.

The raw material in finely divided form enters at 530, passing directly to the low temperature carbonization step indicated at 531. Distillation products are removed from 531 and are separated into gaseous and liquid products in the separation equipment indicated generally at 532.

The coky carbonization residue is conducted to the combustion stage 533 where air is also introduced. The stack gases are taken off at 534 and the hot residue at 535. A portion of this residue is returned to the carbonization stage 531 through line 536 to supply heat for carbonization, and the second portion of this carbonaceous residue is conducted to the water gas generation stage 537. Steam is added at 538 and ash constituents of the original fuel are drawn off at 539. The gas, which is largely CO and hydrogen, is taken off at 540 and a portion of this may be drawn off for heating or other purposes at 541. To the remainder of the gas an additional quantity of steam is added at 542 and the mixture is passed through a catalytic conversion step 543 wherein carbon monoxide is converted with steam to carbon dioxide.

The remaining gas is compressed at 544 and carbon dioxide is separated at 545. Substantially pure hydrogen remains which is then employed for the hydrogenation of the liquid distillation products produced from the original carbonization. This is accomplished in the hydrogenation stage 546.

The combustion and the water gas generation stages are conducted just as indicated in the previous description of Fig. 4, that is to say while the solid material is in a fluidized condition. The conversion of the CO to CO₂ and hydrogen by means of steam and the hydrogenation step may be effected as outlined in connection with Fig. 3.

The apparatus of the present process is all constructed for operation at relatively low pressure, but high temperatures are required, especially in the gas generation zone and in the associated pipes. The equipment should be lined with high temperature tile or brick and it is found that there need be little wear if the velocity of the fluidized stream is kept down in the range of 25 to 75 feet per second. The operation of the reaction zones is smooth and proceeds without difficulty. The upward gas velocity should be of the order of 0.5 to 6 feet per second, where the solid is say 50 to 200 mesh, and progressively higher with larger sizes say 10 to 20 feet per second with lumps of 1/4 to 1/2". These velocities are sufficient to prevent the settling of the solid into compact masses and the reactions occur very rapidly while carried out when the solid is in a fluidized condition. Moreover, as indicated before, temperature control is extremely accurate. The velocity of the gas required for maintaining the fluidized condition varies somewhat with the nature and size of the solid particles and on the particular fluidizing gas, but in general the variation is not wide and the minimum amount is of the order of 0.02-0.07 cubic feet per pound. When fluidizing with such a small amount of gas, a very dense suspension or stream results and the only effect of adding additional gas to the fluidized stream is the reduction of the density and the suspension. Advantage is taken of this property of the fluidized stream in order to effect the flow of the material from zone to zone. Thus, in Fig. 1 the stream is caused to flow down the pipe 7 and up the pipe 8 by the addition of

air at the point 10. The density of the fluidized stream in the pipe 7 is much greater than in the pipe 8 and a pressure differential is thus generated, which is equal to the product of the height of the column in pipe 7 multiplied by the density therein, minus the product height of the column 8 multiplied by the density of the stream flowing therein. The equipment must be carefully designed throughout so that the pressure differential is sufficient to overcome the loss due to friction. Small amounts of gas should be added to pipes and chambers at various points so as to maintain the fluidization. This is particularly important where a fluidized stream is flowing downwardly through a pipe or chamber.

It should be understood that whenever the use of an oxidizing gas, such as air or oxygen, is suggested in the above description of my process oxygen will be preferred when it is desired to reduce the amount of inert gases, such as nitrogen, in the reaction zones and/or the conversion products of my process. For instance, when it is desired to produce a fuel gas suitable for the synthesis of liquid and solid hydrocarbons by the catalytic conversion of CO and H₂ the gas generators 9, 218 and 418 may be so operated as to produce the desired ratio of H₂:CO, for instance by a proper adjustment of the temperature, and oxygen is preferably used as the oxidizing gas supplied to the gas generator.

In all the embodiments of my invention described above, the finely divided solid carbonaceous starting material may be fed from the hoppers 1, 201 and 401 in the form of a dense aerated mass without further dispersion downwardly into the first conversion zone or, instead of being fluidized prior to its introduction into the first conversion zone, be directly fed into the first conversion zone without the preliminary addition of any fluidizing gas, for instance by means of a screw conveyor or the like and converted within the first conversion zone into a fluidized mass with the aid of the gaseous and vaporous reactants and/or reaction products present therein.

The present process is thus capable of carbonizing coal and producing a high quality fuel gas continuously. The advantages will be fully understood by those skilled in the art.

I claim:

1. An improved process for producing valuable liquid and gaseous products from solid carbonaceous materials which comprises passing a stream of finely divided carbonaceous solid material into a carbonization zone to form a fluidized mass of solids therein maintained at a carbonization temperature, whereby distillable portions of the material are removed, leaving a coky residue in finely powdered fluidized form, withdrawing said fluidized residue and passing the same into a gasification zone to form a fluidized mass of solids therein, reacting said mass with steam at a gasification temperature, withdrawing a fuel gas and withdrawing a fluidized residue of low carbon content from the gasification zone, feeding said latter residue to a combustion zone to form a fluidized mass of solids, therein, generating heat in said combustion zone by burning the carbonaceous constituents of said latter residue, withdrawing hot fluidized solid combustion residue from said combustion zone and feeding said hot combustion residue to said carbonization zone and to said gasification zone to supply heat required therein.

2. A process according to claim 1 in which

11

inert mineral matter is charged to the circulating solid material as a heat carrier.

3. A process according to claim 1 in which a material which raises the melting point of the ash of the solid carbonaceous material is added to said solid material.

4. A process according to claim 1 wherein a portion of the heat required in the carbonization zone is supplied by burning a portion of the carbonaceous material in the carbonization zone with an oxidizing gas supplied to the carbonization zone.

5. The process as claimed in claim 1 wherein an oxidizing gas is supplied to said gasification zone to generate heat by combustion therein.

6. The process of converting solid carbonaceous material into valuable volatile fuels which comprises passing finely divided solid carbonaceous material through a circuit comprising a carbonization zone, a gasification zone and a combustion zone, maintaining said material as a fluidized mass of solids in said zones, feeding fresh solid carbonaceous material to said carbonization zone, (carbonized solid material to said gasification zone and solid gasification residue to said combustion zone) and controlling the temperature in said carbonization and gasification zones by recycling solid residue highly heated in said combustion zone to said gasification zone and returning solid gasification residue to said carbonization zone.

7. A process according to claim 6 in which inert mineral matter is charged to said circuit as a heat carrier.

8. A process according to claim 6 in which a

12

material which raises the melting point of the ash of the solid carbonaceous material is added to said circuit.

9. A process according to claim 6 wherein a portion of the heat required in the carbonization zone is supplied by burning a portion of the carbonaceous material in the carbonization zone with an oxidizing gas supplied to the carbonization zone.

BRUNO E. ROETHELI.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,379,038	Odell	May 24, 1921
1,687,118	Winkler	Oct. 9, 1928
1,924,856	Heller	Aug. 29, 1933
1,984,380	Odell	Dec. 18, 1934
2,420,145	McAfee	May 6, 1947
2,451,803	Campbell et al.	Oct. 19, 1948
2,462,366	Davies Jr. et al.	Feb. 22, 1949
2,482,187	Johnson	Sept. 20, 1949

FOREIGN PATENTS

Number	Country	Date
413,130	Great Britain	July 12, 1934
632,466	France	Oct. 10, 1927
564,870	Germany	Nov. 24, 1932

OTHER REFERENCES

Meade: "Modern Gasworks Practice," (2nd edition) pgs. 406 and 407.