

April 5, 1960

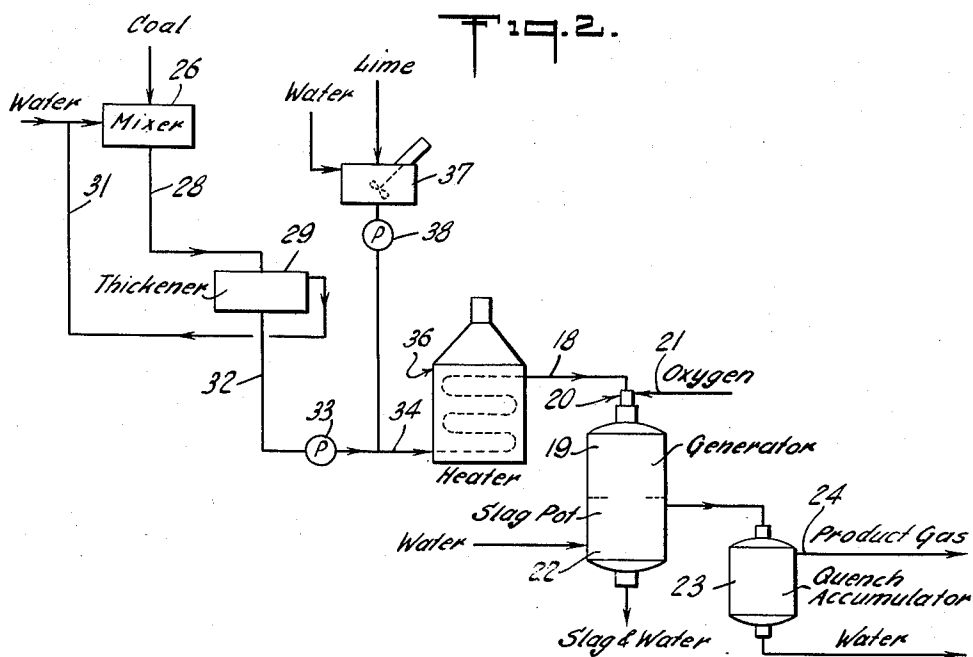
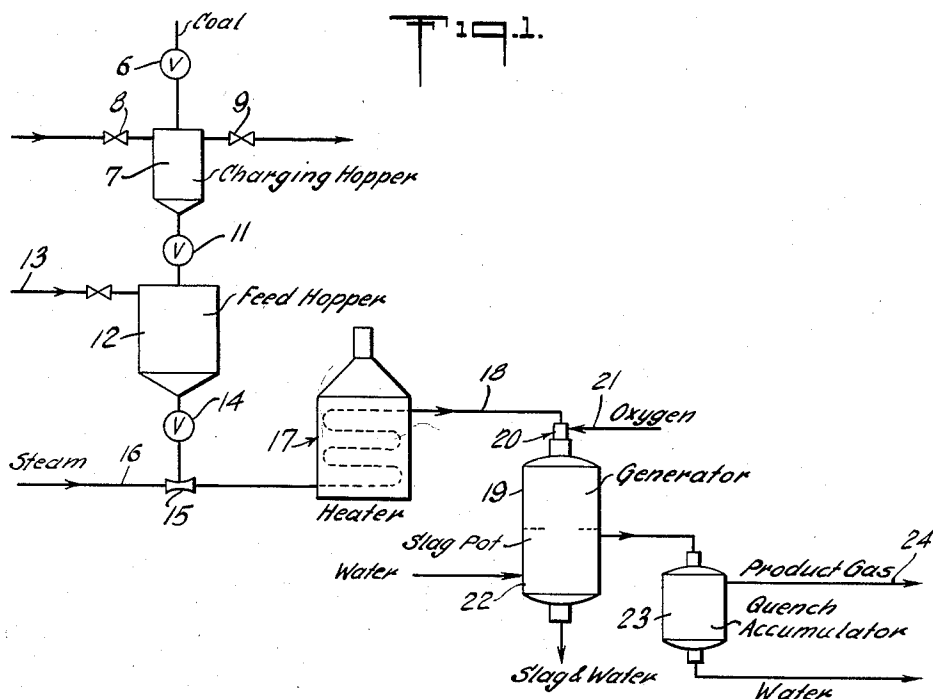
DU BOIS EASTMAN

2,931,715

APPARATUS FOR THE GASIFICATION OF SOLID FUELS

Filed Oct. 24, 1956

3 Sheets-Sheet 1



April 5, 1960

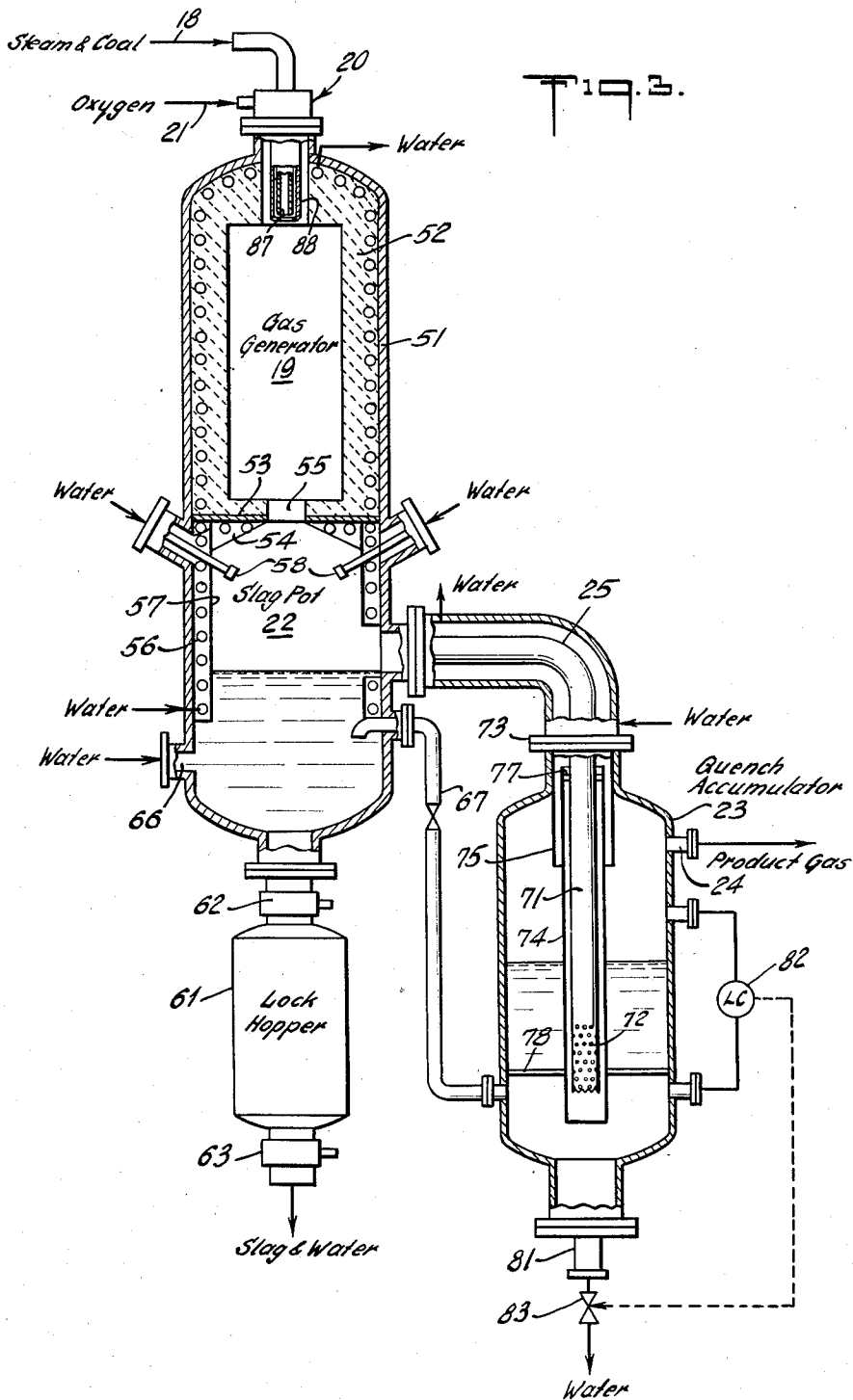
DU BOIS EASTMAN

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APPARATUS FOR THE GASIFICATION OF SOLID FUELS

Filed Oct. 24, 1956

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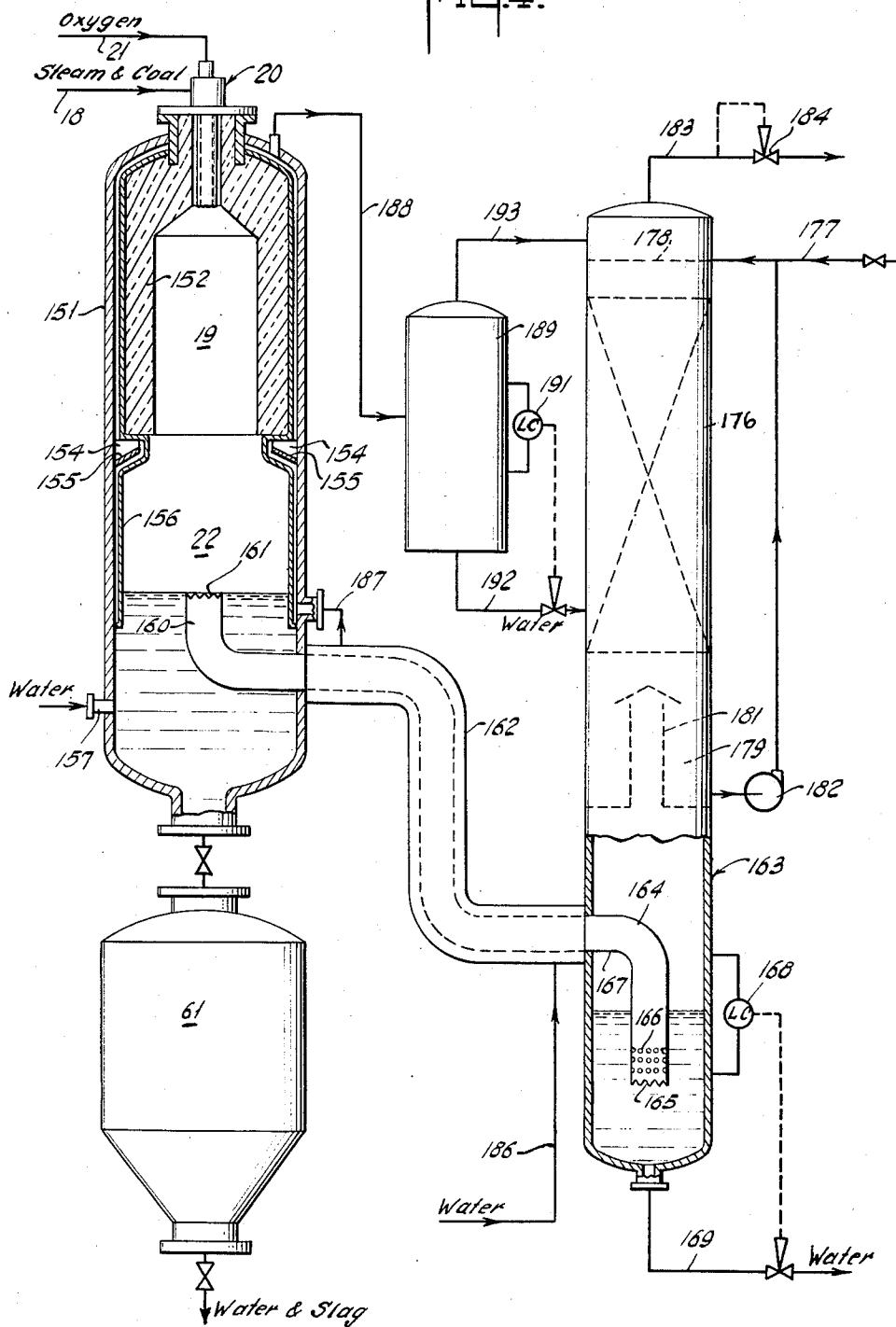
2,931,715

APPARATUS FOR THE GASIFICATION OF SOLID FUELS

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Fig. 4.



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2,931,715

APPARATUS FOR THE GASIFICATION OF SOLID FUELS

Du Bois Eastman, Whittier, Calif., assignor to Texaco Inc., a corporation of Delaware

Application October 24, 1956, Serial No. 618,082

9 Claims. (Cl. 48—63)

This invention relates to a process for the manufacture of valuable gaseous products from a solid carbonaceous fuel. In one of its more specific aspects, this invention relates to a process for the production of carbon monoxide and hydrogen from a solid carbonaceous fuel by the interaction of said fuel with a mixture of oxygen and steam. Coke and various coals, including lignite, anthracite, and bituminous coals, are suitable as feed materials for the process of this invention.

The gasification of solid fuels by simultaneous reaction with oxygen and steam at elevated temperatures is fairly well known. This type of gasification has been previously carried out successfully at temperatures above about 2000° F. in reactors containing a large excess of carbon. The solid fuel is generally maintained in a stationary, moving, or dense phase fluidized bed. Due to previous heat treatment, the solid fuel undergoing reaction is substantially completely, if not entirely, in the form of coke or char, and consists essentially of carbon and ash. Thus, the steam and oxygen are reacted with coke or char, rather than with raw coal. A number of the commercially attractive fuels are coals containing volatile matter and often having caking tendencies. Caking coals impose a problem in gasification and severely limit the field to which many processes may be applied. Caking tendencies may be eliminated by various treatments. Removal of the volatilizable constituents by distillation, or coking, is generally most satisfactory but costly. The process of the present invention may be used for the gasification of caking type coals without previous coking or pretreating of the coal.

This application is a continuation-in-part of my copending application Serial No. 525,240, filed July 29, 1955, now Patent No. 2,871,114.

In accordance with the present invention, solid fuel in powder form is reacted under pressure with relatively pure oxygen and steam in a flow type reaction zone. Pulverized solid fuel is dispersed in steam and reacted in dilute phase with an oxygen-containing gas, preferably commercial oxygen of above about 90 percent purity by volume. The gasification reaction is carried out in an unobstructed reaction zone at a pressure in excess of about 100 pounds per square inch gauge. Free heat transfer by radiation is achieved so that the entire reaction zone operates essentially at a single uniform temperature. The quantity of solid fuel supplied to the generator is just sufficient to react with the gases. Ash is withdrawn from the generator as a fluid slag.

Contrary to previous reports to the effect that particles smaller than about 0.05 mm. (50 microns) in diameter tend to escape gasification because of insufficient motion relative to the gaseous reactants, I have found that an impalpable powder is preferred for the present process.

Particles of solid fuel on the order of 40 microns and smaller are very suitable as feed; advantageously the largest particles should not exceed 150 microns in average diameter. Furthermore, I have found, unexpectedly, that pressure is favorable to the gasification reaction even

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though theoretically, from the consideration of the volume increase upon gasification, pressure should be detrimental. I have also found, contrary to general opinion, that elevated pressures do not result in the production of methane to any appreciable extent. Another finding not supported by previous reports is that a residence time of at least one second is required for effective carbon utilization at these temperatures. Theoretically much longer times could be used but substantially complete carbon consumption has been obtained with 2 seconds' reaction time at pressures ranging from 100 to 500 pounds per square inch and temperatures of 2200 to 2600° F. At the higher temperatures, the reaction time is less than at the lower temperatures.

For effective gasification of powdered fuel and successful operation of the gas generator, the operating temperature must be maintained above about 2200° F. While there may be a limited zone at the point of maximum heat release, due to the highly exothermic reaction between carbon and oxygen, where the temperature is considerably higher, heat is distributed very rapidly and uniformly throughout the gasification zone. The measured temperature is very close to that obtained by thermodynamic calculations.

The temperature of the stream of effluent gases from the generator is preferably quenched by direct contact with water.

The pressure must be above about 100 pounds per square inch gauge and may range as high as 1000 pounds per square inch; preferably a pressure within the range of 200 to 500 pounds per square inch gauge is used.

Mixing of the reactants in the gas generator may be effectively accomplished by introducing a stream of oxygen and a stream of steam containing powdered coal into contact with one another at relatively high velocity. Inlet velocities of 100 to 200 feet per second give satisfactory mixing with the streams introduced through concentric tubes. It is preferable to preheat the reactants to a temperature above about 600° F. The oxygen is preferably preheated to a temperature of 600 to 800° F. and the steam and coal, to 800 to 1200° F. or higher.

In a copending application of Du Bois Eastman and Leon P. Gaucher; Serial No. 490,214, filed February 24, 1955, now U.S. Patent 2,864,677, a novel process for heating and pulverizing carbonaceous solids is disclosed. In accordance with the method disclosed in said application, particles of a solid carbonaceous material, for example coal, are admixed with a liquid to form a suspension and the suspension passed as a continuous confined stream in turbulent flow through a heating zone comprising an externally heated conduit. The slurry is heated in the heating zone to an elevated temperature sufficient to vaporize the liquid, thereby suspending the solid particles in vapor and preheating the solid. The solid particles are pulverized by turbulent flow at relatively high velocity through a grinding zone. This novel step of heating and pulverizing solid carbonaceous material is preferably employed in connection with the present process for gasification of the resulting powder with oxygen and steam. The solid fuel particles used for making up the slurry need be only moderately pulverized. Particles having average diameters less than 40 microns, and even less than one micron, may be economically produced by this method.

In a preferred embodiment of this invention, coal in particle form is mixed with sufficient water to form a fluid suspension or slurry. The particles may range from about one-quarter inch in average diameter to powder; generally a moderately pulverized coal containing random sizes below about one-eighth inch is readily obtainable and suitable as feed. The slurry preferably contains only as much water as is required to make it readily pumpable. The slurry is passed through a tubular heating zone where-

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in it is heated to a temperature at least sufficient to vaporize the water. The heating step produces a dispersion of powdered coal in steam which is fed into the gas generator. Sufficient oxygen is supplied to the generator into intimate admixture with the steam and solid fuel to maintain the temperature of the generator within the range of from about 2200 to about 3200° F.

A flux may be used to reduce the fusion temperature of the slag or to render it more fluid. The flux may be admixed with the coal and water during the preparation of the slurry. Alternatively, a separate slurry of the flux may be prepared and injected into the coal feed stream either before or after the slurry of coal and water is passed through the heating zone.

Lime is generally required as the flux, where one is indicated, although with some coals it may be desirable to add fluorite, silica or alumina together with lime to increase the quantity of fluidity of the slag. The addition of lime to the generator not only increases fluidity of the slag and decreases the fluxing temperature but also effects removal of at least a portion of the hydrogen sulfide from the product gas stream. The amount of lime required as flux may be determined from the composition of the coal ash. In general, the most satisfactory fusion is obtained when the sum of the lime and magnesia in the feed is approximately equal in weight to the sum of the silica and alumina. The lime and magnesia may be in the form of the carbonates, but should be converted to equivalent quantities of the oxides in determining the quantity of flux required.

Part of the vapors may be separated from the powdered solid in the effluent from the heating step before the stream is fed into the generator.

Some coals require substantial theoretical amounts of steam for the production of hydrogen and carbon monoxide by reaction with steam and oxygen. Others contain water in sufficient quantity or even in excess of the theoretical requirements. Anthracite is an example of the former, requiring a considerable quantity of steam, for example 30 percent by weight based on the weight of the anthracite fed. Lignite is an example of the latter and contains more than the theoretical requirement of water. Water in excess of the theoretical requirement is not detrimental to the gasification reaction.

The total oxygen requirements for the generator, that is, oxygen from the steam as well as free oxygen, must be at least 10 percent in excess of the amount theoretically required to convert the carbon content of the solid fuel to carbon monoxide. In general, satisfactory operation may be obtained with a total oxygen supply of 10 to 200 percent in excess of the theoretical requirements. As the steam preheat temperature is increased, the free oxygen requirements decrease. In general, however, it is necessary to use from about 0.4 to about 1.0 pound free oxygen per pound of coal. From about 0.3 to about 2.0 pounds of steam per pound of coal may be used.

Preferably the ratio of area of the internal surface of the generator to the surface of a sphere of equal volume is less than about 1.5. A cylindrical reaction zone having a length-to-diameter ratio not above about 3:1 or below about 1:1 is generally preferred.

The reaction mixture should be directed away from the wall of the reactor. The path of flow and volume of reactants should be such that the proper residence time, as defined above, is obtained. In a preferred embodiment, the reactants are introduced axially into one end of a cylindrical reaction space and the product gases discharged from the opposite end.

The reactor is preferably constructed with an outer steel shell capable of withstanding an internal pressure considerably in excess of the operating pressure and provided with a high temperature refractory lining.

Figure 1 is a diagrammatic view illustrating one arrangement of apparatus for carrying out the process of the present invention.

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Figure 2 is a diagrammatic view illustrating a preferred arrangement of apparatus for the gasification of coal in accordance with the present invention.

Figure 3 is an elevational view in cross section of a preferred form of gas generator and for carrying out the process of this invention.

Figure 4 is a elevational view partly in cross section and partly diagrammatic illustrating a preferred form of gas generation and gas scrubbing apparatus suitable for carrying out the process of this invention.

With reference to Figure 1 of the drawings, crushed coal is admitted through valve 6 into a charging hopper 7. An inert gas is admitted to the charging hopper through valve 8 to build up pressure in the hopper equivalent to the desired feed pressure. Gas may be vented from the charging hopper through valve 9. From the charging hopper the coal is admitted through valve 11 into a feed hopper 12. Provision is made for the addition of a pressurizing gas to the feed hopper through line 13. From the feed hopper powdered coal passes through a feed rate controller 14 into a jet type mixing device 15. For the sake of simplicity in the figure, the feed rate controller is indicated simply as a valve. Suitable rate of feed controllers, e.g., feed screws and toothed wheels, are well known. Steam under pressure is admitted through line 16 to the jet mixer 15 which introduces the coal particles into a stream of steam.

The resulting mixture of steam and coal particles is passed at relatively high velocity through a conduit 18, which may be externally heated, for example by a heater 17, wherein the coal is preheated and subjected to further disintegration. Heat may be supplied by external heating or all of the heat required for preheating the coal may be supplied by the steam. A dispersion of powdered coal in the steam is discharged into generator 19 through a suitable burner 20. Sufficient oxygen is admitted into the generator 19 through line 21 to maintain the temperature in the generator within the range of 2200 to 3500° F., preferably in the range of 2200 to 2800° F. Product gas and slag are discharged from the generator directly into a slag pot 22 placed directly below the generator as illustrated in Figure 3. The slag pot and generator may be conveniently contained in a single pressure vessel, as illustrated. It will be evident, however, that separate pressure vessels may be employed for the generator and slag pot, respectively. Water is supplied to the slag pot to collect and solidify the slag. The product gas from the slag pot, together with some of the quench water, is passed into quench accumulator 23 where the gas is intimately contacted with water. Figure 3 illustrates a preferred method of effecting intimate contact between the gas and water. The cooled product gas is discharged through line 24.

The operation of the charging hopper and feed hopper is as follows. With valves 8 and 11 closed and valve 9 open, the charging hopper is at atmospheric pressure. Coal is then admitted through valve 6 until the desired amount enters the charging hopper. Valves 6 and 9 are then closed and pressurizing gas admitted through valve 8 until the pressure in the charging hopper is equal to the pressure in the feed hopper 12. Valve 11 is then opened and the charge transferred from the charging hopper 7 into feed hopper 12. The cycle is then repeated. By this means, coal may be fed continuously at an elevated pressure and at a constant rate and an adequate supply of coal maintained at all times in the feed hopper 12.

With reference to Figure 2 of the drawings, a preferred feeding system is illustrated. Crushed coal is fed into a mixer 26 operated at atmospheric pressure wherein it is admixed with sufficient water to form a fluid slurry. From the mixer 26 of the slurry is passed through line 28 into a thickener 29. Excess water is eliminated from the slurry in the thickener 29 and recycled to the mixer through line 31. The resulting slurry, containing only sufficient water to render it fluid,

is withdrawn from the thickener 29 through line 32 and charged by means of a pump 33 through line 34 into a heater 36 operated at an elevated pressure.

The water is vaporized in the heater dispersing the powdered coal in steam. The dispersion is passed through line 18 into the gas generator 19 as in Figure 1. Oxygen under pressure is admitted through line 21 into admixture with the reactants from line 18 at or near the point of introduction of the reactions to the generator. The generator is operated at a suitable temperature, for example at a temperature within the range of 2200 to 2500° F. Product gas and slag are discharged from the generator into a slag pot 22. Slag produced in the generator is quenched with water as described in more detail in connection with Figure 3. Gas and quench water pass from slag pot 22 into quench accumulator 23.

Lime in an amount sufficient for flux in the subsequent gasification step is admixed with water in a mixer 37 to form a slurry and this slurry charged by pump 38 into line 34 where it is admixed with the coal slurry and passed through the heater 36. Alternatively, the lime-water slurry may be injected into the coal-steam stream following vaporization of the water from the coal-water slurry, or lime may be mixed with the coal before or during the preparation of the coal slurry.

Figure 3 illustrates a preferred embodiment of the gas generation, slag collection, and gas cooling apparatus for carrying out the process of this invention. The gas generator and slag pot are contained in a pressure vessel having an outer cylindrical steel shell 51 designed to withstand the internal operating pressure. The gas generator section is provided with a liner 52 of suitable refractory and insulating materials to withstand the high temperature generated within the gas generation zone and to protect the shell from overheating. Burner 20 introduces reactants into the upper end of the gas generation zone. A partition 53 divides the vessel into two separate zones, the gas generation zone, or gas generator 19, and the slag quench zone, or slag pot 22. Partition 53 is supported by suitable support members 54. An opening 55 through the liner and partition permits passage of the products of reaction from the gas generation zone directly into the slag quench zone 22.

The internal surface of vessel 51 and the bottom surface of partition 53 are provided with cooling tubes 56. Cooling water is circulated through the tubes to prevent overheating of the walls, partition 53, and structural supports 54. A metal jacket 57 prevents direct contact of the hot gases with the wall of the pressure vessel. In addition, spray nozzles 58 may be provided in the upper section of the slag pot for further cooling of the effluent from the gas generator.

Directly beneath the slag pot is a lock hopper 61 provided with valves 62 and 63 to permit removal of slag from the slag quench zone.

Water may be supplied to slag pot through line 66. Water may be withdrawn from the slag pot through line 67 or through water-jacketed product gas line 25, or both.

Product gas is discharged from the slag pot through line 25 into quench accumulator 23. The quench accumulator is provided with a dip leg or pipe 71 the lower end of which is provided with a serrated edge. Pipe 71 is supported from flange 73 and directly connected to line 25. A section of pipe 71 adjacent its lower end is provided with perforations 72.

A cylindrical shield 74, open at both ends, surrounds pipe 71 from a point below the lower end of pipe 71 to a point near the upper end of the quench accumulator. Cylindrical shield 74 extends above outlet 24 for the product gas. A cylindrical splash guard 75 surrounds shield 74 and extends from the top of quench accumulator 23 to a point below product gas outlet 24. Shield 74 is supported from pipe 71 by lugs 77 and is spaced from pipe 71 and from the wall of the quench accumu-

lator by spacer bars 78 extending from the shield 74 to the wall of the quench accumulator.

An outlet 81 at the bottom of the quench accumulator permits withdrawal of quench water therefrom. A level controller 82, indicated diagrammatically, may be used to control the liquid level within the quench accumulator by controlling the operation of valve 83.

In operation, steam and coal in highly dispersed condition, prepared for example, as described in connection with either Figure 1 or Figure 2, is introduced into the gas generator through burner 20. The dispersion of coal in steam preferably is discharged directly into the gas generator through a burner of the type illustrated in Figure 3. The steam and coal flow through the inner pipe 87 while oxygen flows through the annular passageway between pipes 87 and 88. The outer pipe 88 converges slightly at the burner tip so that the oxygen stream is directed into the stream of coal and steam issuing from the inner pipe 87 providing immediate and complete mixing of the oxygen with the stream of coal and steam. Means preferably are provided, not illustrated in the drawing, to protect the burner from overheating at the high temperatures prevailing in the combustion chamber by circulation of cooling fluid about the burner tip. Preferably, the velocity at the point of discharge of the steam and coal from conduit 87 into the gas generator is above about 30 feet per second. The velocity of the oxygen from the annular passageway at the point of discharge into the gas generator is at least 20 feet per second and preferably in excess of 30 feet per second.

Products of reaction discharged from the gas generator through outlet 55 pass directly into the upper portion of the slag pot. Slag produced during the operation is discharged directly into the slag pot with the hot product gas. The slag drops into a body of water maintained in the slag pot where it is immediately chilled and solidified. Quick cooling of the slag in this manner causes it to form small beads and granular pieces which are easily removed through the lock hopper 61 as described below.

Spray nozzles 58, arranged just below the outlet from the gas generator, may be employed to contact the hot gases and slag with a spray of water immediately upon their discharge from the gas generator effecting a partial cooling of the product gas and slag. The spray nozzles may be used to cool the gases to a safe temperature for handling in steel under pressure. Generally the nozzles are not necessary.

Water is admitted to the slag pot through line 66. The water level may be controlled by means of line 67 through which water may be withdrawn into quench accumulator 23 or the water may be permitted to flow through the gas discharge line 25 (as illustrated in Figure 3) with the product gases into the quench accumulator.

Slag is removed periodically from the slag pot through lock hopper 61. Removal of slag is accomplished by opening valve 62 with valve 63 in closed position, permitting slag and some water, from the slag pot to enter lock hopper 61. Valve 62 is then closed and valve 63 opened, discharging the slag and water from lock hopper 61.

Product gas, together with steam formed by vaporization of water in the slag pot, are discharged through line 25 into the quench accumulator. This gas stream also carries some small solid particles of unconsumed fuel or ash (slag) entrained therein. A body of water is maintained in the quench accumulator the level of which may be controlled in any suitable manner, for example by means of a liquid controller as indicated diagrammatically. Pipe 71 conducts the gases below the level of the water contained in the quench accumulator. The gases escape through openings 72, resulting in intimate contact of the gases with the water, trapping solid particles from the gas stream in the water, and cooling the gases to a temperature well below reaction tempera-

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ture. The product gas is discharged from the quench accumulator through line 24. Water, drawn from the quench accumulator through line 81, may be recycled to the slurry feed preparation step (Figure 2) or to slag pot 22.

With reference to Figure 4 of the drawing, the gas generation chamber and slag quench zone are contained in a pressure vessel (as in Figure 3) having an outer cylindrical steel shell 151 designed to withstand the internal operating pressure. The gas generation section is provided with an insulated lining 152 of suitable refractory and insulating materials to withstand the high temperatures generated therewithin during operation.

The refractory insulating lining 152 in the gas generation section is supported by suitable support members 154. The lower portion of the gas generation reaction chamber opens directly into the slag quench zone, or slag pot, 22.

Cooling of the shell 151 of the pressure vessel is provided by a metal jacket 156 spaced from the wall of the vessel to form an annular space through which cooling water may be circulated. Metal jacket 156 encloses support members 154 surrounding them with cooling water. Baffle 155 deflects the cooling water away from the wall of the vessel to ensure adequate cooling of the members and the shelf portion of jacket 156 supporting the lining 152.

Lock hopper 61 directly below vessel 151 permits removal of slag from the slag quench zone. Water may be introduced into the slag quench zone through nozzle 157. Product gas and water are drawn from slag quench zone through offtake pipe 160 preferably provided with serrations 161 and passed through a water jacketed transfer line 162 to a gas cooling and scrubbing tower 163. The gas from the transfer line 162 is discharged through a vertically disposed dip leg 164 in the lower portion of tower 163. Dip leg 164 is preferably provided with serrations 165 and, optionally, also with perforations 166. An opening 167 (not visible in the drawing) is preferably provided in the dip leg 164 to act as a vacuum breaker to prevent drawing of water from the tower to the slag quench zone when the flow of feed gases to the generator 19 is interrupted. The gases are discharged below the surface of a pool of water maintained in the tower by liquid level controller 168. Water is withdrawn from the tower through line 169 in response to the level control. This water may be returned, with suitable make-up water, to the slag quench zone.

The upper portion of tower 163 is provided with a packed section 176, suitably containing Raschig rings, to provide intimate contact between the gases and a scrubbing liquid. Water is preferably employed as the scrubbing liquid. Water is supplied to the tower as required through line 177 and is distributed over the packing by a suitable spray distributor 178. Scrubbing of the gas with water in the tower not only cools the gas to a uniform temperature approximately the boiling point of water at the existing pressure but also, at the same time, cleanses the gas stream, effecting removal of ash, carbon, or other solid material carried over from the gas generator. Water from packed section 176 is collected in a water trap-out tray 179, having a chimney 181 to permit the gas to pass upwardly through the tray into the packed section of the column. A pump 182 draws water from tray 179 and recirculates it to the top of the tower where it is reintroduced through spray distributor 178.

The scrubbed product gas leaves the column through line 183. A back pressure regulator 184 in the gas discharge line controls the pressure in the tower which in turn determines the pressure in the gas generation chamber 19.

Cooling water is introduced through line 186 into jacketed transfer line 162. Upon leaving the jacket, the water is transferred by line 187 to the cooling space

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formed by jacket 156 through which the water circulates about the jacketed portion of the slag quench chamber and the gas generator reaction chamber. Cooling water is discharged from the generator jacket through line 188, together with any steam generated therein, into an accumulator and steam separator 189. Accumulator 189 is provided with float control 191 to maintain a substantially constant level of liquid therein. Water is withdrawn from the accumulator 189 through line 192 from which it may be introduced, as required, to tower 163 or to the slag quench zone. Steam passes through line 193 to the top of tower 163. Line 193 thereby provides a pressure balance between the internal pressure in the gas generation and slag quench zones and the pressure in the cooling space provided by water jacket 156. This results in a negligible pressure difference at all times between the cooling water in the jacket and the gas in the generator and slag-quench zone and makes possible the use of a relatively thin walled or flexible jacket 156. This construction permits complete protection of the wall of the gas generation section and the exposed portion of the quench section of the pressure vessel by providing a sheath of cooling water along the internal surface thereof. This construction is less costly than conventional cooling tubes which generally do not provide complete wall coverage.

Operation of the apparatus of Figure 4 is very much like that of Figure 3, described above. As illustrated in Figure 4, the oxygen is fed through the inner pipe of the burner, which is essentially a concentric double pipe burner, while the steam and coal flow through the annulus.

In the apparatus illustrated in Figure 4, the lower portion of the reaction zone is fully open to the slag-quench zone. Slag which tends to run down the wall of the reaction zone flows freely to the slag-quench zone without forming restrictions or plugs. Contrary to expectations, it is found that heat loss from the reaction chamber is not excessive with this arrangement even though the end of the reaction chamber is completely open to the slag-quench zone. Apparently, the products from the reaction zone are substantially opaque to radiation, since no appreciable increase in radiation loss is observed in comparison with the closed end reaction chamber illustrated in Figure 3.

For the sake of simplifying the description, various elements of a conventional nature, such as pressure control valves and the like, have been omitted from the foregoing detailed description of the invention.

Example

A No. 4 Buckwheat Pennsylvania anthracite was ground to a size such that 90 percent was finer than 100 mesh and mixed with water to form a slurry. The slurry was thickened in a Dorr thickener to approximately equal parts water and coal by weight. The slurry was fed at the rate of 388 pounds of coal and 357 pounds of water per hour through about 225 feet of ½ inch extra heavy steel pipe in a gas fired preheater wherein it was preheated to 650° F.

The resulting dispersion of powdered coal in steam was discharged into the upper end of a vertical cylindrical gas generator having a reaction space 22 inches in diameter and 30 inches in length. Unpreheated oxygen was fed at the rate of 3550 standard cubic feet per hour and admixed with the coal and steam at the point of introduction to the generator. The mixture of reactants was introduced at the center of the end wall and directed into the generator along its axis. A pressure of 100 pounds per square inch gauge was maintained in the generator. Thermocouples placed at two points along the wall of the generator, one about 7 inches from the upper end and the other about 14 inches from the upper end, indicated a uniform reaction temperature of 2350° F. Molten slag and product gas were discharged through an opening at the opposite end of the reaction space, or the

bottom of the generator, into a slag quench zone in which the slag collected in water. The product gas was quenched by direct contact with cooling water.

Product gas of the following composition was produced at the rate of 12,935 standard cubic feet per hour:

	Mol percent
Carbon monoxide -----	47.11
Carbon dioxide -----	18.23
Hydrogen -----	33.51
Nitrogen -----	1.07
Methane -----	0.08

The ratio of total oxygen to carbon supplied to the generator was 1.54.

Obviously many modifications and variations of the invention as hereinbefore set forth, may be made without departing from the spirit and scope thereof and, therefore, only such limitations should be imposed as are indicated in the appended claims.

I claim:

1. Apparatus for conducting a chemical reaction at elevated pressure and temperature comprising a vertically extending cylindrical pressure vessel shell having a reaction chamber in its upper portion and a gas outlet port in its lower portion disposed at a point intermediate said reaction chamber and the lowermost portion of said shell an inlet for reactants in the upper portion of said reaction chamber, means for maintaining a body of cooling liquid in the lower portion of said shell, a thermal shield comprising a water jacket internally of said shell surrounding said reaction chamber and extending to a point below the level of said liquid, and means associated with said gas outlet port for discharging product gas from said reaction chamber into intimate contact with water, said contact means being in communication with said water jacket whereby the pressure within said reaction chamber and the pressure within said water jacket are equalized.

2. Apparatus for conducting a chemical reaction at elevated pressure and temperature comprising a vertically extending cylindrical pressure vessel shell having a reaction chamber in its upper portion and a gas outlet port in its lower portion disposed at a point intermediate said reaction chamber and the lowermost portion of said shell an inlet for reactants in the upper portion of said reaction chamber, means for maintaining a body of cooling liquid in the lower portion of said shell, a thermal shield comprising a water jacket internally of said shell surrounding said reaction chamber and extending to a point below the level of said liquid, a second vertically extending pressure vessel spaced from said first vessel, a water jacketed transfer line connected with said outlet port and with said second vessel, means for supplying water to said water jacketed transfer line and for discharging water from said jacketed transfer line directly into said internal water jacket within said pressure vessel shell, and means for equalizing the pressure between said internal water jacket and said second pressure vessel.

3. Apparatus for conducting a chemical reaction at elevated pressure and temperature comprising a vertically extending cylindrical pressure vessel shell having a reaction chamber in its upper portion and a gas outlet port in its lower portion, said reaction chamber having a refractory heat insulating wall defining a cylindrical reaction space therewithin and having an axially disposed inlet for reactants at the upper end thereof and an outlet at the lower end thereof, a slag quench zone in the lower portion of said vessel, means for maintaining a body of cooling liquid in said slag quench zone, a thermal shield comprising a water jacket internally of said shell surrounding said reaction chamber and said slag quench zone and extending to a point below the level of said liquid, and means for equalizing pressure between the interior of said gas generation zone and said water jacket.

4. Apparatus for conducting a chemical reaction at elevated pressure and temperature comprising a vertically extending cylindrical pressure vessel shell having a reaction chamber in its upper portion and a gas outlet port in its lower portion, said reaction chamber having a refractory heat insulating wall defining a cylindrical reaction space therewithin and having an axially disposed inlet for reactants at the upper end thereof and an outlet at the lower end thereof, a slag quench zone in the lower portion of said vessel, means for maintaining a body of cooling liquid in said slag quench zone, a thermal shield comprising a water jacket internally of said shell surrounding said reaction chamber and said slag quench zone and extending to a point below the level of said liquid, vertical support members spaced peripherally around the inner wall of said pressure vessel shell and within said water jacket below said heat insulating wall in supporting relationship thereto, and means for circulating cooling liquid through said water jacket.

5. Apparatus for conducting a chemical reaction at elevated pressure and temperature comprising a vertically extending cylindrical pressure vessel shell having a reaction chamber in its upper portion and a gas outlet port in its lower portion, said reaction chamber having a refractory heat insulating wall defining a cylindrical reaction space therewithin and having an axially disposed inlet for reactants at the upper end thereof and an outlet at the lower end thereof, a slag quench zone in the lower portion of said vessel, means for maintaining a body of cooling liquid in said slag quench zone, a thermal shield comprising a water jacket internally of said shell surrounding said reaction chamber and extending to a point below the level of said liquid, vertical support members spaced peripherally around the inner wall of said pressure vessel shell and within said water jacket below said heat insulating wall in supporting relationship thereto, and deflecting means associated with said support members for directing coolant away from said shell to accomplish cooling of said members.

6. Apparatus for the gasification of solid carbonaceous material by direct oxidation with oxygen and steam at an elevated pressure and a temperature above the fusion point of incombustible residue or ash contained in said fuel, which comprises a vertical cylindrical pressure vessel shell having a refractory lined reaction chamber in its upper portion; a quench chamber in the lower portion of said shell adapted to contain a body of water therein; an inlet for reactants in the upper portion of said reaction chamber an outlet port from said reaction chamber directly into said quench chamber, said outlet port being disposed centrally of said pressure vessel; a gas outlet port in said quench chamber intermediate said reaction chamber and the lowermost portion of said shell; means for maintaining a body of cooling liquid in said quench chamber; a thermal shield comprising a water jacket internally of said shell extending from said reaction chamber to a point below the level of said liquid; and means for equalizing pressure between the interior of said gas generation chamber and said water jacket.

7. Apparatus for conducting a chemical reaction at elevated pressure and temperature comprising a vertically extending cylindrical pressure vessel shell having a reaction chamber in its upper portion and a slag quench zone in its lower portion, an inlet for reactants in the upper portion of said reaction chamber, a gas outlet port in the lower portion of said shell disposed at a point intermediate said reaction chamber and the lowermost portion of said slag quench zone, means for maintaining a body of cooling liquid in said slag quench zone, a thermal shield internally of said shell extending from said reaction chamber to a point below the level of said liquid, and means for circulating cooling liquid through said thermal shield.

8. Apparatus as defined in claim 7 wherein said thermal shield comprises a metal jacket.

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9. Apparatus for conducting a chemical reaction at elevated pressure and temperature comprising a vertically extending cylindrical pressure vessel shell having a reaction chamber in its upper portion and a slag quench zone in its lower portion, an inlet for reactants in the upper portion of said reaction chamber, a gas outlet port in the lower portion of said shell disposed at a point intermediate said reaction chamber and the lower most portion of said slag quench zone, means for maintaining a body of cooling liquid in said slag quench zone, a thermal shield internally of said shell surrounding said reaction chamber and extending to a point below the level of said liquid, and means for circulating cooling liquid through said thermal shield.

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