

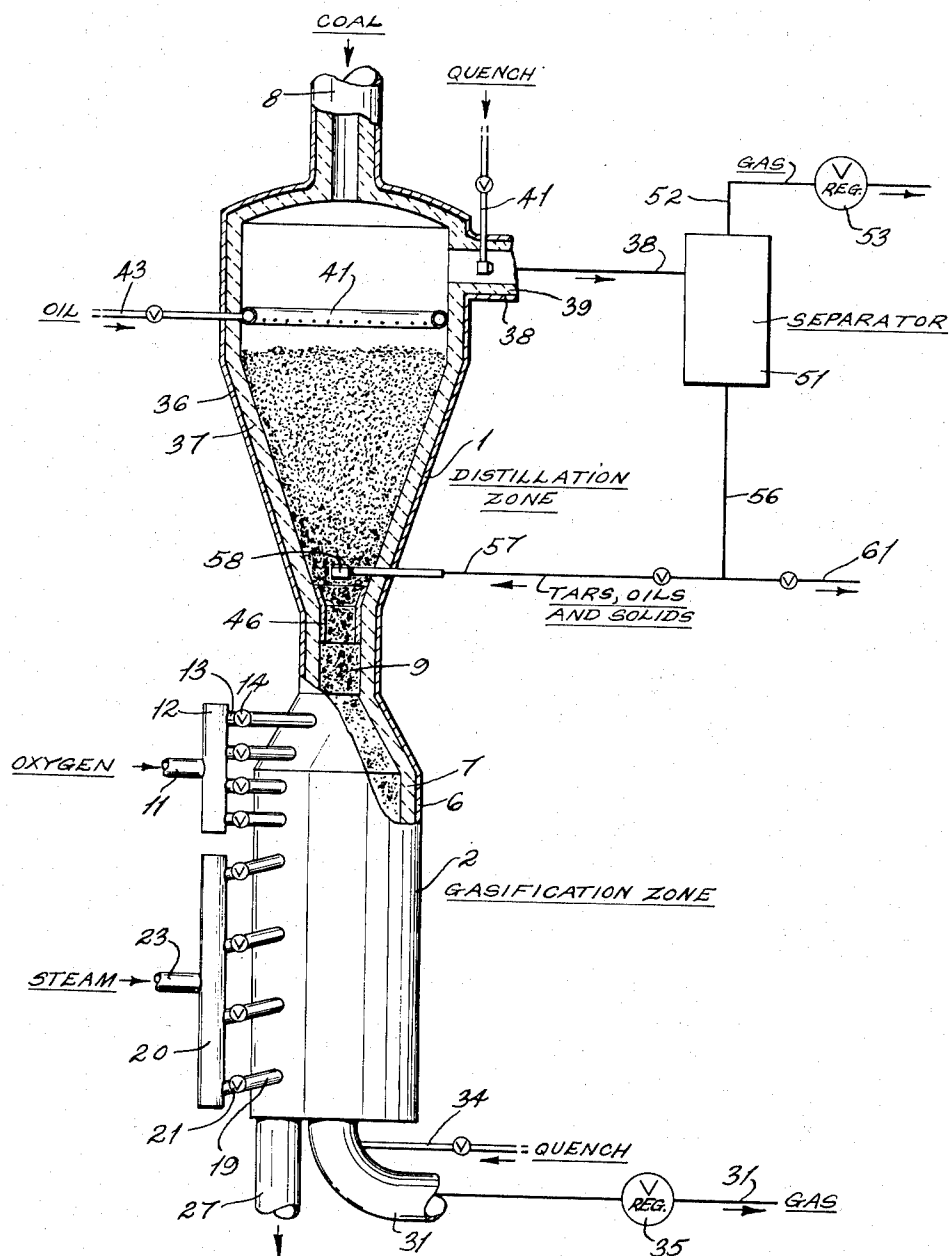
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GENERATION OF HEATING GAS FROM SOLID FUELS

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GENERATION OF HEATING GAS FROM
SOLID FUELS

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This invention relates to a method of and apparatus for the gasification of solid carbonaceous fuels. In one of its more specific aspects, this invention relates to a process for the generation of gas of high heating value from a solid carbonaceous fuel.

The process of this invention is applicable to the treatment of solid carbonaceous materials of various types and grades, for example, anthracite, bituminous coals, lignite and oil shale. The process of this invention is particularly suitable for the gasification of soft coals, waste coals, caking coals, anthracite silt, lignite, or the like.

Petroleum hydrocarbons, including natural gas, refinery gases and fuel oil, are inherently better suited as the starting materials for the production of natural and synthetic locomotion fuel and lubricating oils than any other conceivable feed. At the present time, however, almost half of the current production of this valuable natural resource is being burned as heating fuel or for power generation.

This situation exists because oil and natural gas are easy to handle and burn; they can be transported by pipe lines; the oil can be stored; and in most instances both oil and gas are readily available at prices competitive with solid coal or manufactured gas.

Petroleum hydrocarbons would not be so extensively used for heating if coal could be economically converted to a gas of high heating value and distributed as fuel gas at a price somewhat less than the cost of petroleum hydrocarbons. It follows, therefore, that the conservation of petroleum natural resources and their utilization for the production of locomotion fuels and lubricating oils would be materially enhanced by improvements in the economics of coal utilization. This may be accomplished by an efficient process for the gasification of coal at the source to produce a heating gas competitive with a natural gas having a heating value of about 1,000 B. t. u.'s per cubic foot. Several requirements must be met before such a gasification process is economically attractive:

(1) The gas produced must have a high heating value approaching 1,000 B. t. u.'s per cubic foot to permit economical transportation over long distances.

(2) The process must have high thermal efficiency.

(3) The process must be sufficiently flexible to handle a number of grades of coal, preferably as received from the mines or as by-products without excessive prehandling, such as washing, cleaning, sizing or drying.

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(4) Preferably the process should use fine coal as feed since there is a large accumulation of useless fines in existing coal fields. It is reported that in Pennsylvania alone there are 200,000,000 tons of anthracite silt accumulated and that this by-product of anthracite mining is now being produced at the rate of about 5,000,000 tons per year. In any event, it is cheaper to mine coal mechanically if a large percentage of fines can be tolerated.

(5) The investment must not be too great and the operating manpower requirement must be small. The operating and maintenance costs must be small.

To meet these requirements is a primary object of the present invention.

The complete gasification of coal with oxygen at high thermal efficiency can produce a gas having a heating value of about 400 to 450 B. t. u.'s per cubic foot. A product gas of higher heating value may be obtained by enriching the coal gas with light hydrocarbons of high heating value. Methane, for example, has a heating value of 1012 B. t. u.'s per cubic foot; ethane, 1,762 B. t. u.'s per cubic foot; and propane, 2,509 B. t. u.'s per cubic foot. These light hydrocarbon gases may be supplied to the coal gas by cracking within the coal gasification apparatus which inevitably is operated at a very high temperature, a heavy, less desirable petroleum fraction, such as crude residuum.

An important object of the present invention is to provide an improved method and apparatus for the production of a fuel gas of high heating value from solid carbonaceous materials.

Another object is to provide a process and apparatus for the generation of high heating value fuel gases which are particularly suited to the utilization of low grade solid carbonaceous fuels containing volatilizable constituents, e. g., bituminous coals and lignite.

Still another object of this invention is to provide such a process wherein low grade petroleum hydrocarbons may be utilized to advantage for enrichment of the gases obtained by gasification of solid fuels.

A further object is to provide an improved apparatus for the gasification of solid carbonaceous materials in particle form to produce a mixture of carbon monoxide and hydrogen.

Other objects and advantages of this invention will be evident from the following detailed description.

In accordance with the present invention, finely divided solid carbonaceous material is fed to a distillation zone into a bed of particles under-

going distillation. Hot gases, comprising carbon oxides and hydrogen from a subsequent gasification reaction, are passed upwardly through the bed. The velocity of the gases is such that the bed of particles is maintained in dense fluid phase insuring free flow of solid particles and intimate admixture of fresh feed with heated particles. In the distillation zone, the particles of solid feed material are heated to a temperature sufficient to drive off any volatilizable constituents contained in the feed.

The resulting carbonized preheated particles are fed directly into a gasification zone or flow type gas generator in which the particles are gasified in disperse phase. Gasification is carried out with steam and oxygen at high temperature. Hot gases from the gasification reaction supply heat to the distillation zone. The distillation zone is operated at a temperature considerably lower than the temperature of the gasification zone. Under these conditions, a portion of the hydrogen and carbon oxides from the gasification zone are converted to methane with a resulting increase in the heating value of the product gas.

The gasification zone is operated at a temperature within the range of from about 1800 to about 3200° F. while the distillation zone is operated at a temperature within the range of 1090 to 1800° F., and preferably within the range of 1200 to 1500° F.

In a preferred embodiment of the process of this invention, a hydrocarbon oil, for example, bunker fuel oil, crude residuum, or the like, is injected into the distillation zone at the top of the fluidized bed of carbonaceous particles. The hydrocarbon oil wets the particles of carbonaceous material and substantially eliminates carry-over of the coal particles in the gas stream. As the particles of solid move downwardly through the distillation zone toward the point of inlet of heated gases from the gasification zone, they become heated to a temperature approaching the temperature of the gases from the gasification zone.

Condensable oils and tars volatilized in the distillation zone are separated from the gas stream and may advantageously be returned to the distillation zone, preferably entering the distillation zone at the lowermost portion of the bed of carbonaceous particles. This effects cracking of the tars and oils to gaseous hydrocarbons and residual carbon. The gaseous hydrocarbons enrich the product gas from the coal gasification zone and residual carbon is carried with the carbonaceous feed material into the gasification zone where it is reacted with oxygen and steam to produce additional gas.

The process and apparatus may be operated with coke from coal or petroleum as feed. Coke breeze is particularly suited as feed to the process. With coke as a feed, no volatilizable constituents are present in solid feed to the distillation zone; additional hydrocarbon oil may be supplied to make up this deficiency.

In a preferred form of the apparatus of this invention, a generator of the downflow type described in my copending application, Serial No. 7,446, filed February 10, 1948, is employed as the gasification reactor. The preheating zone and gasification zone of the apparatus of this invention are constructed as a unitary piece of apparatus, the preheating zone or distillation zone disposed directly above and in direct unrestricted communication with the gasification zone.

The novel unitary construction of the present generator is such that coal or other carbonaceous particles of a relatively wide range of sizes may be fed to the apparatus. The construction avoids the necessity for valves or other apparatus with moving parts operated at high temperatures. The novel apparatus, forming a part of this invention, contributes greatly to the improved results obtained from the process of this invention.

The process and apparatus will be more readily understood from the following detailed description taken together with the accompanying drawing.

The figure is an elevational view, partly diagrammatic and partly in cross-section, illustrating a preferred form of the apparatus of this invention.

With reference to the figure, the gasification apparatus is in the form of a unitary reactor comprising a distillation zone 1 and a gasification zone 2. The gasification zone illustrated is the generator disclosed in my copending application Serial No. 7,446, filed February 10, 1948.

The gasification zone is provided with an outer cylindrical steel shell 6 capable of withstanding an elevated operating pressure, and a refractory lining 7 of a material suited to the temperature conditions encountered in operation. Powdered solid carbonaceous material is fed to the apparatus through line 3 into the distillation zone from which it passes through a conduit 9 into the upper end of the gasification zone. Oxygen is supplied to the gasification zone through an oxygen line 11 and oxygen header 12. From the oxygen header, a series of feed pipes 13 introduce the oxygen, as controlled by valves 14, into the gasification zone immediately below the point of introduction of the solid carbonaceous feed material and tangential to the inner surface of the zone.

Steam is introduced into the gasification zone immediately below the points of introduction of oxygen. Steam is admitted to the reactor through a series of feeder pipes 19 in amounts controlled by valves 21. The feeder pipes 19, in turn, are supplied from header 20 and steam line 23. The feeder pipes preferably are directed into the gasification zone tangent to the inner wall and upward so that the particles of coal are directed upwardly and away from the walls, as fully described in said copending application.

Molten ash and slag formed by burning the coal is collected at the lower end of the gasification zone from which it is withdrawn through a slag disposal pipe 27.

A portion of the generated gases, comprising carbon monoxide and hydrogen, are withdrawn from the lower end of the gasification zone through a product gas line 31. Water for quenching the product gas is supplied to the outlet line 31 through line 34. By this means, the hot product gas may be cooled to a temperature below that at which undesirable reactions take place. A regulator valve 35 in the product gas line 31 serves to control the pressure within the gasification zone and the quantity of gases withdrawn through line 31, and therefore differentially controls the amount of hot gas flowing up through conduit 9, as will be brought out more fully hereinafter.

The distillation zone is placed directly atop the gasification zone. The distillation zone comprises an outer steel shell 36 provided with a refractory lining 37. This zone is frusto-conical in cross section with the small end of the frustum connecting with conduit 9. Thus, the diameter,

and area, of the distillation zone increases from conduit 9 upwardly along the path of flow of gases from the gasification zone.

Product gases from the distillation zone are discharged through an outlet pipe 38 provided with a refractory lining 39. Water may be admitted through pipe 41 to pipe 38 for quenching the gas, i. e., cooling it to a temperature below that at which undesirable reactions take place. Hydrocarbon oils may be supplied to the distillation zone through line 43 and distributed therein by a distributing ring 44.

A removable sleeve 45 of refractory material may be provided within conduit 9 to control the effective diameter of this conduit. The sleeve 45 may be removed or replaced by a sleeve of different internal diameter to vary the capacity of the apparatus in accordance with seasonal variations in demand for fuel gases.

Product gases discharged through line 38 are passed through a separator 51 wherein tars, condensable oils and solids are separated from the gas stream. The resulting gas is discharged from the separator through line 52 to a regulator valve 53 which, in conjunction with valve 35, serves to control the pressure within the gasification apparatus and to control the quantity of gas discharged through line 38. Liquids and solids separated from the gas stream are discharged from the separator 51 through line 56 from which they may be returned to the distillation zone through pipe 57 to a point near the lowermost portion of the distillation zone or point of introduction of hot gases from the gasification zone. These residual materials are distributed by a spray nozzle 58 into the distillation zone. Alternatively, part or all of the tars and oils may be withdrawn through line 61 for other uses.

In operation, particles of coal are fed into the distillation zone 1 through line 8. The particles of coal tend to drop downwardly through the distillation zone due to the influence of gravity. The particles are contacted in the distillation zone by an upflowing stream of hot gases from the gasification zone which retards their downward progress, the extent of the retarding effect of the gases depending upon the velocity of the gases, size of the coal particles, etc. A fluidized bed of particles is maintained in the distillation zone at all times. The particle size of the feed material may range from about one quarter inch in average diameter to fine powder.

The gasification apparatus may be operated at substantially atmospheric pressure or at an elevated pressure, for example, up to about 1,000 pounds per square inch gauge.

The quantity of hot gases supplied to the distillation zone from the gasification zone, and hence, the velocity of the gases in the distillation zone may be controlled by regulation of the valve 35 which restricts the quantity of gas withdrawn from the gasification zone. It will be evident that under steady feed conditions, the quantities of gas evolved from the coal and oil fed to the distillation zone will be approximately constant. Therefore, any desired quantity of hot gases from the gasification zone may be passed upward through the distillation zone through conduit 9 by regulating the quantity of gas passing through valve 35. The remainder of the gases produced in the gasification zone are discharged through conduit 9 into the distillation zone and through line 52 and regulator valve 53.

The quantity of carbonized coal entering the gasification zone from the fluidized bed in the

distillation zone is dependent largely upon the velocity of gases through the conduit 9 and the throat of insert 46. Thus, it is evident that the feed to the gasification zone is controlled by the rate of withdrawal of gases through the regulator valve 35. Fine particles carried out of the fluid bed in the distillation zone through line 38 are recovered in the separator 51 in admixture with tars and oils. The mixture containing solid particles is returned to the distillation zone through line 57. Distillation and cracking of the tars and oils results in formation of coke which increases the particle size of the fine material both by accretion and by agglomeration. Thus, all of the particles fed into the distillation zone eventually drop downwardly through the conduit 9 into the gasification zone.

Gases discharged from the distillation zone through line 38 may be recycled to the bottom of the fluidized bed of solids by means not illustrated in the drawing. The recycled gas may be heated or cooled before introduction into the distillation zone. Further control of the temperature and upward velocity of the gases in the distillation zone may be effected by this means.

The bed of solid particles in the distillation zone is subject to constant agitation and mixing due to the fluidizing action of the hot gases passing upwardly therethrough. Some of the devolatilized particles, or char, moving downwardly through the distillation zone are entrained in the relatively high velocity hot gas stream entering the bottom of the zone and carried upwardly into admixture with fresh coal feed. The bed is a composite mixture of coal in various stages of devolatilization with a somewhat higher concentration of fresh coal in the upper portion of the bed. The mixing action of the fluidized bed helps prevent caking of the fresh feed with resulting plugging and bridging in the lower portion of the distillation zone. Where difficulty is encountered due to the agglomerating characteristics of the feed, the distillation zone may be readily cleared of agglomerates or coke deposits by simply interrupting the flow of coal, reducing the rate of gas withdrawal through valve 35, and allowing some of the steam and oxygen to flow from the gasification zone into the distillation zone for reaction with the interfering deposit.

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. A process for the gasification of a solid carbonaceous material containing volatilizable constituents which comprises maintaining a dense phase fluidized bed of particles of said solid carbonaceous material in a distillation zone wherein said volatilizable constituents are distilled therefrom, disposing said distillation zone directly above a gasification zone and in direct communication therewith through an intermediate zone of restricted cross-sectional area permitting free flow of particles of solid carbonaceous material from the lower portion of said fluidized bed into the upper portion of said gasification zone and free flow of gas from said gasification zone to said distillation zone, introducing oxygen-containing gas into said gasification zone into contact with carbonaceous particles from said distillation zone effecting reaction

with said carbonaceous particles in said gasification zone, passing gaseous reaction product from the upper portion of said gasification zone into the lower portion of said distillation zone through said intermediate zone countercurrent to the flow of said particles entering the gasification zone at a velocity such that said particles are admitted into said gasification zone at a limited rate, and withdrawing additional gaseous reaction product from the lower portion of said gasification zone.

2. A process as defined in claim 1 wherein hydrocarbon oil is sprayed onto the top of said fluidized bed in said distillation zone.

3. A process for the gasification of a solid carbonaceous material containing volatilizable constituents which comprises maintaining a dense phase fluidized bed of particles of said solid carbonaceous material in a distillation zone wherein said volatilizable constituents are distilled therefrom, disposing said distillation zone directly above a gasification zone and in direct communication therewith through an intermediate zone of restricted cross-sectional area permitting free flow of particles of solid carbonaceous material from the lower portion of said fluidized bed into the upper portion of said gasification zone and free flow of gas from said gasification zone to said distillation zone, introducing oxygen-containing gas into the upper portion of said gasification zone into contact with carbonaceous particles from said distillation zone effecting reaction with said car-

bonaceous particles dispersed in gas while passing said particles downwardly through said gasification zone, passing gaseous reaction product from the upper portion of said gasification zone into the lower portion of said distillation zone through said intermediate zone countercurrent to the flow of said particles entering the gasification zone at a velocity such that said particles are admitted into said gasification zone at a limited rate, introducing steam into said gasification zone below the point of introduction of said oxygen-containing gas and below the point of withdrawal of gaseous reaction product introduced into said distillation zone, and withdrawing additional gaseous reaction product from the lower portion of said gasification zone.

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