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COMPLETE SPECIFICATION

Improvements in or Relating to the Method of and Apparatus for Gasifying Carbonaceous Solids

We, PITTSBURGH CONSOLIDATION COAL COMPANY, a corporation organised under the laws of the State of Pennsylvania, United States of America, of Koppers Buildings, Pittsburgh, Pennsylvania, United States of America, (Assignees of Eric Herbert Reichl and Robert Vinton Safford) do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement :—

This invention relates to methods and apparatus effecting complete gasification of carbonaceous solids, particularly lignite, oil shale, bituminous coals, or solid carbonaceous products derived therefrom.

The primary object of the present invention is to provide an improved method and apparatus for converting carbonaceous solids substantially completely to gases useful either as fuels or in the synthesis of liquid hydrocarbons.

Another object of this invention is to provide an improved method and apparatus for reacting carbonaceous solids with steam and oxygen to yield gaseous products particularly carbon monoxide and hydrogen.

A further object of the present invention is to provide an improved method of preheating the steam and the carbonaceous solids supplied to a gasification zone.

Another object of this invention is to provide an improved method and apparatus for completely gasifying carbonaceous solids wherein oxygen is employed for supplying the necessary heat of reaction but is kept at a minimum.

A still further object of our invention is to provide an improved method and apparatus for completely gasifying carbonaceous solids under pressure.

In accordance with our invention, carbonaceous solids are converted to gaseous products by reacting preheated carbonaceous solids with oxygen and preheated steam. We have discovered that the steam and the carbonaceous solids supplied to the gasification zone may be preheated to high temperatures in an apparatus which is simple in form and economical in operation and which does not involve the use of the cumbersome and costly heat exchangers frequently proposed in the past.

Our invention provides for a vessel in which a fluidized bed of the carbonaceous solids is maintained by means of steam which, as introduced into the vessel, is at a relatively low temperature. Associated with this vessel is a combustion zone through which a portion of the carbonaceous solids from the vessel is circulated along with air whereby a part of the circulating solids is burned. The heat of combustion raises the temperature of the circulating solids which are thereafter returned to the bed of solids contained in the fluid vessel. The rate of circulation of the solids through the combustion zone and the amount of combustion therein are regulated so as to produce the desired temperature in the fluid bed. As a result of this elevated temperature in the fluid vessel a certain amount of distillation of the carbonaceous solids therein may take place. These vaporous products along with the steam, which is now at the same elevated temperature by virtue of having passed through the hot fluid bed, are conducted to the gasification zone or vessel. Concurrently a portion of the hot carbonaceous solids is drawn off the fluid vessel and is likewise conducted to the gasification zone. To supply the additional heat required to effect complete gasification of the carbonaceous solids oxygen is introduced into the gasification zone. The final gaseous products and ash are separately removed from the gasification zone.

In the preferred embodiment of our invention, it is desired to convert carbonaceous solids, particularly bituminous coal,

[Price 2/-]

to a gaseous mixture whose principal constituents are carbon monoxide and hydrogen for use in the Fischer-Tropsch process for making liquid hydrocarbons. In this embodiment, we prefer to start with a carbonaceous solid which has been at least partially distilled to effect removal of condensable vapors such as tar which is of value as liquid fuel and as a source of chemicals. The previously distilled solids are raised to a temperature between 1400° F. and 1800° F. in the fluid vessel preheater. The steam and vaporous products are then introduced into a gasification chamber along with the hot previously distilled solids at the same temperature and with the necessary oxygen.

The precise type of gasification chamber employed in our invention is not material thereto except it is essential that it be adapted to operate at temperatures in the neighborhood of 1900° F. and above. Powdered fuel burners of the Koppers or Vortex Combustor types are eminently suitable and for purpose of illustration only the former will be described. In this type of burner, the hot carbonaceous solids first contact the oxygen which is insufficient to effect complete combustion of the solids but is sufficient to raise the temperature thereof several hundred degrees. The hot products then are reacted with the preheated steam whereby a mixture of gases is produced which is mostly carbon monoxide and hydrogen. In such a system, not only is the product eminently suitable for use as synthesis gas in the Fischer-Tropsch process but also the amount of oxygen, which is an expensive reactant, is reduced to a minimum. In view of the desirability of supplying synthesis gas to the Fischer-Tropsch process under pressure, we provide means for operating our apparatus under pressure. The temperature established in the gasification chamber also generally is sufficiently high to effect slagging of the ash produced where separation of gas and ash is facilitated.

According to the present invention there is provided a method of gasifying carbonaceous solids, which comprises maintaining in a preheating zone a bed of carbonaceous solids in a fluid condition by passing steam therethrough, circulating a portion of the solids from said bed through a combustion zone wherein some of the solids is burned with air to raise the temperature of the rest of the solids, returning said heated solids to the fluidized bed, the amount of burning effecting therein being controlled with respect to the amount of solids in the fluid bed to produce a temperature in said bed between 1400° F. and 1800° F., conveying solids and steam which has passed through the fluidized bed from said bed and oxygen to a gasification zone and effecting reaction therein at an elevated temperature to produce substantially complete gasification of the carbonaceous materials in said carbonaceous solids.

The invention also includes an apparatus for the gasification of carbonaceous solids comprising, a fluid zone in which a bed of carbonaceous solids is adapted to be maintained in a fluidized state, means for circulating steam through said bed, a combustion zone associated with said fluid zone for partially burning a portion of the carbonaceous solids from said bed, means for returning hot solids from said combustion zone to said fluid zone, and a gasification zone in which the carbonaceous solids from the fluid zone are gasified by reaction with oxygen and with steam from the fluid zone.

In the accompanying drawing we have shown a schematic showing of the apparatus by the use of which the invention may be practiced and have illustrated a present preferred method of practicing the invention.

Referring to the drawing, numeral *10* designates a gasification chamber wherein finely divided preheated carbonaceous solids are converted to gas by reaction with oxygen and preheated steam. The preheat is supplied to the steam and carbonaceous solids in a preheating vessel indicated by the number *12*.

A conduit 14 serves to conduct steam and carbonaceous solids to the vessel *12*, the solids being fed into the conduit 14 from a hopper 16 by means of screw feeder 18 or similar device. Within the vessel *12* a bed of solids 19 is established.

Leading from the lower end of the bed of solids 19 is a conduit 26 for conducting solids from the bed 19 to a combustion tube 28. A control element 30 is provided in the line 26 to regulate the flow of solids therethrough. Air is supplied to the combustion tube 28 through a conduit 32 impelled by a pump 34.

The combustion tube 28 is directly connected to a cyclone separator 36 by a conduit 38. The separator has a leg 40 extending into the bed of solids 19. Leading from the top of the cyclone separator is a tube 42 which extends through the wall of the vessel *12* and continues as conduit 44 for carrying flue gas. This conduit 44 is arranged with respect to the air conduit 32 to provide a heat exchanger 45 and with respect to conduit 14 to provide a heat exchanger 46. A conduit 47 connects conduit 44 with a turbine expander 48 which drives the blower 34 by means of a shaft 49.

A conduit 50 connects vessel *12* at a point above the level of the bed 19 with the gasification chamber *10* for conducting steam thereto. Another conduit 52 serves to carry solids from the bed 19 to the chamber *10*. A control element 54 is disposed in the line 52

for regulating the flow of solids therethrough. A conduit 56 is arranged to conduct oxygen from a source of oxygen 58 to the gasification chamber *10*. Connecting the oxygen plant 58 with the steam line 14 is a conduit 60 for providing steam needed in the operating of the plant.

The gasification chamber *10* is provided with an outlet 62 for ash produced in the gasification reaction. The gaseous products of the reaction are conducted away by a conduit 64. This conduit is arranged with respect to the conduit 14 to provide a heat exchanger 66 which in conjunction with heat exchanger 46 serves to convert to steam the water introduced into the conduit 14 by a pump 68.

The operation of a preferred embodiment of the invention will now be described. While the invention is applicable to the gasification of any carbonaceous solid, it is particularly applicable to the treatment of oil shale, lignite, bituminous coals and products derived therefrom. We prefer to employ previously distilled coals, i.e., chars, cokes or semi-cokes from which volatile matter has been distilled, preferably at low temperature, in order to derive the benefit of the valuable components of the vaporous products. Accordingly, the operation of the present invention for purposes of illustration only will be described as applied to a distilled coal which for convenience we shall call "coke", this "coke" being produced as a result of the low temperature carbonization of a high volatile Pittsburgh seam coal.

Coke in finely divided form is fed from the hopper 16 by means of a screw feeder 18 into the conduit 14 where it is picked up by steam and carried to the preheater vessel *12*. The steam is produced from water, which is pumped into conduit 14 by a pump 68, by means of heat exchangers 46 and 66 to be described more fully below. The flow of steam and coke into vessel *12* is regulated in the well-known manner to produce a fluidized bed 19 of coke, with steam being the sole fluidizing agent.

The temperature of the fluid bed 19 is maintained in this preferred embodiment within the range 1400°–1800° F. by means of heat supplied by burning a portion of the coke. This is accomplished by removing coke from the bed 19 through a conduit 26, the amount being regulated by a valve or constriction 30, and burning a portion of this coke with air in the combustion tube 28. The air is impelled to the combustor through conduit 32 by means of pump 34. It is preferably preheated by being circulated in heat exchange relation with hot flue gas as indicated by heat exchanger 45. The combustion of a portion of the coke in the upflowing mixture of air and coke in the tube 28 produces hot flue gas and hot coke. These are separated in the cyclone 36, the hot coke being returned to the bed 19 and the hot flue gas being vented through conduits 42 and 44. The circulation of coke through the side-arm combustion tube 28 and the flow of air as well are regulated in such a manner that the temperature of the bed 19 can be maintained at any desired value but preferably in this example is between 1400° and 1800° F. Since the steam passes through this hot bed of coke, it too, attains the same temperature.

In the preferred operation of our invention, the entire system is under pressure. This is accomplished by passing a portion of the hot flue gas coming from the cyclone separator 36 through conduit 47 and exchanger 45 into turbine expander 48 which is directly connected to blower 34. High pressure air is then forced by the blower 34 into the combustor 28. This high pressure extends through the entire system including both the preheater and gasification chamber because of the open communication therebetween. Hopper 16 should in this case be of the locking type and adapted to supply the solids to the system without loss of pressure therein.

Hot finely divided coke from the outer zone 24 of vessel *12* and hot steam from above bed 19 in the same vessel are conducted in any suitable manner through conduit 52 and 50, respectively to the gasification chamber *10*. The flow of hot coke may be controlled by a valve or constriction 54. Oxygen is supplied to the reaction chamber *10* from an oxygen plant 58 in order to provide the additional heat required to promote the reactions between the steam and the coke.

As stated previously, the particular type of gasification chamber employed is not a part of the present invention. However, for purposes of illustration we have shown a powdered fuel burner of the Koppers type. In this burner, the coke is first reacted with a deficiency of oxygen to raise the temperature of the coke. The hot steam then reacts with the hot reaction products of the oxygen and coke to produce principally carbon monoxide and hydrogen. The temperature maintained in the burner is of the order of 1900°–2500° F. if non-slagging of the ash is desired and 2500°–3000° F. if slagging of the ash is desired.

The hot gaseous product which is suitable for use in the Fischer-Tropsch process is conducted through conduit 64 to heat exchanger 66 where in conjunction with the heat exchanger 46 heat obtained from the flue gas of vessel *12* and the synthesis gas from chamber *10* serves to convert water in line 14 to steam. The synthesis gas is then led to any convenient place, preferably

directly to a Fischer-Tropsch unit. The ash from chamber *10* is drawn off through outlet 62.

The shape and design of the preheater *12* may also vary, bearing in mind that for the purposes of this invention it is essentially a heat exchange device for preheating solids and steam with the minimum of change in the character of the solids. Accordingly, the bed of solids is preferably shallow in depth so that the time of contact of steam with solids is just sufficient to raise the temperature of the steam to that desired.

We wish to point out that in the claims wherever the term "coal" is employed it is intended to include all ranks of coal, lignite, bituminous, and anthracite as well as carbonaceous products derived therefrom.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:

1. The method of gasifying carbonaceous solids, which comprises maintaining in a preheating zone a bed of carbonaceous solids in a fluid condition by passing steam therethrough, circulating a portion of the solids from said bed through a combustion zone wherein some of the solids is burned with air to raise the temperature of the rest of the solids, returning said heated solids to the fluidized bed, the amount of burning effecting therein being controlled with respect to the amount of solids in the fluid bed to produce a temperature in said bed between 1400° F. and 1800° F., conveying solids and steam which has passed through the fluidized bed from said bed and oxygen to a gasification zone and effecting reaction therein at an elevated temperature to produce substantially complete gasification of the carbonaceous materials in said carbonaceous solids.

2. The method according to claim 1, wherein both steam and carbonaceous solids are heated above 1400° F. and wherein the reaction temperature in the gasification zone is above 1900° F.

3. The method according to claim 1 or 2, wherein carbonaceous solids from said preheating zone are reacted with a deficiency of oxygen and the reaction products are thereafter reacted with steam.

4. The method according to any of claims 1 to 3 wherein the carbonaceous solids are coal.

5. The method according to any of the preceding claims, wherein said combustion zone is separate from said preheating zone.

6. The method of gasifying carbonaceous solids, which comprises maintaining a bed of carbonaceous solids in a fluid condition by passing steam therethrough, circulating a portion of the solids from said bed through a combustion zone wherein some of the solids is burned with air to raise the temperature of the rest of the solids, returning said heated solids to the fluidized bed, the amount of solids circulated through the combustion zone and the amount of burning effected therein being controlled with respect to the amount of solids in the fluid bed to produce a temperature in said bed between 1400° F. and 1800° F., reacting solids from said fluid bed with a deficiency of oxygen, thereafter reacting the oxygen-solids reaction mixture with steam which has passed through the fluid bed, both of said reactions being carried out under pressure, and recovering the gaseous products.

7. Apparatus for the gasification of carbonaceous solids comprising, a fluid zone in which a bed of carbonaceous solids is adapted to be maintained in a fluidized state, means for circulating steam through said bed, a combustion zone associated with said fluid zone for partially burning a portion of the carbonaceous solids from said bed, means for returning hot solids from said combustion zone to said fluid zone, and a gasification zone in which the carbonaceous solids from the fluid zone are gasified by reaction with oxygen and with steam from the fluid zone.

8. The method of gasifying carbonaceous solids substantially as described with reference to the accompanying drawing.

9. Apparatus for the gasification of carbonaceous solids constructed and arranged substantially as described with reference to the accompanying drawing.

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