

July 17, 1973

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GASIFICATION OF CARBONACEOUS SOLIDS

Filed Sept. 22, 1971

2 Sheets-Sheet 1

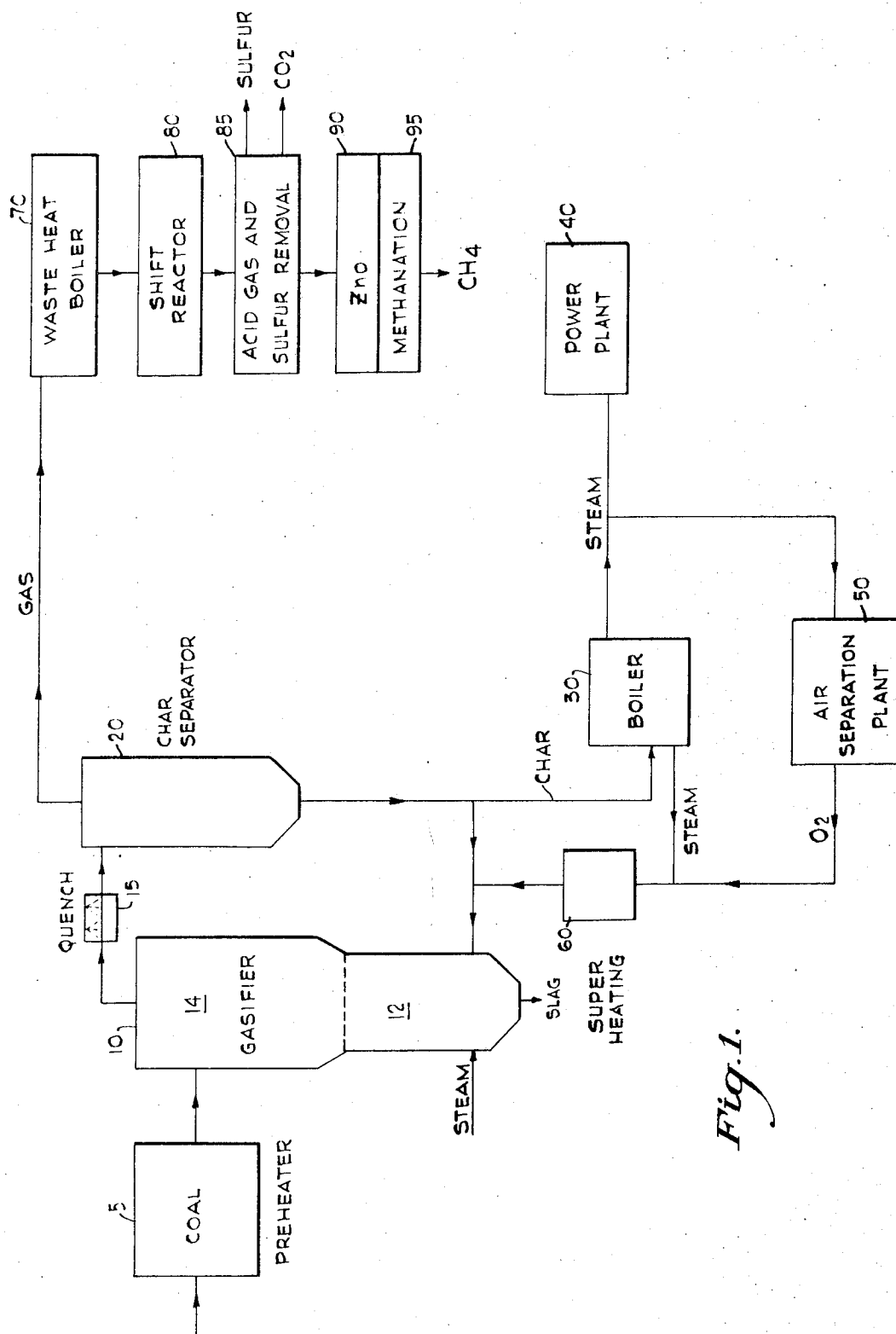


Fig. 1.

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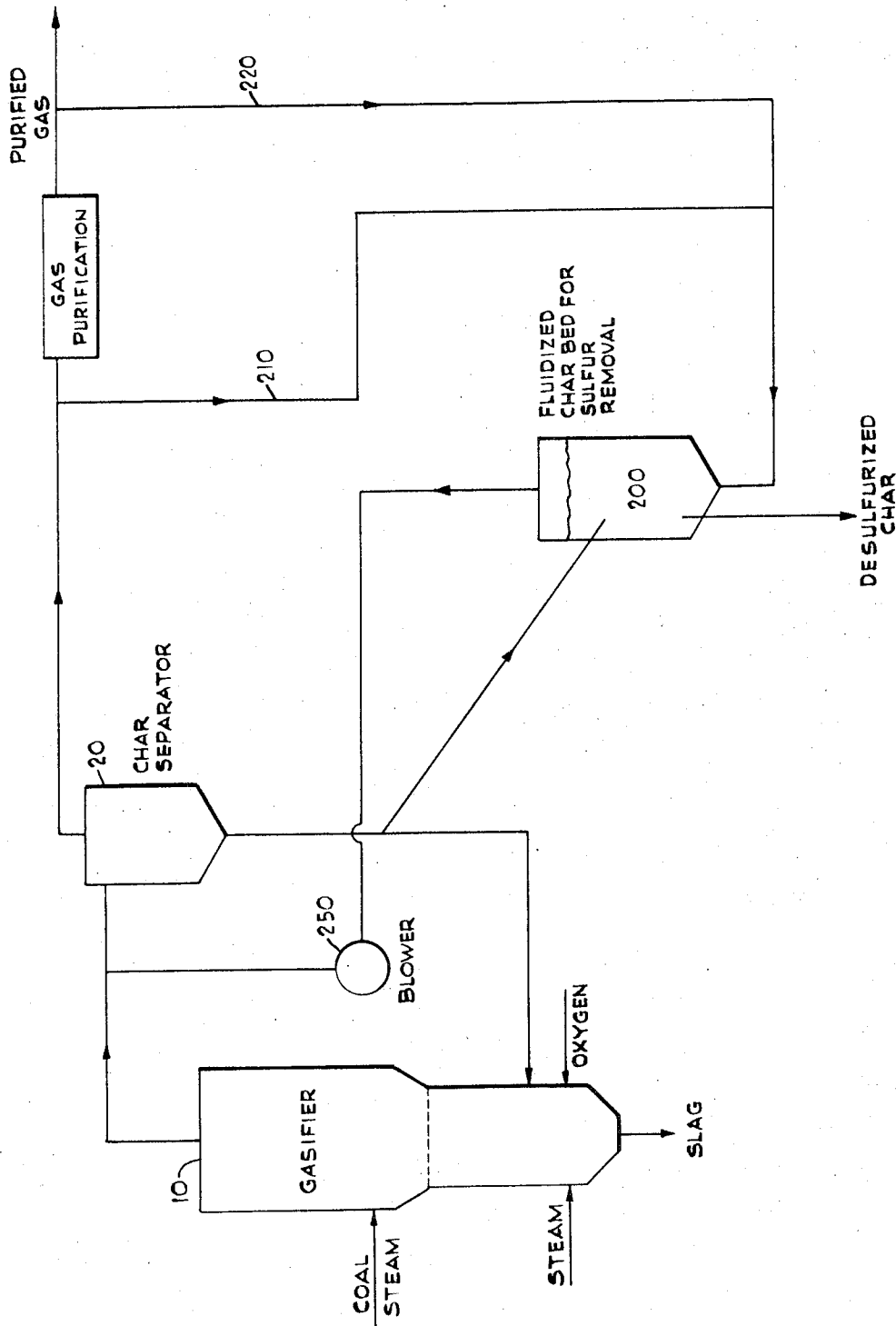


Fig. 2.

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GASIFICATION OF CARBONACEOUS SOLIDS

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8 Claims

ABSTRACT OF THE DISCLOSURE

A continuous process for the gasification of carbonaceous solids, especially coal, wherein a solid, low-sulfur fuel and methane rich gas comprise principal products. The process employs two-stage gasification, each stage characterized by super-pressures and high temperatures. In Stage 1, a low-sulfur char is reacted with oxygen and superheated steam at an elevated temperature and pressure to provide a Stage 1 product gas comprising oxides of carbon and hydrogen. In Stage 2 a charge comprising a carbonaceous solid, such as coal, is heated and reacted under methane formation with Stage 1 product gas and superheated steam to provide a Stage 2 product gas and char which are thereafter quenched and separated for providing gaseous and low-sulfur solid char products. A part of the solid char product is withdrawn from the process for providing a low-sulfur fuel for a boiler fuel and the remaining part is recycled to Stage 1 and there reacted with oxygen and superheated steam for providing additional Stage 1 product gases. The withdrawn char product is burned in a boiler for providing process steam and the gaseous Stage 2 product is further treated for providing methane-rich fuel gas and sulfurous by-product.

BACKGROUND OF THE INVENTION

(1) Field of the invention

This invention relates to the gasification of carbonaceous solids, and more particularly to a two-stage entrained gasification process for carbonaceous solids for providing a solid, low-sulfur fuel and methane-rich gas as principal products.

(2) Description of the prior art

Treatment of carbonaceous solids containing volatile materials with heat and pressure in order to drive off the volatile components and provide solid and liquid products for fuels, and the like, has been carried out by several processes in the past. For example coal has been carbonized by, e.g. pyrolysis techniques wherein the coal is destructively heated in the absence of air to obtain a solid char and gaseous products such as hydrogen, methane and ammonia. Pyrolysis generally takes place in the presence of a reducing atmosphere such as carbon monoxide and hydrogen and liquid tars and oils are additionally obtained as pyrolysis products. The Lurgi process represents a typical high pressure, high temperature carbonization technique, and though providing reasonable gaseous yields, has proven somewhat unsatisfactory for efficiently recovering heating fuels from carbonaceous solids. For example, the amount of methane rich fuel gas produced is unfavorable when compared with that produced by other processes. Additionally the solid char retains most of the sulfur present in the starting material, making it unsatisfactory in many applications due, e.g., to lower heating value than a sulfur-free product. Moreover large quantities of tars and oils are formed, thereby necessitating complex gas cooling systems with provisions for oil and tar separation from the gas stream. In addition

the tars and oils collected must often be further treated for economical utilization of their heating value.

Two-step processes for treating carbonaceous solids comprising both carbonization and gasification have been employed to produce fuel products from those materials. U.S. Pat. 2,662,816 teaches a process wherein a dense fluidized bed carbonization stage is provided in connection with a gasification stage. In the carbonization stage, a carbonaceous fuel is heated in a reducing, or non-oxidizing atmosphere. Thereafter the char and gases produced by carbonization are separated, with char passing to a gasification zone for heating and reaction with the steam and oxygen to produce a gasification product char and gases. In that process temperatures of 1600–2000° F. are present in the gasification zone, and 900–1300° F. in the carbonization zone. Operating pressures are provided in both zones of 200–600 pounds per square inch. Such temperatures and pressures encourage the formation of difficultly processable tars and oils. The char produced in that process may be recycled to the carbonization zone. The patent suggests using part of the char produced for fuel, but, since the process involves a low-pressure carbonization it would be expected that the char would contain a substantial quantity of sulfur.

Pat. No. 2,687,950 likewise discloses a carbonization/gasification process for treating carbonaceous materials. There, the products issuing from a fluidized bed carbonization zone wherein carbonaceous material is heated and reacted with carbon monoxide and hydrogen, comprise volatiles and a carbonaceous residue. The carbonaceous residue is introduced into a gasification zone and there contacted with oxygen and steam to produce carbon monoxide, hydrogen, and methane. Suggested operating conditions for the process comprise temperatures of 1000–1500° F. carbonization, 1400–2100° Fahrenheit gasification, with an overall operating pressure of 100–800 pounds per square inch. Such conditions encourage formation of tars and oils, and likewise encourage retention of sulfur in the char to thereby degrade the solid char produced. The char produced may be recycled, part to the gasification zone and part to the carbonization zone, or may be withdrawn for fuel purposes.

Pat. No. 2,680,065 discloses a gasification process for carbonaceous solids wherein heat for the gasification process is supplied by indirect heat exchange. There char product from a gasification or combined carbonization/gasification process is completely burned to supply heat for process requirements, e.g., for gasification. In the process tars and liquid oils are produced.

A two-stage super-pressure coal gasification process has been developed at Bituminous Coal Research, Inc., Pittsburgh, Pa. (BCR). There a carbonaceous material, such as coal, is gasified in a second stage to produce a methane rich gas and a process char. There, char is recycled and reacted with steam and oxygen in a first stage to produce hot synthesis gases. Those gases are contacted with fresh coal in the second stage whereby the coal is heated and reacted in contact with gases comprising hydrogen, carbon monoxide, and steam to produce methane, process char and additional synthesis gases. That process employs a super pressure, two-stage coal gasification reactor which operates at temperatures in excess of about 1600° F. and pressures in excess of about 60 atmospheres. That process and apparatus have the ability to produce tar-free, low sulfur content char product in addition to a methane rich gaseous product, and is more fully described in a publication of the Department of Interior, Office of Coal Research (OCR), dated 1965 entitled, "Gas Generator-Research and Development Survey and Evaluation."

A computer study entitled, "Computer Study of Stage 2 Reactions in the BCR Two-Stage Superpressure Gasifica-

tion Process" was presented at the National Meeting of the American Chemical Society, Division of Fuel Chemistry, Chicago, Ill., in September 1967. That study suggested that partial gasification would reduce the cost of the pipeline gas if the char were withdrawn from the two-stage gasification process described in the above mentioned OCR report, and use the recycle char as boiler fuel.

It has now been found that the BCR process for manufacturing methane may be substantially improved if a part of the char produced in the two-stage superpressure gasification process is withdrawn therefrom, with the remaining part being recycled to the Stage 1 gasification step of the process. This invention therefore provides an improved two-stage gasification process for carbonaceous materials, especially coal, wherein principal products are produced comprising a methane-rich fuel gas and a low-sulfur solid char. The invention further provides an improved two-stage gasification process which may accommodate a higher proportion of raw coal than heretofore attainable, whereby increased yields of methane may be obtained, based on coal charged to the process. Moreover the invention provides an improved two-stage gasification process for carbonaceous materials which can provide, in addition to increased methane yields, a low-sulfur solid char product which provides an excellent fuel with high heating value which may be employed to efficiently and effectively provide fuel for a waste-heat boiler whereby energy is provided for maintaining the process. Other advantages of the invention will become apparent as this specification proceeds.

SUMMARY OF THE INVENTION

This invention provides a two-stage gasification process for carbonaceous solids, especially coal, wherein a low-sulfur fuel char and a methane rich gas comprise the principal products. The process employs two-stage coal gasification, each stage characterized by super pressures and high temperatures, and each stage further characterized in that each comprises a gasification as opposed to a conventional carbonization. In Stage 1 of the two-stage gasification a low-sulfur process char is reacted with oxygen and steam at an elevated temperature and pressure to provide a Stage-1 product gas. Gas residence, or contact, time in Stage 1 is less than about two seconds, and preferably is less than about one second. In Stage 2 a charge comprising a carbonaceous solid, e.g., coal and superheated steam are heated and reacted with the Stage 1 product to provide a Stage 2 product comprising gases and a low-sulfur process char entrained therein which are thereafter cooled and separated for providing a gaseous product and low-sulfur solid char. Gas residence, or contact, time in Stage 2 is less than about ten seconds, and preferably is less than about four seconds. A selected part of the solid char product is withdrawn from the gasification process for providing a low-sulfur fuel and the remaining part is recycled to Stage 1 of the process and there reacted with oxygen and super-heated steam for providing Stage 1 product gases. The withdrawn Stage 2 char product has a low-sulfur content and high heating value and is burned in a boiler for providing process steam and energy. The Stage-2 gaseous product is preferably further treated for providing a substantially sulfur-free, methane-rich fuel gas and a sulfurous by-product. Withdrawal of the selected part of the total char product from gasification permits an increase in the raw coal charge to Stage 2 of the gasification process which results in a total overall increase in methane production based upon coal charged to the gasification process. Most preferably process gases from Stage 2 are passed through a water gas shift reaction unit and cooled whereby carbon monoxide is converted into carbon dioxide and hydrogen until a hydrogen/carbon monoxide ratio of about 3.05 is reached. The gaseous product is thereafter treated with a selective solvent system to provide a concentrated hydrogen sulfide (H_2S) stream, with subsequent carbon dioxide removal. The hy-

drogen sulfide stream, as formed, may pass to a Claus plant for conversion to elemental sulfur, and subsequent recovery. Most preferably the remaining gases are heated to 500° F. and reacted with a reducing, hydrogenating nickel catalyst for completely methanating the product gas, thus forming a methane rich product gas comprising at least about 90 percent by volume methane.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic representation of a process according to the invention.

FIG. 2 is a schematic representation of an alternative preferred process according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As employed throughout this specification, the term "carbonaceous materials" is intended to designate a solid carbon-containing composition, particularly coal, which will yield a part of that carbon as volatile material upon heating.

The term "carbonization" is intended to designate the destructive distillation or heating of a carbonaceous material in the absence of air or other oxidizing agent in a manner whereby all or part of the volatile portion of the carbonaceous material is liberated.

The term "gasification" is intended to designate the heating of carbonaceous material in the presence of oxidizing agents such as steam, carbon dioxide and oxygen or mixtures thereof in a manner whereby all or part of the volatile portion of carbonaceous material is liberated, and whereby carbon in the carbonaceous material may react chemically with those oxidizing agents or with other reactants present in the gasification process.

Referring now to FIG. 1, coal is preheated in a conventional preheater 5 and thereafter charged with superheated steam to a two-stage gasifier 10. The coal may be charged by known means such as lock hoppers or by a piston feeder and may be injected into gasifier 10 together with a process gas if desired. The coal charged has a particle size small enough to be carried out of the gasifier with process gases via entrainment. Gasifier 10 is of the type described hereinabove, i.e., a Bituminous Coal Research two-stage entrained coal gasifier, and has two gasifying zones, namely Stage 1 and Stage 2 portions, 12 and 14, respectively. Coal is charged into Stage 2, and is there contacted with steam and hot process gas issuing from Stage 1 portion 12 of the gasifier. Those gases have a temperature in excess of 1700° F. and comprise oxides of carbon, hydrogen and steam. The hot gases and steam serve to heat and react with the coal charge for volatilizing volatile components of the coal and for forming methane. It is indicated that at least seventy-five percent of the hydrogen in volatile matter from the coal charge forms methane with additional hydrogen from Stage 1 gas with the remaining carbon in the volatile matter forming oxides of carbon, principally carbon monoxide.

In Stage 2 portion 14 of gasifier 10 operating conditions constitute extremely high temperatures and super pressures. Operating temperatures in Stage 2 are at least about 1600° F. and most preferably are at least about 1700° F. Pressures exceed at least about 60 atmospheres, and most preferably exceed about 70 atmospheres. The superheated steam charge to Stage 2 is generally in excess of 900° F.

The gases entering Stage 2 portion of the process from Stage 1 portion 12 have a temperature greater than about 1700° F. Those gases comprise a synthesis gas including principally hydrogen and carbon monoxide, and superheated steam. The steam and carbon monoxide tend to equilibrate under the water-gas shift reaction to form hydrogen and carbon dioxide. The formation and synthesis of Stage 1 gases will be more fully explained herein after.

After the volatile portion of the coal charged to Stage 2 portion 14 of reactor 10 has been heated and reacted with the hot synthesis gases of Stage 1 portion 12, a Stage 2 product is formed and is continuously withdrawn from the top of gasifier 10. That product comprises generally a gaseous portion having solid char entrained therein. The gaseous portion comprises methane, carbon monoxide, carbon dioxide, hydrogen and steam. In addition hydrogen sulfide is present, having formed from sulfur present in the coal charge. It should be noted here that, due to the extremely high pressures and temperatures, and due to the presence of hydrogen and steam reactants, a large part of the sulfur present in the coal charge is removed as hydrogen sulfide gas. Thus the char produced comprises a low-sulfur char.

Stage 2 gases and entrained char issuing from gasifier 10 are preferably passed to a quenching zone 15 where water is injected into the process stream for cooling the process products from about 1700° F. to about 1100° F. The quenched process stream is then separated into its gaseous and char components. In the figure, a cyclone-type separator 20 is provided for separating the process products whereby a gaseous product may be continuously withdrawn from the top of the cyclone and a solid char product may be withdrawn from the bottom.

Char is withdrawn from the bottom of cyclone separator 20, and is divided into two portions. A part of the char is withdrawn from the gasification process stream and the remaining part is recycled to Stage 1 portion 12 of gasifier 10. Preferably at least about 10 percent by weight, and most preferably at least about 15 percent by weight of the char product is withdrawn from the process stream. The remaining part of the char formed is recycled to gasifier 12 and there its carbon is substantially completely gasified by reaction with superheated steam and oxygen. It has been found that about forty to sixty percent by weight of the coal charge is gasified in Stage 2 of gasifier 10 with the remaining carbon portion in the char product gasified in Stage 1 during recycle processing or withdrawn as char and used as power plant fuel.

In Stage 1 portion 12 of gasifier 10, the recycled char is gasified by contact with superheated steam and heated oxygen which are likewise charged to Stage 1 portion 12. The reactions there are exothermic and a temperature of greater than 2500° F. is reached. There the remaining organic components of the char are substantially completely utilized by gasification. The remaining inorganic ash is withdrawn as a slag from the lower portion of gasifier 10. Process gases issuing from Stage 1 comprise synthesis gas including steam, hydrogen, and oxide of carbon as principal constituents. That gas, i.e., Stage 1 product gas, may then pass into Stage 2 portion 14 of gasifier 10 for heating and reacting with fresh coal charged thereto with additional steam, as hereinabove described. There, fresh coal is partially gasified under methane formation at elevated temperatures and pressures to again institute the process cycle which is operated in continuous fashion.

Referring now to the portion of char withdrawn from the process stream after cyclone separator 20, that char is passed to a boiler 30 of conventional type. There the char is burned for providing steam. All or a part of the steam produced may pass to a power plant 40 for providing energy for the process and for other purposes. A part of the steam formed may pass to a conventional air separation apparatus 50 to thereby provide energy for producing process oxygen. Oxygen produced in air separation unit 50 is mixed with a portion of the steam produced in boiler 30. Both steam and oxygen are superheated to a temperature of at least about 800° F. in heat exchanger 60, and are thereafter charged to Stage 1 portion 12 of gasifier 10. In Stage 1 of the process, the steam, oxygen, and char are reacted to form hydrogen

and oxides of carbon which ascend, together with excess steam and any entrained char, into Stage 2 portion 14. The non-volatile, or slag portion of that char which has been gasified in Stage 1 is liquid at the elevated temperature of Stage 1, i.e., in excess of 2500° F. and may drop to the bottom of gasifier 10, be quenched and discarded.

Referring now to cyclone separator 20, raw gas issuing therefrom is further cooled in waste heat boiler 70, and thereafter passed into a water gas shift reactor unit 80. There carbon monoxide is converted into carbon dioxide and hydrogen until a hydrogen/carbon monoxide ratio of about 3.05 is reached. The gas is thereafter cooled and contacted with a selective solvent system for forming a concentrated hydrogen sulfide stream. Carbon dioxide may likewise be removed from the gas stream at this point in the process. Solvents for selectively removing hydrogen sulfide from a gaseous stream are well known, and the preferred solvent is an organic compound containing basic groups such as e.g. amino groups. The concentrated hydrogen sulfide stream is preferably thereafter passed to a reactor 85 where hydrogen sulfide is converted to elemental sulfur and recovered. The remaining gases are then heated to about 500° F. and enter zinc oxide containing reactor 90 for removing any traces of remaining sulfur in the gas stream. Thereafter, the desulfurized gas stream passes to a reactor 95 containing a nickel hydrogenating catalyst where carbon monoxide is converted into methane. In that fashion a methane-rich product gas comprising at least about 90 percent methane is formed.

In FIG. 2 an alternative preferred process according to the invention is shown. There a gasifier 10 is provided as hereinabove described with respect to FIG. 1 for continuously producing a Stage 2 product gas and char which are cooled and separated in char separator 20. As in the process represented in FIG. 1, a part of the char product is recycled to Stage 1 portion 12 of gasifier 10 and a part is withdrawn from the process cycle. The withdrawn char is charged to a vessel 200 where it is fluidized by contact and reaction at an elevated temperature with a hydrogen containing gas for further reducing the sulfur content thereof. Preferably, the hydrogen containing gas comprises Stage 2 product gases, and most preferably Stage 2 product gases having undergone a shift reaction as described previously herein. The fluidizing hydrogen containing product gas may be withdrawn from the main Stage 2 gaseous process stream either before or after further gas purification through gas streams 210 and 220 respectively, in FIG. 2. As there shown, withdrawn product gas passes into the bottom portion of reactor 200 for fluidizing and reacting with withdrawn char passing downwardly through reactor 200 to be finally withdrawn as further desulfurized char product. Fluidizing gases are drawn from reactor 200 by suitable means, such as a blower, or exhaust fan, 250 and thereafter returned to the main Stage 2 product stream for further processing and purification, e.g. in the manner hereinabove described with respect to FIG. 1. It is most preferred that contact of char and product gases in reactor 200 take place at a temperature of about 1000° F. or greater and also that reactor 200 and the various process lines leading thereto and therefrom be operated at a pressure substantially equal to ordinary process pressures. To that end, withdrawn char and Stage 2 product gases are withdrawn from the main process streams and contacted without substantial pressure reduction.

The process of the invention will be further understood and illustrated by the following example thereof.

EXAMPLE

1000 pounds of coal were injected by means of a piston type feeder together with product gas at a bulk density of 24 pounds per cubic foot and 250 pounds of superheated steam at 1000° F. to Stage 2 portion of a two-

stage gasifier of the type described hereinabove. The coal employed had the following analyses:

Proximate analysis, percent

H ₂ O	1.3
Volatile material	42.5
Fixed carbon	49.0
Ash	7.2

Ultimate analysis, percent

Carbon	74.7
Hydrogen	5.0
Nitrogen	1.5
Sulfur	3.8
Ash	7.2
O ₂ (by diff.)	7.8

Heating value 13,285 B.t.u./lb.

The charge was heated by synthesis gas issuing from Stage 1 of the gasifier. The reactions between the hot synthesis gas issuing from Stage 1, steam, and raw coal charge resulted in gasification of the coal charge under methane formation at 72 atmospheres pressure and a temperature of 1700° F. A Stage 2 product was withdrawn from the reactor now comprising gas having solid char entrained therein. The gaseous product comprised 27,400 standard cubic feet (dry basis) and had the following composition:

Stage 1 product gas composition

	Percent
CO ₂	15.9
CO	38.7
CH ₄	17.3
H ₂	26.0
N ₂	0.7
H ₂ S	1.4

The gas and entrained char product leaving Stage 2 of the gasifier were quenched by water injection and thereby cooled to a temperature of 1115° F. The quenched process stream comprising gas and entrained char were passed into a cyclone-type separator and continuously working sand filter. From the stream leaving Stage 2 were withdrawn 798 pounds of char. Of the total withdrawn char, 144 pounds of char having a 13.0% ash content were withdrawn from the process and cooled in a char cooler. The char was withdrawn by means of lock hoppers. The remaining 654 pounds of char were fed by means of lock hoppers into the Stage 1 portion of the two-stage gasifier together with 475 pounds of oxygen, at 800° F. and 300 pounds of steam superheated to 1000° F. The char, steam, and oxygen reacted exothermically in Stage 1 at 72 atmospheres pressure to form hydrogen and oxides of carbon which ascend together with excess steam and any remaining char into Stage 2 of the gasifier. A liquid slag was obtained from the mineral matter in the char which could not be gasified ("ash"), and was thrown to the walls of the gasifier and flowed downwardly to a narrow throat in the reactor base and into a water bath where the slag was quenched and granulated. The slag slurry formed was depressurized and discarded.

Gas and steam issuing from the cyclone separator were further cooled in waste heat boilers and thereafter were passed into a water gas shift reaction unit in which carbon monoxide was converted into carbon dioxide and hydrogen until a hydrogen/carbon monoxide ratio of 3.05 was reached. That gas was then contacted and cooled with a selective solvent system until a concentrated hydrogen sulfide stream was formed. Thereafter the carbon dioxide was removed. The concentrated hydrogen sulfide stream in solvent was passed to a reactor where the hydrogen sulfide was converted to elemental sulfur and recovered. The remaining gas was heated to 500° F. and passed to a reactor containing zinc oxide for removing any traces of sulfur compounds. Thereafter the completely desulfurized gas was passed to a reactor containing a nickel hydro-

genating catalyst. To control the heat of reaction, product gas was recycled and the catalyst tubes of the reactor were cooled with water boiling under pressure. A product gas was withdrawn at a rate of 9600 standard cubic feet (dry basis) with the following composition:

Product gas composition

CO ₂	percent	1.14
CO	do	0.06
CH ₄	do	94.8
H ₂	do	2.0
N ₂	do	2.0
H.V.	B.t.u./s.c.f.	970

In addition to the foregoing, 33 pounds of elemental sulfur were obtained. The 144 pounds of char which were withdrawn from the recycle char stream were charged to a waste heat boiler for generating steam and power required by the process. Process char had a sulfur content of about 0.72 percent by weight indicating that most of the sulfur present in the raw coal charge was removed during gasification.

It was found that the sulfur content of process char was further reduced when withdrawn char was treated in the fashion described herein with reference to FIG. 2. That is, when withdrawn char was charged to a reactor and fluidized by contact with Stage 2 product gas having a hydrogen/carbon monoxide ratio of about 3.05 (after shift reactions) and a temperature in excess of 1000° F., a process char having a sulfur content of 0.48 was obtained. Both char and product gas were withdrawn and charged to the reactor without substantial pressure reduction, and product gas withdrawn from the reactor was recycled to the main Stage 2 product stream leaving gasifier.

According to the provisions of the patent statutes, I have explained the principle, preferred construction and mode of operation of my invention and have illustrated and described what I now consider to represent its best embodiments. However, I desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

I claim:

1. A process for the gasification of carbonaceous materials comprising,
 - contacting recycle char in a first gasification zone with superheated steam and oxygen whereby said recycle char is substantially completely gasified and whereby a synthesis gas comprising oxides of carbon and hydrogen is formed,
 - charging to a second gasification zone a charge comprising a carbonaceous solid,
 - contacting said carbonaceous solid with superheated steam and with said synthesis gas comprising oxides of carbon and hydrogen formed in said first gasification zone whereby said carbonaceous solid charge is partially gasified,
 - withdrawing from said second gasification zone a product stream comprising solid char entrained in a product gas,
 - separating said solid char from said product gas, withdrawing a portion of said solid char product, introducing said withdrawn portion of said solid char product into a reactor,
 - subjecting said withdrawn portion of said solid char product to a hydrogen containing gas at an elevated temperature and pressure to separate and gasify a portion of the sulfur contained in said withdrawn portion of said solid char product to thereby reduce the sulfur content of said withdrawn portion of said solid char product,
 - burning said withdrawn portion of said char for producing process energy,

recycling said remaining portion of said solid char to said first gasification zone as said recycle char, and

said first and second gasification zones each characterized by an operating pressure of at least about 60 atmospheres and an operating temperature of at least about 1600° F. and the residence times of said gases in said first and second gasification stages comprising less than about ten seconds, respectively.

2. The process as set forth in claim 1 which includes fluidizing said withdrawn portion of said solid char product in said reactor with said hydrogen containing gas.

3. The process as set forth in claim 1 wherein said hydrogen containing gas comprises said product gas from said second gasification zone, said gas having a hydrogen/carbon monoxide ratio of about 3.05 therein.

4. The process as set forth in claim 1 including charging said gas to a water gas shift reaction unit, holding said gas in said reactor until a hydrogen/carbon monoxide ratio of about 3.05 is reached in said gas, removing hydrogen sulfide and carbon dioxide from said gas, and contacting the remaining portion of said gas with a catalyst whereby a methane-rich product gas is formed comprising about at least 90% by weight methane.

5. The process as set forth in claim 3 which includes, withdrawing said hydrogen and sulfur containing gas from said reactor,

combining said withdrawn hydrogen containing gas with said product gas withdrawn from said second gasification zone.

6. The process as set forth in claim 5 wherein said hydrogen sulfide is converted to elemental sulfur, and recovering said elemental sulfur.

7. The process as set forth in claim 4 wherein said steam in said first gasifying zone has a temperature of at least about 800° F. and said steam in said second gasifying zone has a temperature of about 900° F.

8. The process as set forth in claim 7 wherein said operating pressure in said first and second gasifying zones is about 72 atmospheres, said operating temperature in said first gasifying zone is at least about 2700° F. and said operating temperature in said second gasifying zone is about 1700° F.

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U.S. Cl. X.R.

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