

[54] **IN SITU COAL GASIFICATION PROCESS**

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[51] Int. Cl. **E21c 43/00, C10j 5/00**

[58] Field of Search **48/202, 204, 210, 48/215, DIG. 6; 166/256, 270; 299/2, 3**

[56] **References Cited**

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Primary Examiner—Morris O. Wolk

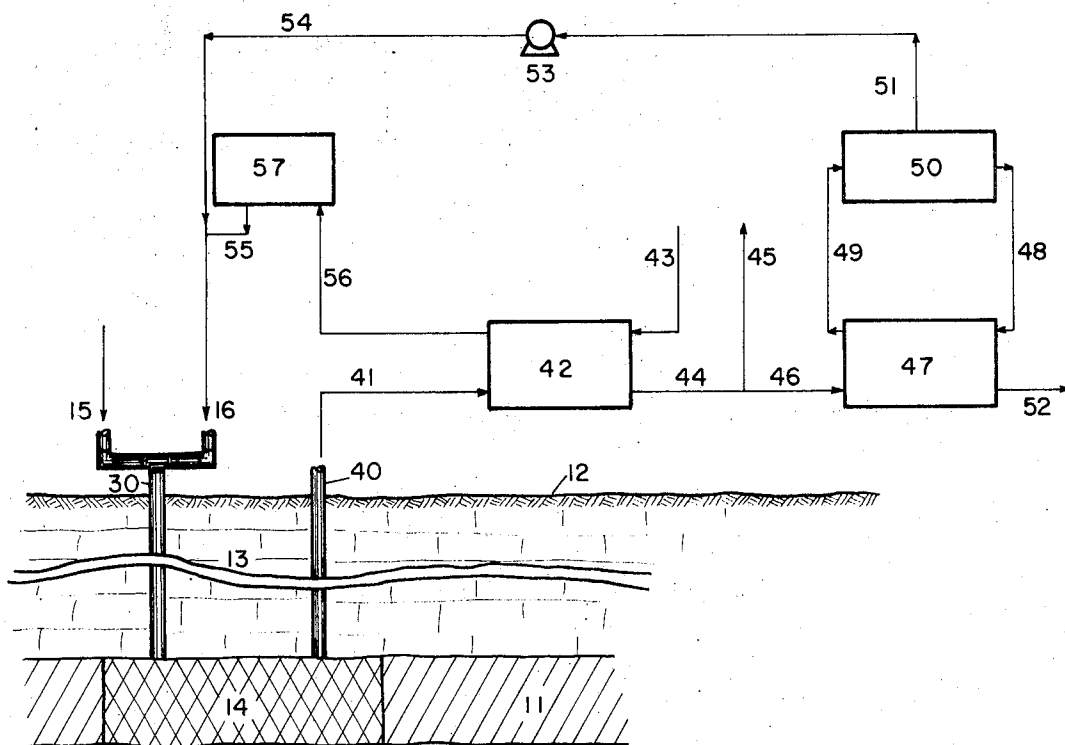
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[57] ABSTRACT

A method for in situ coal gasification to recover a calorific value gas by the water-gas shift reaction for the optimum formation of carbon monoxide and hydrogen through the simultaneous introduction of carbon dioxide and steam into an injection well in order to shift the reaction kinetics of the process to favor the water-gas shift reaction.

8 Claims, 1 Drawing Figure



IN SITU COAL GASIFICATION PROCESS

BACKGROUND OF THE INVENTION

This invention relates to the in situ combustion of a coal seam for the recovery of volatile hydrocarbons and a synthetic calorific value gas. More particularly, the present invention is a method for production of volatile hydrocarbons and calorific value gas through optimization of the water-gas shift reaction by introduction of carbon dioxide in combination with steam into a subterranean coal deposit.

Production of coal energy by the use of the wells through underground mining has been a continuous subject of interest to the field of energy production. Coal gasification by use of above ground retorting is an old art, one of the better known methods being the Lurgi process developed in Germany prior to World War II. By this method, oxygen and steam are simultaneously injected into a field retort and combusted with an energy content gas, having value sufficient for commercial usage, and coal tar liquids being produced. Underground in situ gasification of coal deposits generally involves utilization of a fracture network formed within the coal deposit with air injection followed by steam injection for the subsequent production of a water-gas shift product gas.

The water-gas shift reaction involves the intermingling of steam with carbon contained within the coal at temperatures above 1,000°C for the production of a gas containing carbon monoxide and hydrogen. Generally, the water-gas shift reaction is preferred with a competitive reaction for the formation of carbon dioxide and hydrogen, from the contacting of the carbon monoxide with steam, being a less preferred reaction as a lower calorific value gas is then formed. Therefore, what is required is a means for shifting the reaction kinetics within the in situ gasification process so that the more preferred reaction of the water-gas shift process will be favored so as to obtain a maximum calorific value gas from the subterranean coal deposit.

It is an object of the present invention to provide a method for the combustion of underground coal beds.

It is another object of the present invention to provide a method by which the calorific value of the gas produced by in situ coal gasification may be maximized.

It is still a further object of the present invention to utilize the introduction of carbon dioxide simultaneously with that of steam in order to shift the reaction kinetics of an in situ coal gasification process so that the more preferred water-gas shift reaction is favored.

With these and other objects in mind, the present invention may be more fully understood through referral to the following discussion and description.

SUMMARY OF THE INVENTION

The objects of the present invention are accomplished through utilization of a process for the in situ recovery of a synthetic gas, having a high calorific energy value, from a subterranean coal deposit. In the process a coal deposit is burned to raise the temperature therein above about 1,000°C. as steam is injected therein to produce a water-gas shift reaction product gas. The improvement of the process of the present invention comprises introducing carbon dioxide in the coal deposit in order to favor the reaction kinetics to the water-gas shift reaction. The combustion and steam

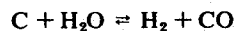
injection steps may be accomplished simultaneously or in separate phases wherein the temperature of the reservoir is maintained at/or above about 1,000°C. The carbon dioxide introduced is generally obtained from the gas produced from the coal deposit. The steam introduced may be contacted with the produced gas from the coal deposit to regain the waste heat content so as to further expedite the energy balance of the system.

BRIEF DESCRIPTION OF THE DRAWING

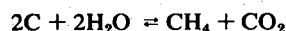
The present invention may be more readily understood by referral to the accompanying FIGURE in which a subterranean coal deposit is depicted in combination with the apparatus utilized in practicing the process of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Disclosed herein is a method for distilling coal in situ to recover a synthetic gas having a high calorific energy content. In the process of the present invention, the in situ recovery of a synthetic gas is obtained through the introduction of the combustion supporting gas into the subterranean coal deposit. The temperature of the coal deposit is raised to above about 1,000°C and steam is introduced for the production of a water-gas shift reaction product gas. The improvement of the process of the present invention comprises shifting the reaction kinetics within the reservoir so as to favor the water-gas shift reaction. Generally, synthetic gas formed by the water-gas shift reaction product is described by the following chemical equations:



wherein a less frequently competing reaction may occur described by the following chemical equation.



Although at temperatures above 1,000°C the water-gas shift reaction is favored, a still further reaction may occur with the carbon monoxide contained in the formation formed by the water-gas shift reaction recombining with the steam injected according to the following competing chemical reaction:



It can be shown that above 1,000°C the reaction for the formation of carbon monoxide and hydrogen dominates with the introduction of carbon dioxide into the injection well. The carbon dioxide injection suppresses the further formation of carbon dioxide through the contacting of carbon monoxide and water or steam so that the reaction formula favor the formation of carbon monoxide and hydrogen. When the formation temperature drops below about 1,000°C, the combustion step must be reinitiated. Therefore, simultaneous combustion and water-gas production is favored.

In general, the product gas formed will consist of steam, carbon dioxide, carbon monoxide and hydrogen. The heat content of the product gas may be utilized to preheat the steam production by contacting the fresh water with the gaseous reaction products in a waste heat exchanger and condenser. Carbon dioxide is absorbed from the product gas with an absorbent or carbon dioxide solvent, for example an aqueous carbonate solution or monoethanolamine. The carbon dioxide recovered is recompressed and combined with the injection steam either in liquid or gaseous form in

order to achieve the more preferred reaction equilibrium characteristics of the present invention. Of course, the reaction conditions of the coal deposit determine the optimum quantity of carbon dioxide to be introduced in order to gain the maximum calorific value and total gas product volume. Therefore, a kinetic design is conducted for each subterranean project to determine the optimum quantities of carbon dioxide to be recycled.

The present invention may be more fully understood by referral to the accompanying FIGURE in which a subterranean coal deposit 11 is depicted having a calorific value gas being produced through utilization of the process of the present invention. An injection well 30 is completed from the earth's surface 12 through overburden rock 13 into coal deposit 11 having fractured zone 14 therein. The means for fracturing the coal deposit 11 may comprise various and sundry means not disclosed nor pertinent to this discussion. Injection well 30 is provided with a wellhead having multiple injection means wherein air 15 and a mixture of steam and carbon dioxide 16 may be introduced simultaneously. A production well 40 connects the coal seam 11 through fracture system 14 with the earth's surface 12 from which steam, carbon monoxide, carbon dioxide and hydrogen 41 may be produced.

The produced gas mixture 41 is then introduced into a heat exchanger and condenser system 42 in which water 43 is countercurrently introduced so as to subject the produced gas to a waste heat boiler for the reclamation of energy while leaving a cooled produced gas 44, having for example a temperature of 50°C and being at atmospheric pressure. The water 45 is then condensed and removed from the produced gas mixture 44. The carbon monoxide, carbon dioxide and hydrogen 46 are introduced into a carbon dioxide absorption unit 47 wherein solvent 48 is countercurrently introduced so as to produce carbon dioxide and solvent 49. The carbon dioxide 51 is reclaimed from the carbon dioxide solvent 49 in a carbon dioxide recovery unit 50. The solvent 48 is recycled to the carbon dioxide absorption unit 47. Water-gas product 52 is produced from the carbon dioxide absorption unit 47 as a high energy, high calorific value synthetic gas. The carbon dioxide 51 is recycled through a compressor 52 to form compressed carbon dioxide 54 which is introduced with steam 55 produced from the heated water 56 exiting from the waste heat exchanger and condenser 42 and cycled through a boiler 57, so as to form heated or superheated steam 55 for introduction as steam and carbon dioxide mixture 16 into the injection well 30 for sustenance of the process of the present invention.

The process of the present invention may further be understood through referral to the following example in which the process to promote the formation of water gas through reinjection of carbon dioxide to provide a buffer against production of carbon dioxide in the subterranean coal deposit at temperatures above 1,000°C is illustrated.

EXAMPLE

A conventional in situ coal gasification process for the production of a high calorific synthetic gas may be initiated utilizing a starting mixture of 1.0 mole of water to yield a product gas at 20 atmosphere and 1,800°F. A similar process may be initiated utilizing the improved process of the present invention wherein a

mixture of 0.05 moles of carbon dioxide and 0.95 moles of water are injected into the same coal deposit. The results indicated in Table 1 may be expected as based upon the reaction kinetics of the system depicting the superior results achieved by utilization of the process of the present invention.

TABLE 1

Mole Fraction of Gases Produced/Mole of Water Injected

	Conventional	Improved Process	% Increase
CO	0.45	0.474	5.33
H ₂ O	0.05	0.0015	
CO ₂	0.05	0.0515	
H ₂	0.45	0.474	5.33

Therefore, the present invention, as it applies to the art of in situ combustion of coal deposits, allows a significant process for the total recovery of energy value from a coal deposit. The invention enhances the art of in situ combustion of coal deposits by representing an economic method for the combustion and reclamation of energy from these deposits through the use of the optimum water-gas shift reaction conducted therein.

While the invention has been described above with respect to certain embodiments thereof, it will be understood by those skilled in the art that various changes and modifications may be made without departing from the scope and spirit of the invention as set forth.

Therefore, we claim:

1. In a process for the in situ recovery of a synthetic gas, having a high calorific energy value, from a subterranean coal deposit wherein the coal deposit is burned to raise the temperature therein above about 1,000°C and steam is subsequently injected therein to produce water-gas by the water-gas shift reaction, the improvement comprising introducing carbon dioxide into the coal deposit in order to favor the reaction kinetics of the water-gas shift reaction.

2. The process of claim 1 further comprising reinitiating combustion of the coal deposit when the temperature therein becomes less than about 1,000°C.

3. The process of claim 1 wherein the carbon dioxide introduced is obtained from the produced gas from the coal deposit.

4. The process of claim 3 wherein the carbon dioxide is removed from the produced gas by absorption.

5. The process of claim 3 further comprising subjecting the steam introduced to contact with the produced gas from the coal deposit to regain the waste heat contained in the produced gas.

6. In a process for the in situ recovery of a synthetic gas having a high calorific energy value, from a subterranean coal deposit wherein a combustion supporting gas and steam are simultaneously injected into the coal deposit to maintain the temperature therein above about 1,000°C and to produce a water-gas by the water-gas shift reaction, the improvement comprising simultaneously introducing carbon dioxide into the coal deposit in order to favor the reaction kinetics of the water-gas shift reaction.

7. The process of claim 6 wherein the carbon dioxide is removed from the produced gas by absorption.

8. The process of claim 6 further comprising subjecting the steam introduced to contact with the produced gas from the coal deposit to regain the waste heat contained in the produced gas.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,770,398 Dated 11-6-73

Inventor(s) George E. Abraham & Carlos M. Royo

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 2 Line 45 reads CO + H₂ should read CO + H₂O

Col. 3 Line 45 delete "52" add --53--

Signed and sealed this 23rd day of April 1974.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents