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PROCESS FOR THE GASIFICATION OF SOLID CARBONACEOUS FUELS

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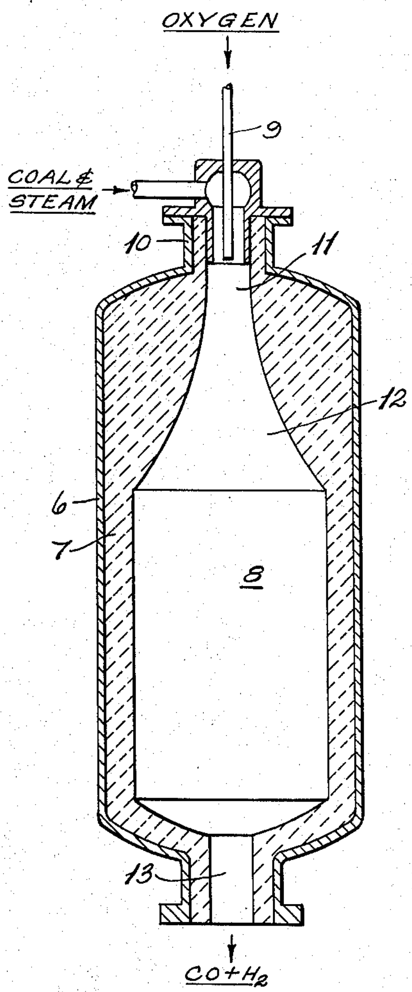

Fig. 1.

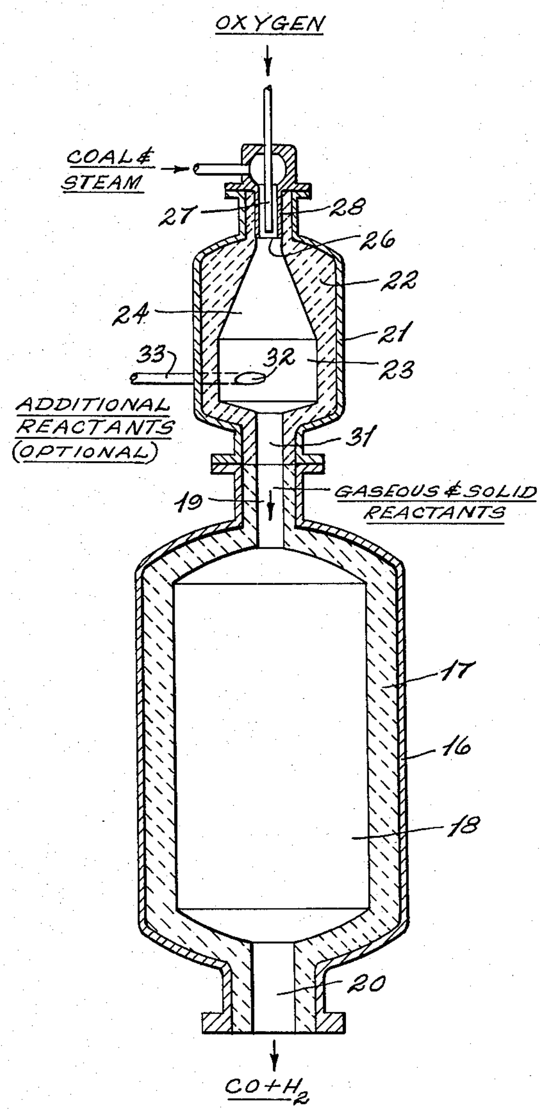

Fig. 2.

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PROCESS FOR THE GASIFICATION OF SOLID CARBONACEOUS FUELS

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2 Claims. (Cl. 48—206)

This invention relates to a process for the generation of carbon monoxide and hydrogen by partial combustion of a solid carbonaceous fuel. In one of its more specific aspects, this invention relates to partial oxidation of a solid carbonaceous fuel in the form of fine particles suspended in a gas stream while subjecting the gas and solid particles to vibration.

This application is a continuation-in-part of my application Serial No. 243,482, filed August 24, 1951, and now abandoned.

In accordance with this invention, coal in fine particle form is gasified in suspension by reaction with an oxygen-containing gas. The reactants and reaction products within the reaction zone are subjected to sonic vibrations. This effects a substantial increase in the rate at which the fuel is gasified as compared with the rate of gasification in the absence of these vibrations.

In the generation of carbon monoxide and hydrogen by the partial combustion of a solid carbonaceous fuel, it has previously been proposed to conduct the gasification reaction while the particles of fuel are in suspension in an oxygen-containing gas and the resulting gaseous reaction products. Coal, for example, has been successfully gasified in this manner by suspending the powdered coal in reactant gases and conducting the reaction in a compact, unpacked reaction zone at temperatures above about 2200° F.

Theoretically, the rate of gasification of solid fuel with an oxygen-containing gas should increase as the particle size of the solid fuel is decreased. This follows from the fact that as the particle size decreases, the surface area per unit mass increases. Since the oxidation takes place on the surface of the particles, it is to be expected that the rate of gasification of very fine particles would be much greater than that of the somewhat larger particles, for example, those granular in size. Accordingly, it might be expected that the very fine particles of solid material which are often entrained in the product gas from the gasification zone would be essentially ash. In practice, however, it is often found that fine particles are carried from the reaction zone in the product gas stream before their carbon content has been completely consumed. Fine particles of solid material carried from the reaction zone in the product gas often contain a surprisingly high proportion of unreacted carbon.

The rate of gasification of coal particles in a gaseous suspension depends to a large extent upon the rate of diffusion of the reactant gases, e.g., oxygen, carbon dioxide and steam through unreactive gases surrounding the particles of coal. Reaction of oxygen with the feed coal is relatively rapid. During the course of the gasification reaction, however, the solid particles become surrounded with a film of unreactive product gas. At the same time, as the particles and reacting gases advance through the gasification zone, the reactions between the hot residual unreacted carbon and carbon dioxide and steam become important. In order to effect reaction of the carbon contained in the particles it is necessary for the reactants

to diffuse through the protective layer of unreactive gases on the surface of the particles.

The fine particles are more readily suspended in the gas than are coarse particles and hence are carried along at about the same speed as the reacting gases so that the rate of diffusion becomes a controlling factor in the rate of their gasification. The coarser particles, on the other hand, due to their inertia are more likely to slip relative to the gas stream and thus have the unreactive gas film swept away by reactant gases. These factors probably account for the observation that the rate of gasification does not increase to the extent which might be expected as the particle size of the fuel is decreased. They also explain why fine particles often escape gasification in the reaction zone.

Very often the coal particles are introduced into the reaction zone in a stream of steam and thereafter contacted with the oxygen-containing gas. This procedure is used to prevent premature reaction and explosions in the fuel handling system. In line with the theory outlined above, it is possible that the gasification, particularly of the fine particles, is hindered by the film of water vapor surrounding these particles and inhibiting the rapid exothermic reaction of the particles with free oxygen.

In accordance with the present invention, the rate of gasification is increased by subjecting the reactants to sonic vibrations. Frequencies of from about 50 to about 500 c.p.s. are preferred. The amplitude of these vibrations should be relatively large. The increase in the rate of gasification may be explained as the result of movement of the reactant gas relative to the solid particles. Fluctuations in the gas flow resulting from the vibrations have relatively little influence on the motion of the particle. Consequently, there is relative movement between the gas and the solid particles, resulting in sweeping the unreactive gas from the surface of the solid particles. Regardless of theory, the present invention, does in fact, increase the rate of gasification. It has been found that gasification rates are increased by this method to a rate many times the rate of gasification in the absence of vibration.

The vibrations are produced autogenously by an unstable flame. An unstable flame results when the combustion conditions are such that the flame does not remain in the same place in the combustion zone. The shape of the combustion space at the point of ignition may cause instability of the flame as will be described in more detail hereinafter. The frequency of vibration of an unstable flame is a function of the size of the vessel as is well known in physics; the frequencies correspond to the resonant frequency of the vessel. In a closed vessel, the wavelength of the resonant frequency vibrations is twice the length of the vessel.

In a preferred embodiment of the present invention the oxygen-containing gas and solid fuel particles are introduced separately into the reaction zone and admixed with one another at the point of introduction to the reaction zone. Either or both of the reactants are introduced at a flow rate in excess of the rate of flame propagation. The rate of flame propagation varies with oxygen concentration, pressure and combustibility of the fuel and is best determined experimentally. The reaction zone adjacent the point of introduction of reactants is tapered to present a gradually increasing cross-section to the stream of reactants in the direction of flow. Variations in the flame in this section of the reactor result in vibrations of the gas stream, thereby subjecting the reactants to vibration throughout the entire reaction zone.

The gasification reaction may be conducted at either atmospheric or at an elevated pressure. Preferably the reaction is conducted at a pressure in excess of 100 p.s.i.g. Pressures on the order of 500 p.s.i.g. or higher may be used. At elevated pressures, the rate of reaction is somewhat higher than at lower pressures.

Figure 1 of the drawings is a more or less diagrammatic elevational view in cross-section illustrating apparatus suitable for conducting gasification of solid fuels in accordance with the present invention. Figure 2 is a similar view of another form of apparatus suitable for carrying out the process of my invention.

With reference to Figure 1 of the drawings, the numeral **6** designates a reaction vessel designed to withstand the desired operating pressure. A refractory lining **7** protects the wall of the vessel from overheating and conserves heat within the reactor. Provision may be made, although not illustrated in the drawings, for cooling the wall of the vessel. The reaction zone **8** is in the form of a cylinder free from packing or catalyst.

Oxygen-containing gas is introduced into one end of the reaction zone through conduit **9**; solid carbonaceous fuel and steam are introduced through conduit **10**. These reactants enter the reaction zone through inlet port **11** and are admixed with one another at the point of introduction to the reaction zone. The specific manner in which the reactants are introduced and admixed may vary without departing from the principle of the invention.

Adjacent the inlet port **11**, the reaction zone is tapered to provide an inlet section **12** of gradually increasing cross-section in the direction of flow. The reactants admitted to the reactor through inlet port **11** are introduced in the center of the inlet end of the reaction zone and directed axially along the reaction zone toward an outlet **13** at the opposite end of the reaction zone.

The reaction zone is operated at a temperature in excess of about 2200° F. At these temperatures, the refractory walls of the reaction zone, including section **12**, are at a fairly uniform temperature due to the high rate of heat transfer by radiation. This temperature insures ignition in section **12**. Ignition may be initiated originally by any suitable means, e.g. by means of a small gas-fired pilot burner, not illustrated in the drawing.

Product gas and ash are discharged from the reactor through the outlet port **13**. The ash or unconsumed portion of the fuel may be discharged through the outlet port as fly ash or in molten form.

In operation, the reactants are introduced through the inlet port **11** into admixture with one another. In the inlet port and in a portion of the tapered inlet section **12** of the reaction zone, a velocity in excess of the rate of flame propagation is maintained. A flame front is established and combustion begins in this tapered section. This flame front tends to fluctuate so that an unstable flame is produced. The tapered walls act as flame holders to prevent blowoff, or extinction, of the flame and permit exceptionally high feed rates to the reactor. Fluctuations in the flame set up vibrations in the reactor. With a cylindrically shaped reactor, the fluctuations in the flame are in resonance with the reactor resulting in vibrations of fairly large amplitude. The vibrations so created result in a great increase in the rate of the gasification reaction.

With reference to Figure 2 of the drawings, a reaction vessel **16**, similar to that of Figure 1, is provided with a refractory lining **17** defining a cylindrical reaction zone **18**. Reactants are introduced into the reaction zone **18** through an inlet **19** and discharged therefrom through outlet **20**. Prior to introduction to reaction zone **18**, the reactants are passed into an ignition chamber or primary reaction zone maintained at a temperature in excess of 2200° F. in which reaction between the coal and oxygen is initiated. Reactants entering reaction zone **18** comprise, at least in part, reaction products from the ignition chamber or primary reaction zone.

The ignition chamber or primary reaction zone comprises a vessel **21** designed to withstand the desired operating pressure. The vessel is provided with a refractory lining **22** defining a generally cylindrical chamber **23**, at one end of which is a frusto-conical section **24** through which reactants are introduced. At least a portion of the coal, steam, and oxygen are introduced into the ignition chamber or primary reaction zone through inlet port **26** by way of a burner comprising an oxygen conduit **27** and a concentric conduit **28** for steam and coal. The walls of vessels **16** and **21** may, if desired, be provided with cooling means, not illustrated in the drawings.

The reactants are introduced into the tapered section **24** of the ignition chamber or primary reaction zone at a velocity in excess of the rate of flame propagation. Section **24** gradually increases in cross section the direction of flow of reactants introduced through inlet port **26**. A velocity in excess of the rate of flame propagation is maintained in a portion of the frusto-conical section **24**. The reactants admitted through conduits **27** and **28** are introduced at the center of the inlet end of the ignition chamber or primary reaction zone and are directed axially toward an outlet **31** at the opposite end of the combustion chamber and coincident with inlet **19** of the vessel **16**. The outlet **31** is of relatively small diameter as compared with the diameter of reaction zone **23**.

Optionally, additional reactants may be introduced into chamber **23** through an inlet **32** to which reactants are supplied by conduit **33**. Reactants supplied through conduit **33** enter the cylindrical section **23** of the chamber, tangential to the peripheral wall of the chamber. In a preferred specific embodiment of the present invention, a minor proportion of the reactants are introduced into the primary reaction chamber through inlet port **26** while the major portion of the reactants are introduced through inlet port **32**. The reactants introduced through port **32** may be admixed at the point of introduction to the ignition chamber or primary reaction zone in a manner corresponding to the introduction of reactants through inlet port **26**. The specific manner in which the reactants are introduced and admixed may vary without departing from the principle of the invention.

The reactants introduced through inlet port **26** may be richer in oxygen than the desired overall mixture supplied to the generator so that combustion taking place in the tapered section **24** of the ignition chamber is relatively rapid and generates more than the usual quantity of heat. This preheats the additional reactants introduced through line **32**. The additional reactants then contain a relatively smaller amount of oxygen so that the composite mixture discharged from outlet **31** if of approximately the desired composition for the production of optimum quantities of carbon monoxide and hydrogen from the reactants. Instead of introducing the additional reactants into the ignition chamber via conduit **33**, they may be introduced directly into the reaction zone **18** into admixture with the effluent from the ignition chamber. The specific manner of introduction of reactants into the reaction zone **18** is relatively unimportant and does not, per se, form any part of the present invention.

The primary purpose of the ignition chamber or primary reaction zone **23** is to provide pulsations within the reaction zone **18** to increase the rate of gasification of the solid carbonaceous fuel therein. The ignition chamber or primary reaction zone is quite effective for producing such pulsations and the apparatus of Figure 2 is somewhat less sensitive to rates of feed than is the apparatus of Figure 1. Resonant frequency vibrations are set up in the primary reaction zone. The wavelength of the fundamental resonant frequency vibrations in this case is twice the length of the primary reaction zone, as is known from the laws of physics. The secondary reactor **18** may be designed to resonate at the same frequency (fundamental or harmonic) as the primary reaction zone.

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. In a process for the generation of carbon monoxide and hydrogen by partial combustion of a solid carbonaceous fuel in fine particle form with an oxygen-containing gas at a temperature above about 2200° F. wherein the fine particles of said carbonaceous fuel are reacted with said oxygen-containing gas in a closed reaction zone while in suspension in gases comprising gaseous reactants and products of reaction, the improvement which comprises suspending fuel particles in steam, admixing the suspension of said fuel particles in steam with oxygen-containing gas forming a stream of mixed reactants flowing at a velocity in excess of the rate of flame propagation, introducing said stream of mixed reactants into said reaction zone through an inlet section of gradually increasing cross-sectional area along the path of flow of said reactants at a rate sufficient to maintain the velocity of flow of mixed reactants along an initial longitudinal portion of said inlet section in excess of the rate of flame propagation and along a further downstream portion of said inlet section at a velocity less than the rate of flame propagation maintaining an unstable flame in said inlet section therebetween and generating resonant frequency vibrations within the range of from about 50 to about 500 cycles per second in said reaction zone of sufficient magnitude to achieve mixing of reactants, and withdrawing resulting products of reaction from said reaction zone.

2. In a process for the generation of carbon monoxide and hydrogen by the partial combustion of a solid carbonaceous fuel in fine particle form with an oxygen-containing gas at a temperature above about 2200° F. wherein particles of said fuel are reacted with said oxygen-containing gas in a reaction zone while in suspension in gases comprising gaseous reactants and products of reaction, the improvement which comprises suspending fuel particles in steam, introducing the suspension of said fuel

particles in steam into admixture with oxygen-containing gas in relative proportions effective for said generation forming a stream of mixed reactants flowing at a velocity in excess of the rate of flame propagation, introducing the mixture of reactants at said velocity axially into the inlet end of a first closed cylindrical reaction zone through an inlet section of gradually increasing cross-sectional area along the path of flow of said reactants at a rate such that the velocity of flow of the mixed reactants along an initial longitudinal portion of said inlet section is maintained at a velocity in excess of the rate of flame propagation and along a further downstream portion of said inlet section at a velocity less than the rate of flame propagation thus maintaining an unstable flame in said inlet section therebetween and generating resonant frequency vibrations within the range of from about 50 to about 500 cycles per second in said reaction zone of sufficient magnitude to achieve mixing of reactants, discharging resulting reaction products axially from the outlet end of said first reaction zone as a pulsating stream through an intermediate zone of restricted cross-sectional area axially into the inlet end of a second closed cylindrical reaction zone setting up sonic vibrations in said second reaction zone, said second reaction zone having a greater cross-sectional area than said first reaction zone, maintaining a temperature in excess of 2200° F. in said second reaction zone and discharging resulting reaction products from the outlet end of said second reaction zone.

References Cited in the file of this patent

UNITED STATES PATENTS

2,344,007	Totzek	Mar. 14, 1944
2,500,008	Richardson	Mar. 7, 1950
2,702,744	Totzek	Feb. 22, 1955
2,767,233	Mullen	Oct. 16, 1956
2,777,813	Totzek	Jan. 15, 1957

OTHER REFERENCES

Scientific American, vol. 188, No. 5, May 1953, pages 29 to 35.