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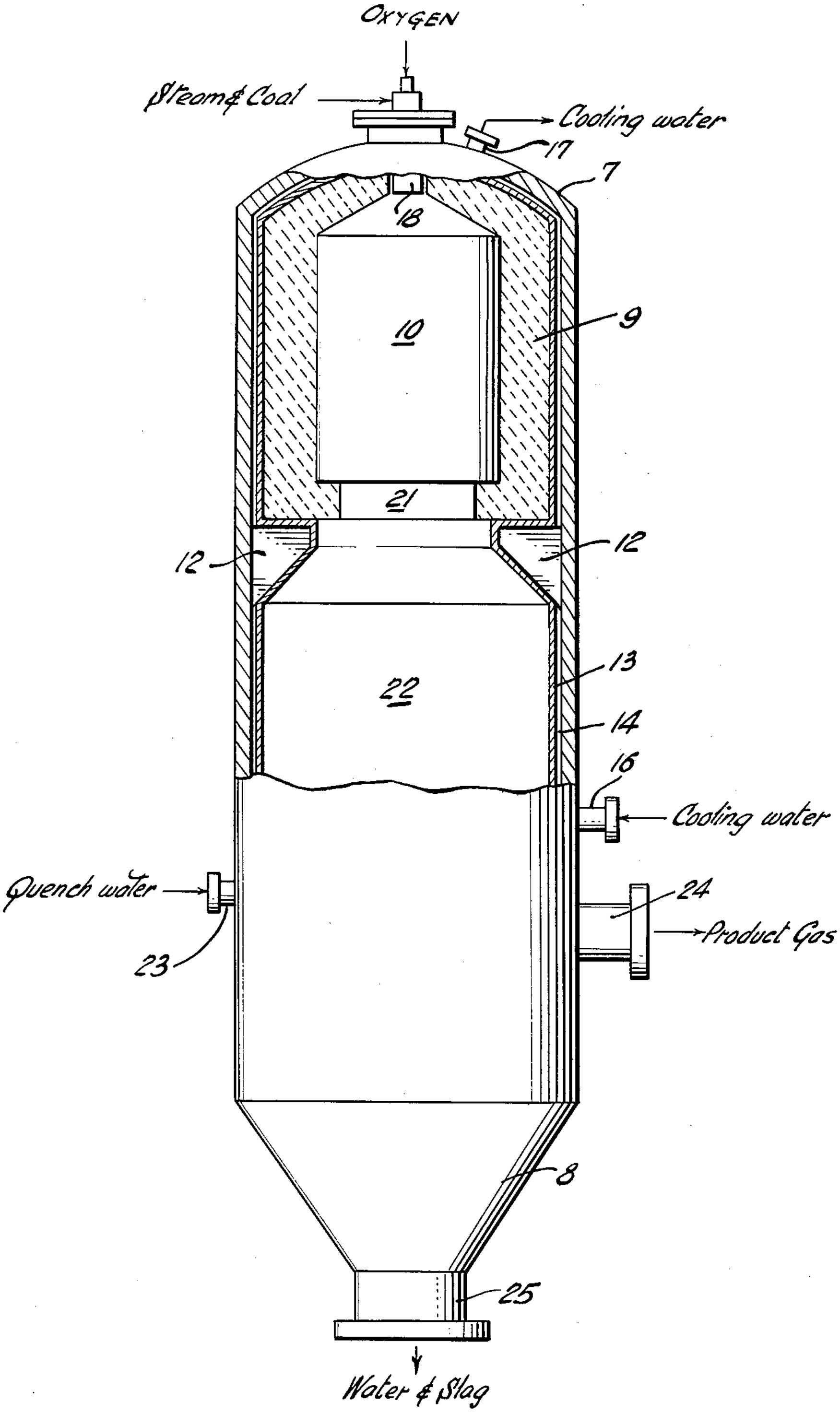

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COAL GASIFICATION APPARATUS

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This invention relates to gasification of solid carbonaceous fuel by reaction with oxygen-containing gas. In one of its more specific aspects the invention relates to the method of and apparatus for production of carbon-monoxide and hydrogen from solid fuel by the interaction of said fuel with a mixture of oxygen and steam.

The gasification of solid carbonaceous fuels by reaction with a limited quantity of oxygen to produce carbon monoxide may be carried out successfully at temperatures above about 1,800° F. Generally, the reaction is most satisfactorily conducted at a temperature in the range of 2,200° to 3,200° F. While air may be used directly as the source of oxygen for gasification, it is generally desirable to employ oxygen-enriched air or substantially pure oxygen in the gasification reaction to reduce the quantity of nitrogen in the product gas. The reaction of a carbonaceous fuel with uncombined or free oxygen is an endothermic reaction. Steam or carbon dioxide, both of which undergo endothermic reaction with carbon, may be employed as supplemental reactants to produce additional amounts of carbon monoxide and hydrogen.

The present invention is directed to an improvement in the gasification of coal, by direct reaction with oxygen and steam in a flow-type gasification reactor. The flow-type coal gasification process may be defined as one in which coal in pulverized form is suspended in oxygen and steam and gasified while in suspension. The flow-type gasification process operates most efficiently at elevated pressures, e.g., 100 to 800 p.s.i. and at temperatures above about 2000° F., e.g. 2200° to 3200° F. The temperatures required for efficient operation are generally above the melting point of the ash from the coal so that a fluid molten slag is produced.

The molten slag is drawn from the reactor through an outlet port or opening in the wall of the reactor into a relatively cold slag quenching zone containing water into which the slag drops and wherein the slag is quench cooled and solidified. To prevent excessive heat loss from the reactor, it is customary to provide a slag port of small cross-sectional area. Removal of the molten slag from the generator presents a number of problems, particularly the plugging of the outlet from the gas generator with solidified slag. These problems are complicated by the fact that the gas generator is operated under an elevated pressure. It has been our observation that even when temperatures approaching incipient melting of the refractory are maintained in the reactor, there is a gradual reduction in the area of the outlet port until complete plugging or excessive pressure drop develops, necessitating shutting down the reactor.

At the present time accepted practice is to provide an outlet port of relatively small area as compared with the cross-sectional area of the reactor, through which molten slag may be withdrawn. As pointed out above, the purpose of restricting the area of the outlet port is to prevent heat losses from the reactor to the cold slag quenching zone. Attempts have been made to overcome the problem of plugging the slag outlet port by drawing part or all of the product gas through the outlet port together with the molten slag. Even though product gas and slag are removed through a common outlet, numerous problems have been encountered with slag buildup and excessive pressure drop at the outlet and with excessive erosion of the refractory surrounding the outlet port. Another suggested solution to this problem is to place the reactant inlet near the slag outlet port to maintain the zone of highest temperature in the reactor immediately adjacent this point and thereby prevent plugging of the outlet port.

We have now discovered that with a cylindrical reactor having a length at least equal to its diameter fired at one end, the radiant heat loss from the opposite end is substantially negligible even though the outlet is equal in cross-sectional area to that of the reactor. This is most surprising in view of the fact that the luminous reactants and reaction products and the hot refractory surfaces can "see" the relatively cold water in the slag quench zone and that the slag quenching zone is essentially a "black body," i.e., a surface which effects nearly total absorption of radiant heat energy. We have also found, however, that although the radiant heat loss through the opening from the reactor is negligible, there may be an excessive heat loss from the reactor due to recirculation of relatively cold gas from the slag quench zone into the reaction zone. We have further found that this heat loss may be prevented by providing a ring or inwardly extending annulus of refractory around the periphery of the gas generator which prevents backflow of cold gases into the reaction zone.

This invention will be better understood with reference to the accompanying drawing illustrating our invention and which is a somewhat diagrammatic elevational view, partly in cross section, of a suitable flow-type reactor for the gasification of coal in suspension.

With reference to the drawing, the gas generator and slag quench zone are contained in a pressure vessel having an outer cylindrical steel shell **6** with a semi-elliptical head **7** and a conical bottom **8**. The gas generation section is a vertically disposed cylindrical chamber **10** provided with an insulating lining **9** of high temperature refractory and insulating materials to withstand the high temperatures generated in reaction zone **10** during operation. Reactants may be introduced into the upper end of the reaction zone and product gas discharged from the lower end thereof.

The refractory insulating lining in the gas generation section is supported by gusset plates **12**, several of which are spaced around the inner wall of the pressure vessel. A jacket **13** within the outer shell and spaced from the wall of the vessel forms an annular passageway **14** through which cooling water may be circulated, cooling the wall of the vessel and preventing the steel pressure vessel shell from overheating. Cooling water is introduced to the jacket through nozzle **16** in the wall of the vessel and is discharged therefrom through nozzle **17**.

Reactants, oxygen, steam and coal, are introduced into the reaction zone through a mixer-burner **18** which discharges a stream of steam and coal and a separate stream of oxygen into admixture with one another at the point of introduction of the reactants to the reaction zone. The mixture of reactants is charged centrally and axially into the upper end of reaction chamber **10**. The lower end of the reaction chamber opens directly into the slag quench zone **22** through an outlet or throat **21**.

Quench water is introduced into the slag quench vessel through nozzle **23** at a rate sufficient to maintain a pool of water within the quench zone **22**. Molten slag formed in the generation of synthesis gas by reaction of coal with steam and oxygen in reaction chamber **10** passes with the product gas through outlet **21** into the slag quench zone where the slag drops directly into the pool of water. The product gas is discharged through outlet nozzle **24**. Slag, solidified into the form of small beads or granular pieces, is discharged from the slag quench zone, together with quench water, through outlet nozzle **25**.

The reaction zone is of generally vertical cylindrical form provided with reactant inlets at its upper end and a reaction products outlet at its lower end opening directly into a relatively cold slag quench zone. The reaction zone length is at least equal to its diameter and, preferably, is from one and one half to four times its diameter. In accordance with our invention, the throat or outlet opening from the reaction zone into the slag quench zone has an area at least 40 percent of the free cross-sectional area of the reactor and not more than 95 percent of the free cross-sectional area. Preferably the throat area is within the range of 0.7 to 0.9 times the free cross-sectional area of the reactor.

We have now found, contrary to present practice and prevailing theory, that the throat area, i.e., the area of the opening from the reactor into the slag quench zone, may have an open area as great as 0.95 times the total cross-sectional area of the reaction chamber. We have also found that even with this radical departure from the present practice the heat loss from the reactor is negligible.

Without limiting the present invention in any way, the following is offered as a possible explanation as to why these unexpected results have been observed. It is believed that the gaseous products from the reaction zone are in themselves relatively opaque to radiant heat energy and that they effectively shield the locus of the exothermic reaction which is somewhere within the reaction zone between the point of introduction of reactants and the product outlet, from excessive heat loss by direct radiation to the relatively cold quench zone. Although heat loss by direct radiation is not a significant factor, if there is no barrier between the reaction zone and the quench zone, cooling of the reaction zone by recirculation of gases takes place. That is, product gases which have been appreciably cooled in the quench zone, as mentioned hereinbefore, are displaced from the quench zone by hot reaction products and flow back up into the reaction zone, which results in considerable cooling of the reaction zone and a heat loss therefrom which has an adverse effect on the performance of the reactor.

The movement of cold gases from the quench zone into the reactor with its attendant undesirable cooling effect may be effectively prevented by an inwardly projecting ledge or ring of refractory along the periphery of the wall of the reactor. This ring deflects the flow of gases along the wall toward the axis of the reactor. The mass flow of hot product gas from the reactor to the quench zone effectively prevents recirculation of the relatively cold gases to the reactor. The relatively cold gas is thus confined to the slag quench zone.

The effectiveness of the deflector ring to prevent excessive heat loss is evidenced by the efficiency of the generator for the conversion of coal to usable products, namely carbon monoxide and hydrogen. The "cold gas efficiency" of the generator is an effective measure of the efficiency of the gas generator. Cold gas efficiency may be defined as the total heating value of the product gas as compared with the heating value of the fuel fed to the gas generator.

In the following examples, powdered coal suspended in steam is fed at 600° F. into a cylindrical generator of the type described above. The generator in each case has a length at least two times its diameter and not more than five times its diameter. Air preheated to about 800° F. is separately supplied to the generator into admixture with the coal-steam dispersion. The generator in each instance is operated at 400 p.s.i.g. About one pound of steam and about 6.25 standard cubic feet of air is fed per pound of coal. Coal is fed at the rate of about 50 pounds per hour per cubic foot of reactor volume.

In these runs the coal had the following ultimate analysis:

	Weight percent
Carbon	77.3
Sulfur	2.6
Oxygen	5.4
Nitrogen	1.5
Hydrogen	4.9
Ash	8.3

The product compositions, in mol percent, dry basis, are given below:

	Example I	Example II	Example III
Run number	8	10	79
Hydrogen	11.8	15.5	15.1
Carbon monoxide	8.6	11.3	14.4
Carbon dioxide	13.6	14.3	11.0
Methane	0.4	0.6	0.1
Nitrogen	65.6	58.3	59.4
Ratio of outlet area to reactor area	1.00	0.382	0.750
Ratio of outlet diameter to reactor diameter	1.00	0.615	0.865
Cold gas efficiency (percent)	39.1	53.5	61.3

It will be evident from the foregoing examples that the increase in efficiency when the area of the outlet is reduced from the full area of the reactor to three fourths of the reactor area, yet further decrease in area of the outlet to 38 percent of the reactor area shows little, if any, added advantage. We have determined by mathematical analysis that if the area of the outlet exceeds 95 percent of the cross-sectional area of the reactor, back flow of gases takes place reducing the reactor temperature excessively.

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.

We claim:

1. Apparatus for the production of carbon monoxide and hydrogen from a solid carbonaceous fuel comprising an incombustible residue by direct partial oxidation with uncombined oxygen and steam at an autogenously maintained temperature above about 2000° F. and above the fusion point of said residue wherein said fuel in particle form is reacted with said gaseous reactants while in suspension therein and in the resulting reaction products, which comprises, in combination, a vertically extending cylindrical pressure vessel shell having a reaction chamber in its upper portion and a gas outlet port in its lower portion, said reaction chamber having a refractory heat insulating wall defining a vertical cylindrical reaction space therewithin and having an axially disposed inlet for reactants at the upper end thereof, a water-containing slag quench chamber immediately below said reaction chamber in the lower portion of said vessel through which products of reaction from said reaction chamber are discharged to said outlet, and an annular deflector of refractory material extending inwardly from the inner wall of said reaction chamber above said quench chamber and providing a free opening therebetween within the range of 0.4 to 0.9 times the cross-sectional area of said reaction chamber.

2. Apparatus for the production of carbon monoxide and hydrogen from a solid carbonaceous fuel comprising an incombustible residue by direct partial oxidation with uncombined oxygen and steam at an autogenously maintained temperature above about 2000° F. and above the fusion of said residue wherein said fuel in particle form is reacted with said gaseous reactants while in suspension therein and in the resulting reaction products, which comprises, in combination, a vertically disposed cylindrical pressure vessel shell, a generally cylindrical reaction

chamber in the upper portion of said shell, said reaction chamber having a cylindrical refractory wall and a refractory top entirely disposed within said shell, a water-containing slag quench chamber disposed in the lower portion of said pressure vessel shell immediately below said reaction zone, said quench chamber having a cross-sectional area at least equal to the cross-sectional area of said reaction chamber; a gas outlet port from said quench chamber; an annular refractory deflector at the lower end of said reaction chamber positioned above said quench chamber and providing an unobstructed central opening therebetween having a cross-sectional area within the range 0.7 to 0.9 times the free cross-sectional area of the reaction chamber, whereby gaseous products of reaction from said reaction may pass freely into said quench chamber together with unconverted portions of said fuel including molten ash or slag and the backflow of cool gas from said quench zone into said reaction zone is substantially prevented.

References Cited in the file of this patent

UNITED STATES PATENTS

2,368,827	Hanson et al.	Feb. 6, 1945
2,699,384	Peery et al.	Jan. 11, 1955
2,701,755	Strasser	Feb. 8, 1955
2,818,326	Eastman et al.	Dec. 31, 1957
2,871,114	Eastman	Jan. 27, 1959
2,931,715	Eastman	Apr. 5, 1960