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PROCESS FOR PRODUCTION OF COMBUSTIBLE GASES

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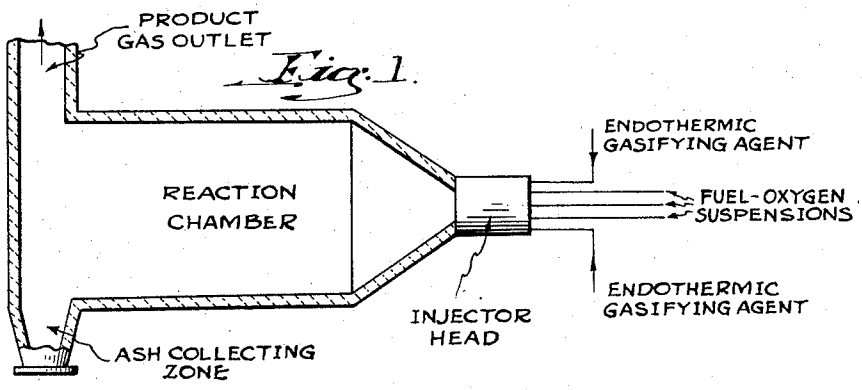

Fig. 1.

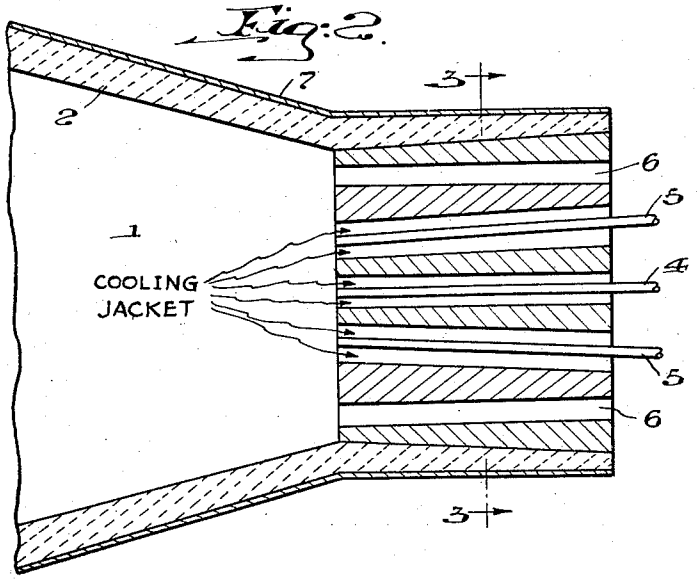

Fig. 2.

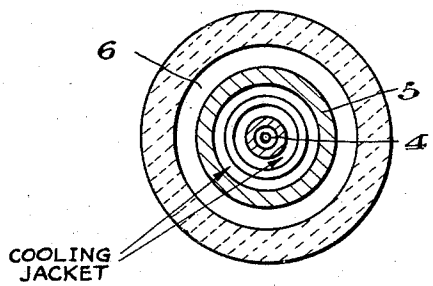

Fig. 3a.

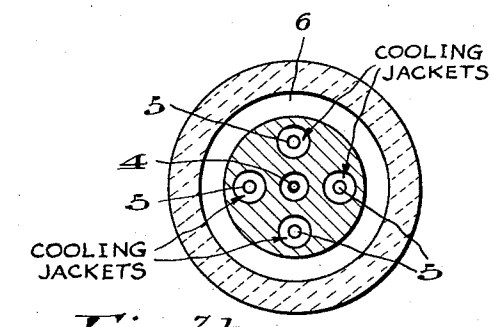

Fig. 3b.

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PROCESS FOR PRODUCTION OF COMBUSTIBLE GASES

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Claims priority, application Germany, December 24, 1953

13 Claims. (Cl. 48—203)

The present invention relates to a process and apparatus for the production of valuable gases, particularly gases which contain carbon monoxide and hydrogen, by conversion of carbonaceous fuels with oxygen and endothermically reacting gasification media of the group consisting of carbon dioxide and steam.

In the conversion of fuels by their partial combustion with oxygen and reaction of the products with, for example, steam, the fuel, in admixture with oxygen, is injected comparatively cold into a reaction space maintained at high temperature, and flows first through a temperature range which is between its inlet temperature and its ignition temperature, the ignition temperature depending on the chemical nature of the fuel and the inert content of the gasification oxygen. As soon as the ignition temperature is exceeded, partial combustion takes place and there is formed at some distance from the injection nozzle a proportionately limited flame zone in which a very high temperature (more than 2,000° C.) prevails. Such partial combustion is relatively slow and the reaction products are composed, to a great extent, of carbon monoxide and carbon. In the adjacent zone, the so-called endothermic zone, the carbon formed by the incomplete combustion of the fuel is converted by the endothermic gasification agent to carbon monoxide and, when steam is present, hydrogen is also formed. The endothermic reaction decreases the temperature of the product gas to between 900° and 1,300° C. depending on the type of fuel introduced. In passing through the flame zone the fuel arrives at a temperature range in which, especially in the case of higher hydrocarbons, a considerable cracking occurs with the formation of free hydrogen, low molecular weight hydrocarbons and elemental carbon in the form of soot. Before this elemental carbon accumulating in molecular form—possibly with graphite structure—can react with the carbon dioxide or steam in the endothermic zone adjacent the flame zone, there occurs an agglomeration of the carbon to rather large particles, the gasification of which is no longer, or no longer completely, possible in the space available for the endothermic reaction, since, during prolonged operation, there is a tendency of the flame zone to wander from the nozzle and gradually encroach on the endotheric zone, thereby reducing the space available for the endothermic reaction. Part of the carbon content of the introduced fuel thus remains ungasified. This portion can, according to the type of fuel used, amount to as much as 20–25% by weight of the carbon charged.

One object of the invention is the improvement of the carbon-gasification rate in the conversion of carbonaceous fuels with oxygen by decreasing the amount of solid carbon (soot) forming in the conversion.

Another object of the invention is to accelerate the ignition of the mixture of fuel and oxygen in such manner that the flame zone is formed closer to the nozzle, so that the flame zone is more concentrated and a larger space is simultaneously maintained inside the reaction chamber for the endothermic reaction.

In the process of the present invention, the gasification of the carbonaceous fuel is accomplished by injecting two different mixtures of fuel and oxygen into the reaction chamber. The first mixture is composed of fuel and an excess of oxygen, that is, at least sufficient oxygen to convert all of the carbon of the fuel in the mixture to carbon dioxide. The second mixture is composed of fuel and a deficiency of oxygen, that is, insufficient oxygen to convert all of the carbon of the fuel in the second mixture to carbon dioxide. The total amount of oxygen in both mixtures is controlled, so that the total amount of oxygen introduced into the reaction chamber is insufficient to convert all of the carbon of the fuel in both mixtures to carbon dioxide.

The two mixtures are injected simultaneously into a reaction chamber maintained at at least the ignition temperature of the first mixture of fuel and an excess of oxygen. Upon its entry into the reaction chamber, the first mixture ignites and the carbon is substantially completely burned. The point and manner of introduction of the second mixture is so chosen in relation to the combustion zone of the first mixture that the partial combustion of the second mixture is accelerated by the radiation of heat from the flame of the first mixture. The carbon monoxide or steam endothermic gasifying agent is introduced into the reaction chamber simultaneously with the two fuel-oxygen mixtures and is introduced in such a manner as to avoid contact with the fuel-oxygen mixtures until the combustion reactions are substantially complete.

By the complete combustion of the first mixture of fuel and excess oxygen, there occurs a radiation of heat from the hot flame of the first mixture, so that the fuel of the second mixture reaches a sufficiently high temperature for ignition in a comparatively short time after its introduction into the reaction space. The flame zone of the second mixture is thus greatly concentrated and remains concentrated close to its point of introduction during prolonged operation of the process.

The excess oxygen injected with the first mixture is heated to a high temperature and is reacted with the fuel of the second mixture, so that carbon monoxide is mainly formed. The elemental carbon still forming in relatively smaller amounts in the flame zone of the second mixture reacts, as a result of the enlarged reduction zone, with the carbon monoxide or steam endothermic gasification media to form carbon monoxide. Calculated on equal amounts of $CO+H_2$, this signifies a decreased requirement of oxygen. Moreover, as a result of the increased endothermic reaction, the temperature of the outlet gas is advantageously decreased.

The radiant intensity of the flame of the first mixture can also be improved by including in the mixture before its injection non-volatile, or only slightly volatile, inorganic material in finely-divided form, for example, powdered ashes, metal oxides, especially those of alkaline earth metals, metal salts, or the like. These inorganic,

non-combustible substances are heated to incandescence as a result of the heat formed in the conversion of the fuel with oxygen, and radiate intense heat to the second mixture. A particularly suitable additive for the first mixture is the ungasifiable residue of the fuel used in the process of the present invention, which residue is recovered in finely-divided form.

The amount of fuel for the first mixture, calculated on the fuel of the second mixture, can generally be kept low. According to the type of fuel to be converted, a quantity of fuel up to about 5% of the total amount of fuel is sufficient to produce the desired effect.

In the accompanying drawings, which are for illustrative purposes only, Figure 1 represents diagrammatically the apparatus for the present invention.

Figure 2 is a vertical section showing in detail the injector head of Figure 1.

Figures 3*a* and 3*b* are sections taken along the line 3—3 of Figure 2, and represent two different embodiments of the invention.

Reaction chamber **1** is enclosed by a heat-resistant inner lining **2**, which is surrounded by metallic shell **7**. At one end of the chamber **1**, there is located an injector head, which has axially disposed centrally therein a conduit **4** enclosed in a cooling jacket. Surrounding conduit **4** is annular conduit **6** and positioned between conduits **4** and **6** are cooling-jacket-encased conduits **5**. As shown in Figure 3*b*, there may be several conduits **5** or as in Figure 3*a*, there may be one conduit **5**, annular in form, surrounding conduit **4**.

In operation of the apparatus, a first fuel-oxygen mixture containing a smaller part of the total carbon to be reacted and at least sufficient oxygen to convert all of the carbon of the smaller part of the total fuel to carbon dioxide is injected through conduit 4, into reaction chamber **1**, which is maintained at a temperature sufficiently high to ignite the mixture as it enters the chamber. Simultaneously, a second fuel-oxygen mixture containing the remaining part of the total fuel and having an oxygen deficiency, that is, insufficient oxygen to convert all of the carbon of the remaining part of the total fuel to CO_2 is introduced into the reaction chamber through the intermediate conduit means **5**, and an endothermic gasifying agent is introduced through outer annular conduit **6**. The first mixture conduit is arranged convergently around the second mixture conduit means so that the first and second fuel-oxygen mixtures are directed to come in contact with each other shortly after their injection into the reaction chamber, whereas, the aforesaid endothermic gasifying agent such as steam is directed to flow between the walls of the reaction chamber and the combustion zone, so as to avoid immediate contact with the mixtures. In this manner, the walls of the reaction chamber are protected by the steam from the high temperatures of the combustion reaction, and additionally, the combustion can proceed substantially to completion unburdened thermally by the presence of the endothermic gasifying agent in the combustion zone all in accordance with my parent process of applications Serial Nos. 43,950, now abandoned, and 43,953, filed August 12, 1948, the latter being Patent No. 2,670,280, of which this application is an improvement continuing in part common subject matter owned by the common assignee and successively continued through Patents 2,702,743 and 2,702,744 and through the still copending application of this inventor Serial No. 297,965, filed on July 9, 1952.

Upon its entry into the reaction chamber, the first mixture ignites and the hot products of combustion thereof together with any excess oxygen, which has been heated to a high temperature, come in contact with the second mixture, thereby heating the second mixture rapidly to promote its ignition for partial combustion with the formation of carbon and carbon monoxide. Subsequently, the hot combustion products of both mixtures and the endothermic gasifying agent interdiffuse with the formation of additional carbon monoxide and, when steam is present as the endothermic medium, hydrogen.

When the procedure outlined above is followed, the combustion zone is maintained nearer the injector head than in my prior apparatus aforesaid, during prolonged operation of the process and does not gradually encroach on the endothermic zone. In addition, by contacting the second mixture with the hot combustion products of the first mixture, the temperature of the second mixture is increased more rapidly than heretofore, thereby promoting more rapid partial combustion and a favoring of the formation of carbon monoxide, rather than the production of carbon and carbon dioxide, which latter condition obtains when the second mixture is heated relatively slowly as above noted. Thus, the gasification of the fuel is more complete than could be accomplished by the processes known heretofore, since in the process of the present invention, not only is more fuel converted to carbon monoxide during the partial combustion reaction, but additionally, the smaller amounts of carbon that are formed during the partial combustion reaction have a larger endothermic zone in which to be gasified by endothermic reaction.

The following example is given by way of illustration only and is not to be considered as limiting the invention in any manner.

A bituminous coal having an average content of 1.95% moisture and an ultimate analysis on a dry basis as follows:

	Percent
C	79.50
H_2	4.27
S	1.88
O_2	4.41
N_2	1.19
Ash	8.75

is ground until 90% will pass through a standard No. 170 sieve. One pound of the finely-divided coal is suspended in 30 cu. ft. of 95% oxygen, and the suspension is injected axially into the reaction chamber, where it ignites and burns. Simultaneously, a second suspension containing 24 lbs. of finely-divided coal suspended in 200 cu. ft. of 95% oxygen is also axially injected into the reaction chamber in such a manner as to come in contact with the hot combustion products of the first mixture, and at the same time, superheated steam (500–600° C.) is introduced into the reaction chamber to flow between the walls of the chamber and the combustion zone. The flow of steam is regulated to supply one pound of steam for each pound of coal fed into the reaction chamber. For each 25 lbs. of coal supplied, there is obtained 950 cu. ft. (measured at 60° F. and 30 in. mercury) of product gas having the following analysis:

	Percent
CO_2	12
CO	43
H_2	43
H_2S	0.5
N_2	1.5

The average calorific value of the product gas is 273 B. T. U. per cu. ft.

Although in the above example, finely-divided coal is used as the fuel to be gasified, it will be obvious to those skilled in the art that other carbonaceous fuels can be used. For example, the fuel of the first mixture may be either a liquid or a gaseous fuel. Similarly, the fuel of the second mixture may be either a liquid or a gaseous fuel. Any combination of liquid, gaseous, or solid fuels may be used. For example, the fuel of the first mixture may be gaseous and the fuel of the second mixture may be liquid or solid.

In the foregoing specifications, the term "oxygen" is used to designate substantially pure oxygen or oxygen-enriched air. The term "endothermic gasifying agent" is used to designate steam, carbon dioxide, or mixtures thereof.

Although a preferred embodiment of the invention has been shown and described herein, it is to be understood that this description is merely illustrative and not limiting. The invention is to be limited only by the scope of the appended claims.

I claim:

1. A process for the production of a gas containing carbon monoxide comprising: injecting axially into a reaction chamber while at ignition temperature a first mixture of a carbonaceous fuel and a free oxygen-containing gas selected from the group consisting of substantially pure oxygen and oxygen-enriched air, the oxygen of said gas in said first mixture being in excess of the amount necessary to convert all of the carbon of the fuel in said first mixture to carbon dioxide, whereby said first mixture ignites substantially immediately upon its entry into the reaction chamber to form a combustion zone adjacent its point of entry, axially injecting an annular stream of an endothermic gasifying agent of the group consisting of carbon monoxide and steam into the reaction chamber in surrounding relation to said first mixture to flow between said combustion zone and the walls of the reaction chamber, axially injecting into the reaction chamber between said first mixture and said annular stream of endothermic gasifying agent, a second mixture of a carbonaceous fuel and a free oxygen-containing gas selected from the group consisting of substantially pure oxygen and oxygen-enriched air, the oxygen of said gas of said second mixture being present in an amount insufficient to convert all of the carbon of the fuel in said second mixture to carbon dioxide, the total oxygen content of both mixtures being insufficient to convert the total carbon content of both mixtures to carbon dioxide and said second mixture being directed at said combustion zone thereby promoting its ignition by the heat of the first mixture with partial combustion of said second mixture closer to its point of entry, to promote more rapid partial combustion favoring the formation of carbon monoxide; thereafter interdiffusing said endothermic gasifying agent and the hot combustion products of said first and second mixtures for reaction to form the final gas containing carbon monoxide.

2. The process of claim 1 in which the first mixture contains in advance of its ignitions finely-divided substantially non-volatile inorganic material.

3. The process of claim 1 in which the second mixture is introduced into the reaction chamber in a plurality of streams.

4. The process of claim 1 in which the second mixture is injected into the reaction chamber as an annular stream surrounding the first mixture.

5. The process of claim 1 in which the endothermic gasifying agent is steam.

6. The process of claim 5 in which the fuel of the first mixture comprises not more than 5% of the total amount of fuel.

7. The process of claim 5 in which the fuel of the first mixture comprises liquid fuel.

8. The process of claim 5 in which the fuel of the first mixture comprises a gaseous fuel.

9. The process of claim 5 in which the fuel of the second mixture comprises a liquid fuel.

10. A process for the production of a gas containing carbon monoxide comprising: injecting axially into a reaction chamber while at ignition temperature a first mixture of a carbonaceous fuel and a free oxygen-containing gas selected from the group consisting of substantially pure oxygen and oxygen-enriched air, the oxygen of said gas in said first mixture being in excess of the amount necessary to convert all of the carbon of the fuel in said first mixture to carbon dioxide, whereby said first mixture ignites substantially immediately upon its entry into the reaction chamber to form a combustion zone adjacent its point of entry, axially injecting an annular stream of steam as an endothermic gasifying agent into the reaction chamber in surrounding relation to said first mixture to flow between said combustion zone and the walls of the reaction chamber, axially injecting into the reaction chamber between said first mixture and said annular stream of steam, a second mixture of a finely divided solid carbonaceous fuel and a free oxygen-containing gas selected from the group consisting of substantially pure oxygen and oxygen-enriched air, the oxygen of said gas of said second mixture being present in an amount insufficient to convert all of the carbon of the fuel in said second mixture to carbon dioxide, the total oxygen content of both mixtures being insufficient to convert the total carbon content of both mixtures to carbon dioxide and said second mixture being directed at said combustion zone thereby promoting its ignition by the heat of the first mixture with partial combustion of said second mixture closer to its point of entry, to promote more rapid partial combustion favoring the formation of carbon monoxide; thereafter interdiffusing said steam as endothermic gasifying agent and the hot combustion products of said first and second mixtures for reaction to form the final gas containing carbon monoxide.

11. The process of claim 10 in which the ungasifiable residue is recovered and at least a portion thereof is added to said first mixture.

12. A process for the gasification of a finely-divided solid carbonaceous fuel which comprises forming a first suspension of a finely-divided solid carbonaceous fuel in a free-oxygen-containing gas selected from the group consisting of substantially pure oxygen and oxygen-enriched air, the oxygen of said gas in said first suspension being present in an amount at least sufficient to convert all of the carbon of the fuel in said first suspension to carbon dioxide, forming a second suspension of a finely-divided solid carbonaceous fuel in a free-oxygen-containing gas selected from the group consisting of substantially pure oxygen and oxygen-enriched air, the oxygen of said gas in said second suspension being present in an amount insufficient to convert all of the carbon of the fuel in said second suspension to carbon dioxide, the total oxygen content of both suspensions being insufficient to convert the total carbon content of both suspensions to carbon dioxide, injecting said first suspension axially into a reaction chamber maintained at at least the ignition temperature of said first suspension whereby said first suspension ignites substantially immediately upon its entry into the reaction chamber to form a combustion zone adjacent its point of entry, injecting an annular stream of an endothermic gasifying agent surrounding said first suspension and directed to flow between said combustion zone and the walls of the reaction chamber, injecting said second suspension into the reaction chamber between said first suspension and said annular stream of endothermic gasifying agent, said second suspension being directed onto said first suspension at the line of flow of said first suspension into said combustion zone where the heat of reaction of the first suspension promotes the ignition of said second suspension closer to its point of entry into the chamber, to promote more rapid partial combustion favoring the formation of carbon monoxide, and flowing said endothermic gasifying agent and the hot combustion products of said first and second suspensions away from their point of entry with reaction of their constituents with each other during such flow.

13. The process of claim 12 in which the fuel of the

first suspension is not more than 5% by weight of the total fuel charged to the reaction chamber.

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