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(54) PROCESS FOR THE PRODUCTION OF A VALUABLE GAS COMPRISING CARBON MONOXIDE AND HYDROGEN

(54) PROCÉDE POUR LA PRODUCTION D'UN GAZ DE VALEUR COMPRENANT DE L'OXYDE DE CARBONE ET DE L'HYDROGENE

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The invention relates in general to the production of valuable gases especially fuel gases containing carbon monoxide and hydrogen. More particularly, the invention relates to a gas producing method of the type which involves gasifying a suspension of a finely divided fuel, especially pulverized fuel, with oxygen by injecting a preformed and highly homogeneous suspended mixture of the finely divided solid fuel and oxygen into a reaction chamber while the latter is being held above ignition temperature, and effecting in the reaction chamber an endothermic reaction between the residual part of the carbon of the fuel in suspension on the one hand and endothermically reactive gaseous media on the other hand by means of the heat of the exothermic reaction of the oxygen with part of the fuel of the suspension introduced into the reaction chamber.

The term "gasifying in suspension" characterizes a mode of operation wherein a finely divided fuel is suspended in a highly homogeneous manner in a fluid gaseous medium, the finely divided fuel flowing essentially in the same direction as the suspending gaseous medium.

Fuels which may be gasified by means of the method according to the invention are pulverized coal, brown-coal, younger coal with a high portion of volatiles, lignite, peat, etc., and degasified products from such fuels, such as coke from coal or brown coal, low temperature coke, etc.

Finally, it is also possible to gasify by the process, liquid fuels in finely divided form, such as hydrocarbon oils.

The term "oxygen" as used in the following ~~specification~~ ^{DISCLOSURE} and claims means pure oxygen, as well as air enriched with oxygen, or oxygen with a content of inert contaminants of less than 20 per cent.

The term "endothermically reactive media" is used to denote water vapor (steam) as well as carbon dioxide (waste combustion gases and fuel gas containing carbon dioxide) or a mixture of steam and carbon dioxide.

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The invention has for an essential object the provision of an improved method for the gasification of a suspension of finely divided fuels with oxygen and with endothermically reactive media which may be performed with a reduced consumption of expensive oxygen and an increased conversion into gas of the carbon of the fuel to be gasified so that the whole gasifying process is more economical.

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Another object of the invention is a new gasifying process wherein the temperature which is to be held during the exothermic reaction between oxygen and fuel may be reduced.

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In an earlier application, we describe the gasification of a finely divided solid fuel in suspension in gas comprising oxygen, to produce valuable fuel gases by performing a highly homogeneous suspended mixture of oxygen and the finely divided fuel, introducing this mixture in the form of a jet axially into a reaction chamber while it is being held at ignition temperature for exothermic reaction, and simultaneously flowing an annular stream of steam into the reaction chamber through discharge openings which surround the fuel-oxygen mixture entrance, and thus cause the zone of primary exothermic reaction between oxygen and fuel to be enveloped by a mostly coherent or closed envelope of steam. In said process the oxygen is present in amount to burn part of the fuel in amount sufficient to provide the heat for the endothermic reaction of the rest of the fuel with part of the surrounding steam but insufficient to raise the temperature of the ash of the fuel to

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the melting point of the ash,

The steam in the primary or interior reaction zone which is formed from the volatile compounds of the fuel of the suspension and/or by evaporation of the natural water content or moisture of the fuel of the suspension reacts on a part of the residual non-oxidized carbon of the fuel under the influence of the high temperature of the exothermic reaction of the oxygen and part of the fuel in suspension in the exothermic zone, thus producing water gas in accordance with the well known reaction:



The unreacted carbon which still escapes from the primary zone in an unoxidized state is also subsequently converted into valuable water gas upon entering by diffusion the steam envelope surrounding the primary zone by endothermic reaction of the envelope in the reaction chamber with the residual hot un-oxidized carbon to form water gas.

The raising of the temperature of all of the steam to be reacted to water gas up to the temperature for the water gas reaction may be effected by preheating the envelope steam to 1200 - 1300°C. (2192 - 2372°F.) or by the burning of the fuel while all the steam for the water gas reaction is in the suspension.

The preheating of the steam to a temperature which is necessary for the water gas process reaction, that is, a temperature of about 1200 - 1300°C. (2192 - 2372°F.), may be performed by means of regenerators or by admixture to the steam of hot waste gases from combustion.

It may be stated that it is known to continuously inject steam and a mixture of finely divided fuel and oxygen into a reaction chamber. But this known method is based on the

idea that the steam to be injected together with fuel and oxygen should contain, in the form of sensible heat, that amount of heat which is necessary to reach 1200 - 1300°C. (2192 - 2372°F.) and maintain such temperature, above the temperature of 300 - 500°C. (572 - 932°F.) at which the water gas reaction begins to take place, that the endothermic reaction between un-oxidized carbon and steam can take place to substantial completion in order to form water gas. There are, however, at least two points why this known method could not be applied with success. The first reason is to be seen from the fact that it is rather difficult and very expensive to preheat the steam outside the reaction chamber to the above-mentioned degree of 1200 - 1300°C. (2192 - 2372°F.). The second reason, a more technical one, consists in that it is rather impossible to prepare outside the reaction chamber a sufficiently homogeneous mixture of fuel and oxygen on the one hand and such a very highly preheated steam on the other hand without the gasifying reactions starting at once, upon mixing of the three components at that temperature, before this three-fold mixture reaches the reaction chamber.

If all of the steam for the water gas reaction that possibly could react thermodynamically were introduced, at a temperature below 300 - 500°C. (572 - 932°F.), with the fuel suspension, the preheating and endothermic reaction of the same in the burning suspension would lower the temperature of the reaction suspension to the point of favoring the production of carbon dioxide rather than carbon monoxide.

In the process of the aforesaid application, all the steam required for the subsequent endothermic reaction of the residual hot unreacted carbon of the suspension, in addition to

the steam formed from the volatile compounds of the fuel and to such steam as is formed from the natural water or moisture content of the fuel in suspension, was introduced around the jet of suspension as a part of the envelope of endothermic reactive
5 medium. Specifically, such steam was preheated to above the temperature $1200^{\circ} - 1300^{\circ}\text{C}$. ($2192 - 2372^{\circ}\text{F}$.), and in said case it was very difficult and very expensive to preheat the steam outside the reaction chamber to above 1200°C . (2192°F .).

According to the present invention, the new gasifying
10 method consists in injecting into a reaction chamber in which the gasifying of the fuel in suspension is to be completed, while surrounded by the steam envelope of the aforesaid process, a preformed suspension of a mixture of fuel (finely divided), oxygen and endothermically reactive medium (steam) that is to
15 react with a portion of the residual unreacted fuel of the suspension and wherein composition, temperature and speed of flow of the mixture and/or its compounds are so chosen that the heat above $300 - 500^{\circ}\text{C}$. ($572 - 932^{\circ}\text{F}$.) which is necessary for the endothermic reaction at a temperature above 1200°C . (2192°F .)
20 in the reaction chamber is produced essentially by the exothermic reaction between fuel and oxygen within the primary exothermic reaction zone in the reaction chamber.

In contrast to the known methods, the gasifying process according to the present invention is performed in
25 such a way that the heat above $300 - 500^{\circ}\text{C}$. ($572 - 932^{\circ}\text{F}$.) required in the endothermic reaction chamber for the endothermic reaction to substantial completion is supplied essentially by the heat surplus of the exothermic reaction within the reaction chamber between the oxygen and only
30 such a part of the fuel as will supply the heat for the

endothermic reaction of the remaining part of the fuel with steam or CO_2 , and that only part of all of the steam that could be reacted thermodynamically to form water gas is introduced along with the suspension, and both at a temperature below 100°C., say 50°C. (122°F.).

The exothermic reaction



causes temperatures to be maintained in the primary exothermic zone of the reaction chamber of more than 1600°C. (2912°F.) and within the temperature range 1200 - 1600°C. (2192 - 2912°F.) the conversion of the non-oxidized carbon of the fuel and steam with formation of water gas proceeds very intensively, i.e., to substantial completion. If, according to my invention, the composition, temperature and speed of flow of the threefold composed gasifying mixture are chosen in a suitable manner, then it is possible to produce a water gas in which the portion of the composition converted to carbon monoxide plus hydrogen is considerably higher than is known from the usual gasifying processes using finely divided fuel in suspension. Simultaneously the portion of non-gasified carbon in the ash is decreased.

The part of the steam which, according to the present invention, is introduced into the reaction chamber at a rather low temperature, below 300 - 500°C. (572 - 932°F.), together with an homogeneous suspension of fuel in oxygen is introduced at temperatures below 100°C. (212°F.), and causes the temperature in the central primary exothermic zone to sink down to a certain degree due to the heat consumption of the endothermic reaction. In this way the danger of a destroying influence in the walls of the reaction chamber, which may be caused by the

very high temperature in the central zone, will be diminished.

According to the invention, the portions of steam on the one hand and oxygen on the other hand in the mixture are to be provided in such a way that the reaction temperature of the primary zone as a result of the steam may not sink down below a degree where the formation of carbon dioxide is favored and the formation of carbon monoxide will not be completed with a sufficient yield. Yet, in each case the relative portions of fuel, oxygen and steam in the mixture formed from these components are so provided that only the exothermic reaction between oxygen and fuel suspended therein delivers the heat energy which will be consumed above 300 - 500°C. (572 - 932°F.) by the endothermic reaction in the formation of water gas at 1200 - 1600°C. (2192 - 2912°F.) but that the ash of the fuel is not heated to above its melting point. Although where melting of the ash is preferred, then more of the fuel may be burned with use of more oxygen, resulting in less carbon for reaction with steam in the water gas reaction.

The exact amount of each of the components of the mixture depends firstly on the analysis of the fuel to be gasified. It may be mentioned that besides the portion of the steam which is to be introduced in mixture with oxygen and fuel, a certain amount of steam resulting from the natural humidity or moisture of the coal also will be decomposed in the primary zone to form water gas and, in addition, that amount of steam which is formed by burning or cracking of the volatile compounds expelled from the fuel also will be decomposed in the primary zone. In addition, residual non-oxidized very hot carbon of the suspension from the primary exothermic reaction zone upon diffusion into the surrounding envelope reacts with

the steam or CO_2 thereof forming water gas, $\text{CO} + \text{H}_2$.

The speed of flow which the fuel-oxygen-steam mixture shows on leaving the injector nozzle depends principally on the speed of ignition of the mixture, i.e. it depends on the time which passes until the comparatively cold mixture will be heated up by influence of heat radiation from the chamber walls to such a temperature at which the exothermic reaction between fuel and oxygen will start. Besides this condition the speed of flow of the mixture is influenced by the pressure in the gas feed lines and the speed of flow of the mixture to be provided as high as to exceed the rate of flame propagation to prevent a back flow of the hot combustion products from the reaction chamber into the feed lines for the said mixture. A preferred height of the gas pressure is the atmospheric pressure or at the most 50 - 100 mm (2-4 inches) of water column higher than atmospheric pressure.

The temperature of the mixing components, especially the temperature of the oxygen and steam components in the suspension may be held down, according to the invention, to such a low degree, $50^\circ - 100^\circ\text{C}$. ($122 - 212^\circ\text{F}$.) that a preheating of these components and the expense thereof especially of the steam is no longer necessary. The main limitation in this regard being that the mixture is held at a temperature at which the steam cannot condense on the fuel as the mixture is being introduced to the reactor, in order to prevent the nozzles and pipe lines from plugging due to the formation of a muddy or slurry mixture of fuel.

The very high temperature caused by the exothermic primary reaction in the central zone of the comparatively small reaction chamber tends to act very intensively on the chamber

walls. In order to keep this heat influence in allowable bounds the invention provides a preferably preheated gaseous medium to be injected into the reaction chamber in such a way, as taught in the earlier application referred to, that a closed
5 gaseous envelope is formed surrounding the very hot zone of reaction between oxygen and carbon and flowing or moving essentially in the same direction as the reactive components of the primary zone. The so formed envelope will lay a heat protective veil upon the reacting chamber walls so that the flow of
10 heat from the primary zone to the chamber walls is reduced to thus avoid having the chamber wall heated up to an undesired high degree.

— In order to form the gaseous envelope surrounding the primary reaction zone, suitable gases or vapors or a mixture of gaseous media may be used. It is possible for instance,
15 to use a fuel gas containing CO_2 which in a preferred manner may be diverted as a portion from the whole fuel gas produced in the primary reaction zone. This fuel gas added is in no way altered except possibly its CO_2 , in the reaction chamber
20 so long as the primary reactions run in the desired way except that the sensible heat of the added fuel gas will be increased by receiving heat from the primary zone and the CO_2 may be endothermically reacted to CO . In such case, in the event of a failure in feed of the finely divided fuel to the primary
25 zone, the fuel gas introduced in order to form the protective envelope will then react on the free oxygen thus preventing the gasifying process from producing a certain amount of oxyhydrogen gas (an explosive mixture of oxygen and hydrogen) in the gas lines.

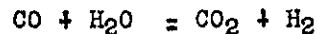
30 Instead of a fuel gas it is also possible to use

water vapor for the gaseous envelope which preferably is heated to a temperature of not more than 300 - 500°C. (572-932°F.).

The use of water vapor shows another advantage besides its heat protective effect, namely a higher yield of valuable gases from the process as the residual non-oxidized very hot carbon of the fuel of the suspension from the primary reaction zone, when reaching the envelope, reacts endothermically on some of the steam of the envelope thus producing more carbon monoxide and hydrogen.

Finally, it may be mentioned that carbon dioxide as well as a mixture of carbon dioxide and steam may also be used as the endothermic gaseous media in order to form the gaseous envelope around the jet of fuel and its exothermic zone, as the fuel issues into and ignites on entering the reaction chamber. In such case they may be introduced at temperatures above 500°C. (932°F.) if they are at that temperature, and so do not need preheating of them.

In order to complete the invention in respect of the ratio of H to CO, to the hot gases escaping from the primary zone after the endothermic reactions of the steam in the free mixture is finished, is added a certain amount of steam or water vapor sufficiently high for the shift reaction for the purpose of adjusting the ratio of hydrogen to carbon monoxide



in the direction of a better yield of hydrogen. As the gases leaving the reaction chamber are very hot, about 1200°C. (2192°F.), it is not necessary to preheat the steam or water for the shift reaction except to a slight degree, if any. Under certain circumstances it is possible to use water as liquid in finely divided form. The essential for the shift

reaction is that the gases are not cooled too suddenly or too low, as then the shift reaction will not take place, as is well known and conventional.

In general, to gasify coal per pound, a mixture of
5 the coal with 8-10 cu. ft. of O_2 and 0.05 - 0.3 lbs. H_2O in
the form of steam are introduced axially in the form of a jet
into a reactor while a protective envelope of gas ^{flows} ~~is flown~~ in
surrounding relation in the form of an annular stream as the
jet issues into and ignites on entering the reactor, in amount
10 equivalent to about 0.50 - 0.80 pounds of steam per pound of
coal. For the shift reaction 0.3 - 0.5 pounds of steam per
pound of coal are used in the final gas.

The amount of steam introduced in mixture with the
coal is limited mainly by the amount of steam that the mixture
15 will retain in the suspension without condensation which would
result in converting the suspended coal to a muddy mass. The
inlet conduit is usually heated in order to avoid condensation,
and the amount of steam admixed may be regulated by instruments,
but preferably the amount of steam is regulated by saturating
20 the oxygen with steam by bubbling the oxygen through water at
a temperature of from 49 - 77°C., (120 to 170°F.). In this
manner the mixture contains no more H_2O than saturates the
oxygen at those temperatures.

In such amounts, 0.05 to 0.3 pounds of steam per
25 pound of coal, the steam is sufficient for the water gas reac-
tion of an amount of the non-oxidized carbon, after the exo-
thermic reaction, without lowering the temperature of the
reacting jet to a degree at which CO_2 formation is favored at
the expense of CO formation, which amount taken with the water
30 gas reaction of the moisture in the coal and water content from

the burning or cracking of the volatile compounds expelled from the fuel, and the subsequent reaction of residual unoxidized carbon with the H₂O or steam of the envelope, results in the completion of the gasification of the fuel to the extent of
5 85-95 per cent of the carbon of the fuel.

With this process the exothermic reaction of the oxygen and fuel generates most of the heat of from 50°C. to 1200°C. - 1600°C. (122°F. to 2192 - 2912°F.), required for the endothermic reactions. This results in this heat being pro-
10 duced more economically than when much of that heat is provided from extrinsic sources.

To this end the final gases are sprayed with steam or water to create in the gas the shift reaction $\text{CO} + \text{H}_2\text{O} = \text{CO}_2 + \text{H}_2$, thus increasing the H₂ content and increasing the
15 ratio of H₂ to CO in the final gas to the desired ratio.

The following data are to be considered as a specific example of performance of the invention in gasification of a particular type of coal:

In order to gasify 1 kilogram (2.2 pounds) of coal, which has been dried and pulverized, a mixture of the coal with
20 0.59 normal cubic metres (22 cu. ft.) of oxygen-gas containing 95% of oxygen and 0.08 normal cubic metres (3.0 cu. ft.) of steam, both gases having a temperature of about 50°C. is flowed into a reaction chamber held at an increased temperature.

25 Simultaneously 0.8 normal cubic metres (30 cu. ft.) of steam of not more than 300 - 500°C. (572 - 932°F.) is injected into the reaction chamber by an annular nozzle surrounding the injector nozzle for the before-mentioned fuel-oxygen-steam mixture. This is equivalent to 10 cu. ft. of oxygen per pound of coal
30 with 0.06 pounds of steam per pound of coal in the axial jet,

and 0.6 pounds of steam per pound of coal for the envelope.
In the reaction chamber a water gas is produced in which, after
the shift reaction, accomplished by the addition of a tertiary
supply of steam or water in the second reaction space, for
5 instance 0.4 pounds of steam per pound of coal, the content of
carbon monoxide + hydrogen is as high as 83% or more, the
balance being nitrogen and CO₂. The portion of non-gasified
carbon in the ash amounts to about 6%.

The drawing shows diagrammatically, as an example,
10 an apparatus suitable for practicing the process of the inven-
tion. The carbon is gasified initially in the inlet reaction
chamber 1 the walls of which are constructed of refractory
material. A preferred shape of the inlet reaction chamber is
that of a truncated cone. The inlets for the reaction media
15 are provided in the front wall at the smaller end of the
chamber. In the axial center of this front wall there is
arranged the injector nozzle 4 for the mixture of fuel, oxygen
and steam, and the axis of the nozzle extends in the same
direction as the axis of the chamber 1. Instead of only one
20 nozzle 4 a series of narrow spaced nozzles may be provided.

The nozzle 4 is surrounded by a number of gas nozzles
5 arranged on a circle around the nozzle 4 in such a way that
the gas ~~flows~~^{flows} in by the nozzles 5 will form a closed envelope
around the central zone of the exothermic reaction media from
25 nozzle 1. In order to complete the formation of the gas
envelope it is preferred to arrange the nozzles 5 in such a
manner that the jets of the steam through the nozzles 5 and
the axis of the reaction chamber wall form a certain angle so
that the enveloping gas is directed towards the tapered walls
30 to form a closed protective layer sliding helically inside the

chamber walls.

After the heat reaction products have left the reaction chamber 1 they enter a second reaction space 6 where they react endothermically on slightly superheated steam which has been introduced into the space 6 through nozzles 9 in amount to effect the shift reaction $\text{CO} + \text{H}_2\text{O} = \text{CO}_2 + \text{H}_2$. Each of the nozzles 9, however, may be constructed as an atomizer by which the water will be divided to form finely divided droplets which after their introduction into the space 6 will react on the hot gases with the formation of water gas by the shift reaction. The gases are drawn off from the reaction space 6 through the outlet line 7 to be further treated in any of the known ways.

The unburnable residue, ash or slag, may be removed from the gas reaction chamber 6 through ash opening 8.

The foregoing process may be practiced under super-atmospheric pressure.

From the foregoing it will be noted that an important aspect of the present process resides in: introducing the finely divided fuel at a temperature below 100°C . with the fuel in suspension in gas comprising oxygen and added steam, the oxygen being in amount sufficient to burn such a part of fuel as will provide the heat to raise the temperature from 50°C . to 100°C . - 1200°C . to 1600°C . plus the heat required for the endothermic reaction of the remainder of the fuel of the suspension at above 1200°C ., and the steam being in an amount within the range of amounts up to the uppermost amount of steam which could react endothermically with the unoxidized fuel left over after the exothermic reaction in the exothermic reaction zone, along with the endothermic reaction of the

moisture content of the fuel of the suspension and water content resulting from the burning or cracking of the volatile content of the fuel in the exothermic reaction, without lowering the reaction temperature of the exothermic reaction zone

5 below a degree at which the formation of carbon dioxide would be favored at the expense of carbon monoxide formation in the exothermic reaction zone; comingling the products of the endothermic reaction zone and its surrounding envelope in a second reaction zone to further the endothermic reaction of residual

10 unoxidized fuel of the suspension; and adding H₂O to the gas in the second reaction chamber in amount to effect the shift reaction $CO + H_2O = CO_2 + H_2$ to adjust the ratio of H₂ to CO in the final gas in the direction of a better yield of hydrogen.

15 The invention as hereinabove set forth is embodied in a particular form and manner but may be variously embodied within the scope of the following claims.

The embodiments of the invention in which an exclusive property or privilege is claimed, are defined as follows:-

1. A process for the production of a gas containing carbon monoxide and hydrogen which comprises forming a suspension of a finely-divided carbonaceous fuel in a free oxygen-containing gas at a temperature below the ignition temperature of said fuel in such proportion that only a part of said fuel will react exothermically with the oxygen of said gas, introducing said suspension, together with from 0.03-0.5 lb. of endothermic gasifying agent per pound of fuel, as a jet axially into a reaction chamber maintained at a temperature above the ignition temperature of said fuel, thereby subjecting said part of said fuel to combustion to produce a mixture of combustion products and unconsumed fuel, injecting peripherally of said jet along the wall of said reaction chamber in a direction cocurrent with the direction of said jet an annular stream of an endothermic gasifying agent which has been preheated to a temperature of not less than 300° C. and not more than 500° C. and mixing and reacting said combustion products and unreacted fuel and said preheated endothermic gasifying agent to produce a gas containing carbon monoxide and hydrogen.

2. A process for the production of a gas containing carbon monoxide and hydrogen which comprises forming a suspension of a finely-divided solid carbonaceous fuel in a free-oxygen-containing gas at a temperature below the ignition temperature of said fuel in such proportion that only a part of said fuel will react exothermically with the oxygen of said gas, introducing said suspension together with 0.05 to 0.3 lb. of steam per lb. of fuel as a

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jet axially into a first reaction chamber maintained at a temperature above the ignition temperature of said fuel thereby subjecting said part of said fuel to combustion, injecting peripherally of said jet along the wall of said reaction chamber in a direction cocurrent with the direction of said jet, an annular stream of an endothermic gasifying agent which is at a temperature of not less than 300° C. and not more than 500° C., mixing and reacting the combustion products and the unconsumed fuel with said endothermic gasifying agent, and adding H₂O to the resulting mixture in a second reaction chamber, said H₂O being added in amount sufficient to effect the water-gas shift reaction $\text{CO} + \text{H}_2\text{O} = \text{CO}_2 + \text{H}_2$ in the direction of a better yield of hydrogen.

3. The process of claim 2 in which the oxygen is present in said suspension in an amount sufficient to provide the heat necessary for raising the temperature to 1200-1600° C. and for the ensuing endothermic gasification of the fuel unconsumed by the combustion.

4. A process as claimed in Claim 2, in which said fuel comprises coal and in which the H₂O added to the gas in the second reaction chamber is added in amount of 0.3 - 0.5 pounds of steam per pound of coal.

5. A process as claimed in Claim 4, and in which the stream of gas of endothermic gasifying agent comprises steam at a temperature below about 500° C. in amount equivalent to about 0.50 - 0.80 pounds of steam per pound of coal.

6. A process as claimed in Claim 5, and in which the H₂O added to the gas in the second reaction chamber is added in amount of 0.3 - 0.5 pounds of steam per pound of coal.

7. A process as claimed in Claim 3, and in which the fuel comprises coal, and in which the stream of endothermic

gasifying agent comprises steam at a temperature below about 500° C. in amount equivalent to about 0.50 - 0.80 pounds of steam per pound of coal.

8. A process as claimed in Claim 3, and in which the fuel in suspension comprises coal, and in which the H₂O added to the gas in the second reaction chamber is added in amounts of 0.3 - 0.5 pounds of steam per pound of coal.

9. A process as claimed in Claim 3, and in which the fuel comprises coal, and in which the oxygen is present in the jet in amount insufficient to raise the ash of the fuel to a temperature above the melting point of the ash of the fuel in the suspension.

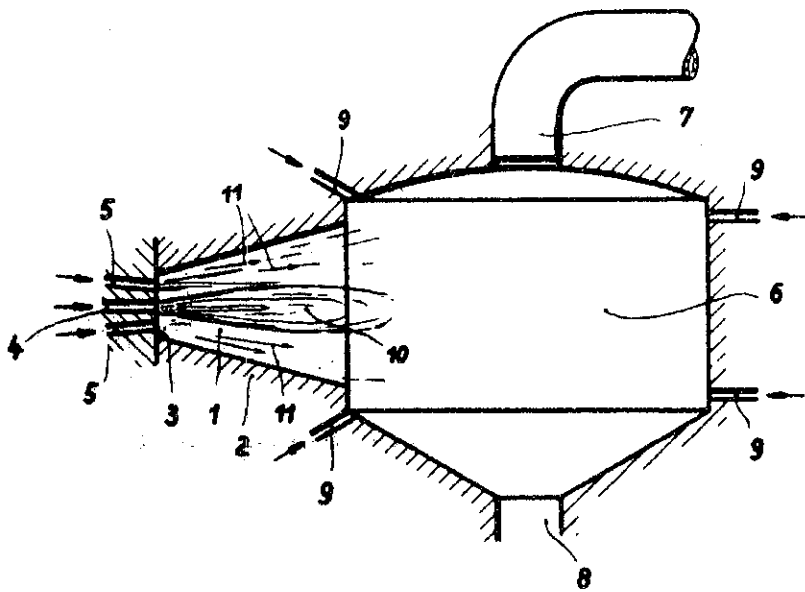
10. A process as claimed in Claim 3, and in which the fuel comprises coal, and in which the oxygen is present in the jet in amount to raise the ash of the fuel to a temperature above the melting point of the ash of the fuel in the suspension.

11. A process as claimed in Claim 3, and wherein the endothermic gasifying agent comprises fuel gas containing CO₂.

12. A process as claimed in Claim 11, and in which the fuel gas that comprises the endothermic gasifying agent is part of the fuel gas produced as an end product of the process, while still hot therefrom.

13. A process as claimed in Claim 3, and in which the H₂O added to the gas for the shift reaction in the second reaction zone is added in the form of steam without being preheated to more than about 200° C.

14. A process as claimed in Claim 3, and in which the H₂O added to the gas for the shift reaction in the second reaction zone is added as water in finely divided liquid form.



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