June 11, 1940. R. RUMMEL 2,204,003

PRODUCTION OF WATER GAS

Filed April 9, 1938 2 Sheets-Sheet 1

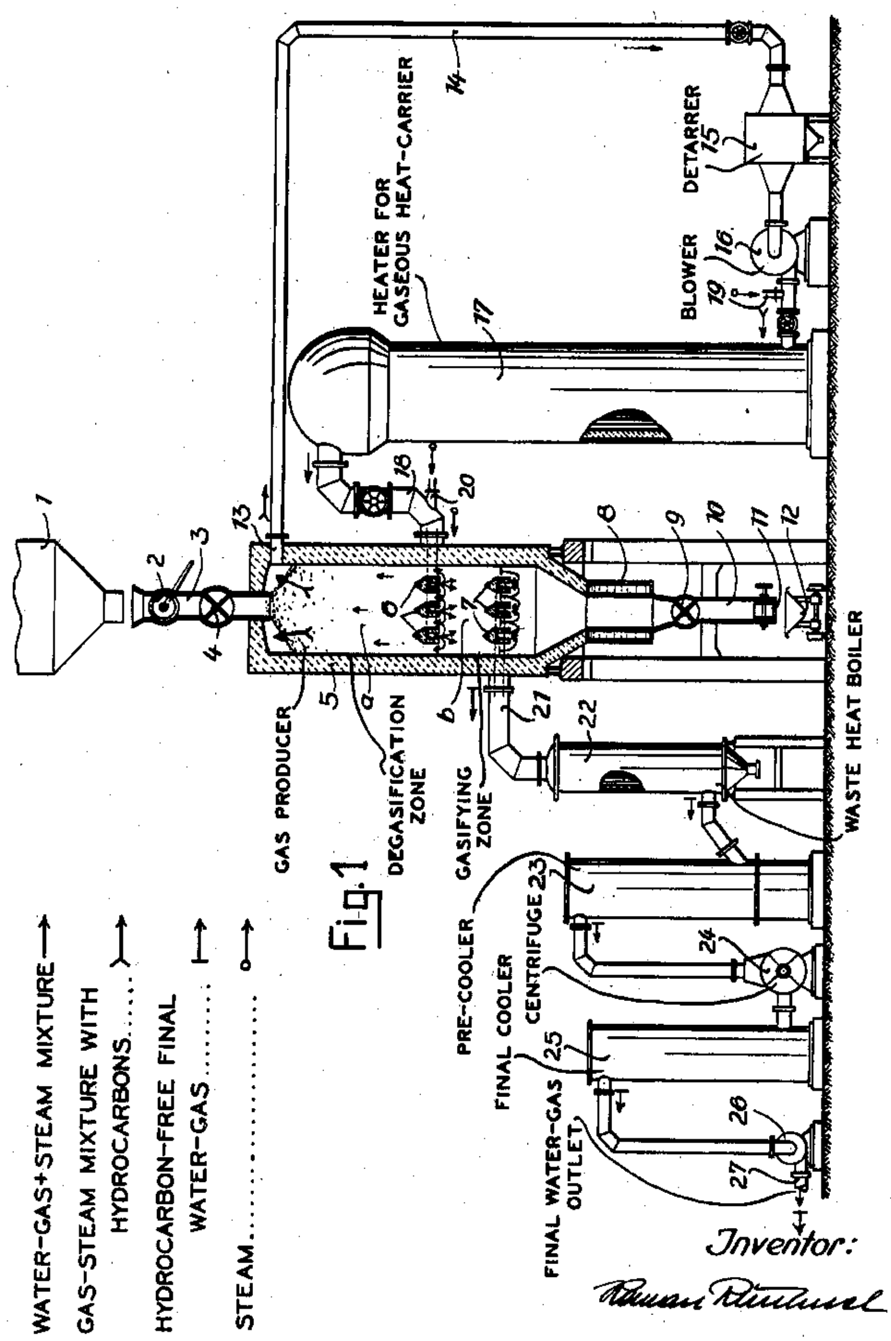

Fig.1

Inventor:

Rudolf Rummel

June 11, 1940. R. RUMMEL 2,204,003

PRODUCTION OF WATER GAS

Filed April 9, 1938 2 Sheets-Sheet 2

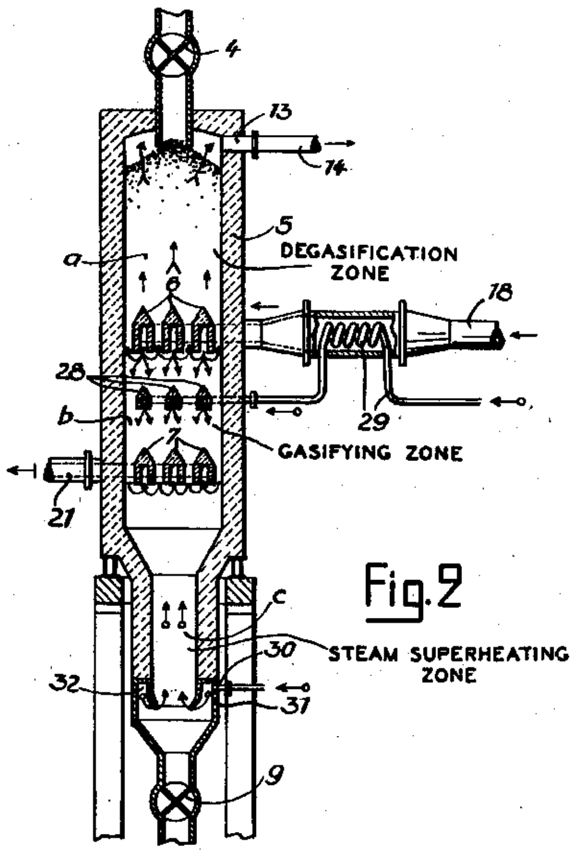

Fig.2

Inventor:

Roman Rummel

UNITED STATES PATENT OFFICE

2,204,003

PRODUCTION OF WATER GAS

Roman Rummel, Ruhland, Germany, assignor, by mesne assignments, to Koppers Company, Pittsburgh, Pa., a corporation of Delaware

Application April 9, 1938, Serial No. 201,193
In Germany April 10, 1937

7 Claims. (Cl. 48—206)

The present invention relates to the production of water gas or the like from solid fuels especially from bituminous coals, by using a highly heated mixture of steam and gases, preferably a part of the water gas produced, for heating the fuel up to the temperature of the water gas reaction, said mixture serving as a heat carrier and I shall term the said mixture in this description as "heat carrier."

In order to produce water gas or the like from bituminous fuels, a shaft furnace is employed which is traversed by the fuel from the top downwards. In various zones of the shaft, there have been provided means for introducing gases into the shaft and/or for withdrawing gases from the shaft. Contrivances for heating up the gases, for instance regenerators, such as of the Cowper-system well-known for heating-up the air of blast furnaces, are connected with the shaft. The heat carrier, i. e., the mixture of gas and steam, heated-up in these contrivances, is introduced into the shaft and extracted from the shaft in such a manner that the fuel on its way from the top downwards is brought into contact with the hot heat carrier and is heated thereby gradually, reaching finally that temperature at which the steam reacts with the carbon of the fuel with the formation of a mixture of carbonic acid, carbon monoxide, hydrogen and other constituents, such mixture being the so-called water gas.

When the bituminous fuel, for instance brown coal, lignite, shale or any other suitable coal, is charged into the shaft, the fuel is first dried and degasified in the upper part of the shaft, analogously to the well-known coal distillation process. As soon as the fuel is heated to a sufficiently high temperature, the reaction of carbon with steam begins. The upper part of the shaft is, therefore, called by me the degasification zone and the lower part is termed hereinafter as gasifying zone. The exact position of both these zones, which under certain circumstances are not sharply separated from each other, especially when treating reactive fuels, depends on the working conditions, in particular on the temperature of the heat carrier and the position of the inlets and outlets for the heat carrier and for other gases and vapours.

A part of the gases and vapours developed in the shaft and a part of the heat carrier which is cooled-down in the shaft, is led again to the heater, raised there to the desired high temperature, and circulated back to the gas producer shaft. In this way, it is possible to produce the water gas or the like in continuous operation. If regenerators are employed for heating-up the heat carrier, it is of advantage to provide several of such regenerators and to connect them in alternation, by means of suitable shut-off and reversing valves, with the gas producer shaft in such a manner that continuously a hot heat carrier from one regenerator or from several regenerators is introduced into the gas producer shaft.

In many instances, it is desirous of obtaining the water gas, free from hydrocarbons which are formed during the degasification of the bituminous fuels. For the synthesis of valuable hydrocarbons from hydrogen and carbon monoxide in the presence of certain catalysts, containing nickel or cobalt or other substances, it is a requirement, for instance, that the gas be one which is free from such hydrocarbons which, similar to the tarry constituents formed at the degasification of bituminous fuels, tend to deposit on the surface of the catalysts, which will thereby become ineffective or at least less effective.

In order to produce by means of a heat carrier a water gas, free from all such hydrocarbons, by means of a heat carrier a part of the heat carrier and of the newly developed water gas may be extracted from the gasifying zone of the gas producer shaft at such a point where the fuel is already fully degasified, i. e., practically free from bituminous matter or where the fuel is degasified at least to such a degree that the remaining hydrocarbons decompose at the temperatures existing in the gas producer. The remaining part of the heat carrier and of the freshly made water gas, which is not withdrawn from the gasifying zone of the gas producer, flows upwards through the degasification zone of the gas producer and gives off its heat to the fuel which is thus distilled.

A considerable disadvantage of the before described process consists in that the heating-up of the fuel to the water gas reaction temperature and the gasifying of same takes place in one single zone. Thereby, the temperature of the heat carrier after entering the gasifying zone, drops very quickly and the water gas reaction takes place slowly. Moreover, the fuel undergoes a secondary degasification by its being heated in the gasifying zone, whereby also the hydrocarbons are withdrawn into the useful gas, notwithstanding the fact that the water gas necessary for the synthesis process should, however, be free from all tarry hydrocarbons, if possible.

An essential object of my present invention is to provide such improvements of the described method of water gas production which will overcome the before mentioned disadvantages and attain other improvements as hereinafter more particularly set forth and described.

Principally, my invention consists in introducing two separate heat carrier streams into the gas producer, of which the one stream mainly degasifies and preheats the fuels, and other stream gasifies, wholly or partly, the degasified and preheated fuel in the presence of steam. The heat carrier in this manner, enters the degasification and the gasifying zones respectively preferably at an equal temperature and is led into the gasifying zone in co-current and into the degasification zone in counter-current, to the direction of movement of the fuel moving within the gas producer shaft from the top downwards. In this manner, the fuel reaches the gasifying zone at approximately the same temperature as the heat carrier. The sensible heat of the heat carrier and of the fuel is utilized for the formation of water gas. Since the fuel enters the gasifying zone in hot condition and is subjected to no further temperature rise, after it reaches the water gas reaction zone then no secondary degasification of the fuel occurs, whereby no hydrocarbons enter the synthesis gas, as occurs with the old process in which the heat carrier when hottest first meets the hottest water gas reaction zone, instead of as here wherein the heat carrier when hottest first meets the fuel in advance of its entering the water gas reaction zone, thus giving up its highest specific heat in preheating the fuel as it is about to enter the water gas reaction zone before the endothermic reaction takes place. In this manner, the fuel just above the water gas reaction zone is more highly preheated to closer the reaction temperature before entering that zone, and the heat carrier is cooled somewhat of its excessive heat before reaching the endothermic water gas reaction zone. Consequently the water gas reaction is made to take place more rapidly and chance of secondary degasification avoided.

Furthermore, the present invention contemplates and makes it possible for the admission of steam, necessary for the production of water gas, into the gasifying zone, and if necessary directly into the degasification zone of the gas producer, and it comprehends the utilization of the sensible heat of the fuel residue for the additional production of water gas.

Figure 1 of the drawings shows schematically an exemplification of the process according to the present invention.

Figure 2 shows schematically a gas producer in which the steam necessary for the production of water gas is introduced into the gasifying zone and the sensible heat of the fuel residue is led back to the gasifying zone by means of steam for the additional production of water gas.

The fuel is discharged from the storage hopper 1 (of Fig. 1) by opening the slide 2 into the reservoir 3, from where it is delivered through a continuously or intermittently operated feeding device 4 to the gas producer 5. The gas producer 5 is illustrated on the drawings as a shaft-furnace. For the supply of the heat carrier, there have been provided several bridges 6 by which the heat carrier is uniformly distributed over the cross section of the shaft. Above these bridges is situated the degasification or preheating zone *a*, underneath the bridges is the gasifying zone *b*. The highly heated mixture consisting of heat carrier and steam, enters the shaft of the gas producer below the bridges 6 and separates here into two streams. The first heat carrier stream is passed through the zone *a*, where it distills, and as its temperature lowers it then, at low temperature, dries and preheats the fuel, by giving-off its sensible heat. The second heat carrier stream is led through the zone *b* in which lies the fuel which was heated previously in the zone *a*. Under the influence of the steam from the heat carrier upon the glowing fuel, water gas is produced in the zone *b*. The water gas together with the heat carrier leaves the shaft of the gas produced through the bridges 7. The fuel residue below the bridges 7 is now for instance indirectly cooled in the boxes 8 through which water is led. It is then delivered by means of the continuously or intermittently operated feeding device 9 from the gas producer into the container 10 from where it is discharged into cars 12 after opening the slide 11.

Due to the steam present in the heat carrier, water gas is also partly produced in the degasification zone *a*, as long as the necessary temperature is sufficiently high. This water gas and the low temperature distillation gases as well as the steam generated from the water content of the fuel, flow along together with the heat carrier passing through the zone *a*, and leave the gas producer through the gas outlet 13, and are delivered through the pipe line 14 into the detarrer 15.

The blower 16 sucks-off the tar-free gas and delivers it to the heater 17 for the gaseous heat-carrier, where it is raised to the necessary degree of temperature. Here, a cracking and conversion of hydrocarbons originating from the low-temperature distillation gases, takes place by means of steam. Then the heated gaseous heat-carrier is led through the pipe line 18 to the bridges 6, whence it reaches again the gas producer shaft. The steam necessary for the production of water gas and for the conversion of hydrocarbons is added to the gaseous heat-carrier before the heater 17 through the pipe line 19, or behind the heater 17 through the pipe line 20, or through both. The temperature of the gaseous heat-carrier can hereby be controlled extremely well.

The gaseous heat-carrier that is passed through the zone *b* and the water gas produced in this zone, leave the gas producer shaft through the bridges 7 as the hydrocarbon-free final water gas, and flow through the pipe line 21 to the heat exchanger 22, where they transmit the greatest amount of their sensible heat. The heat exchanger 22 is constructed preferably as a waste-heat boiler in which the steam necessary for the production of water gas is generated. Then the gases are delivered to a cooling and cleaning plant consisting for instance of a precooler 23, a mechanical gas purifier 24 and a final cooler 25. The blower 26 sucks the gas from the cleaning plant and delivers it to the pipe line 27 which leads to the places of consumption.

The heat carrier streams are controlled through the blowers 16 and 26. So much of the heat carrier is introduced into the degasification zone *a*, as is necessary for the distillation, low-temperature process, drying and preheatment of the fuel. The heat carrier together with the low-temperature distillation gases, as well as the vapours and the water gas produced within the range of high temperatures in zone *a*, leaves the gas producer through the gas outlet 13 at a temperature lying above the dew point of the gas so that the steam contained in the gas does not condense. In the gas heater 17, the gases are heated-up to such an extent that a cracking and conversion of the hydrocarbons from the low temperature distillation gases takes place in reaction with steam. The heat carrier enters the gas producer through the bridges 6 at a temperature necessary for the water gas process. This temperature mainly depends on the reactivity of the coke lying underneath the bridges 6, and on the composition of the water gas to be produced. The quantity of heat to be utilized for the reaction of the water gas process in the zone *b* is taken from the heat carrier passing through this zone and partly from the heat stored in preheated coke when it reaches the zone *b*, so that both media are cooled-down by the endothermic water gas reaction. The effect of the temperature drop in the zone *b* is determined by the composition of the water gas to be produced. The inlet and outlet temperature of the heat carrier of the zone *b* is, therefore, predetermined and fixed for the composition of water gas that is to be made and for the kind of fuel that is to be used. The quantity of this heat carrier comprises the amount of water gas generated in the zone *a* and the low-temperature distillation gases, which are cracked in the heater and converted, since the quantity of the heat carrier passing through the zone *a*, must be maintained permanently. This latter quantity may be controlled by the heat carrier blowers and is determined by the heat quantity to be utilized in the zone *a* for the production of water gas as well as for the low-temperature distillation treatment, drying and preheating of the fuel. Therefore, the production of water gas according to the present invention may be also carried out in the zone *a*, whereby the temperature drop in the zone *b* can be altered correspondingly. By regulating the heat-carrier temperature and by altering the two heat carrier streams, water gas of any composition can be produced from all kinds of fuel. The fuel must, however, be such as to allow for the passage of the heat carrier. The fuel, therefore, has to be of lumpy-size, i. e., finely grained fuel must be briquetted before being used.

Another mode of carrying out the process according to the present invention is shown in Figure 2. The heat carrier is delivered through the pipe line 18 to the bridges 6, separates within the gas producer 5 below the bridges into two streams as above described. If now a fuel is pre-treated in the zone *a* for the production of water gas, which fuel has a high percentage of moisture and requires a great amount of heat for its drying and low-temperature distillation, it is more advantageous to carry out the water gas production only in the zone *b*. For this reason, another set of bridges 28 are also for instance arranged in the zone *b*. Steam only, for the production of water gas is admitted through the bridges 28 to the zone *b*, said steam together with the heat carrier from bridges 6 flows to the bridges 7 and on its way thereto it is converted to water gas with the glowing coke-carbon. In order to avoid a rapid and considerable drop of temperature in the zone *b*, the steam is superheated to the temperature existing in the zone *b*, which for instance can be arrived at by a superheating pipe coil 29 which is arranged in the heat carrier pipe line 18.

If the fuel is not to be gasified completely, but if a certain quantity of coke is still to be left ungasified to be recovered for heating the heat carrier, it is of advantage to make use of the sensible heat still contained in the residue of coke leaving the zone *b*, to obtain an additional production of water gas. Steam is passed through the coke underneath the bridges 7 in counter-current to the fuel. Said steam takes the heat from the coke, superheating the steam and later-on being utilized in the reaction for the formation of water gas. The steam superheating process takes place in zone *c* of the gas producer shaft. The saturated or somewhat superheated steam flows in at point 30 in the box 31 which is in connection with the shaft zone *c* through the slots 32. The steam enters the zone *c* through the slots 32 and flows to the bridges 7. In this way, the coke is cooled-down and the steam is superheated until it has reached the degree of temperature necessary for the water gas reaction with coke in the portion of the fuel bed under the water gas reaction zone. The water gas thus developed is withdrawn, along with the water gas leaving the zone *b* through the bridges 7.

By the separation of the heat carrier stream within the gas producer as aforesaid, the cross section load of the gas producer is considerably improved, since the preheating and the gasification of the fuel are separated from one another. The capacity based on the cross-section of the furnace is therefore larger than with the known processes. The sensible heat of the fuel residue is utilized in the gasifying zone for the water gas reaction. Therefore, also the heat required for the carrying out of the process will become less. Moreover, the quantity of heat carrier circulating is hereby reduced.

Any kind of fuel may be used for the treatment. Even wholly or partly degasified fuels allow for advantageous gasification, if carried out according to my present invention. In this case, the fuel in the zone *a* is mainly preheated to the temperature required for the production of water gas. It is also possible to perform any desired stage of the water gas production within the zone *a*. The steam herefor may be added to the heat carrier before entering the gas producer or by the introduction of steam into the zone *a*, i. e., through the bridges similar to the kind described before in connection with zone *b*, the heat carrier passed through the zone *a* being returned to the gas producer. By carrying out the gasification partly in the zone *a*, a uniform cross section load across the entire height of the gas producer shaft can be attained which is of special advantage with those fuels which require for their gasification and preheating a smaller amount of heat than for their partial and full gasification in the gasifying zone *b*.

Accordingly, the highest efficiency can be arrived at with the present invention, because of the full utilization of the entire space of the shaft.

Another exemplification of the process according to the present invention consists in leading both heat carrier streams separately into the gas producer shaft. Thereby, it is rendered possible to let them enter the degasification zone and the gasifying zone at a different temperatures, which permits a further control and adaption to the gasifying fuel. Furthermore, steam may be added to each heat carrier stream for a definite production of water gas in either or in both zones.

If a synthesis gas is to be produced which, in addition to the water gas constituents, still contains other gases, they can be added to the heat carrier stream, according to the present invention, either outside the gas producer or inside the gas producer, in the gasifying zone, or in the degasification and preheating zone. For example, during the manufacture of a synthesis gas containing nitrogen in the gasifying zone, air is introduced. The oxygen of the air combines with the carbon of the fuel mainly to form carbon monoxide, whereas the nitrogen of the air leaves the gas producer as an inert gas, together with the gases resulting from the gasifying zone. The gas mixture leaving the gas producer is led, if required, to a conversion plant in order to reduce all undesired gas constituents into synthesis gas components. If a high content of carbon monoxide is required to be produced by the heat carrying gas, which cannot be attained even with a hot run of the water gas process, then oxygen is, for instance, added to the heat carrier stream in the gasifying zone. This addition of oxygen effects a gasification of the fuel to carbon monoxide, whereby an enrichment of the heat carrying gas with this gas takes place.

Furthermore, it is possible to maintain the composition of the heat carrying gas by the introduction of foreign gases into the gasifying zone. In the presence of glowing fuel and reactive gases, said gases are cracked or converted in the heat carrier. By this means or by any other combination suitable for the special case, it is possible to obtain any desired composition of heat carrying gases within the utmost limits, quite independent of the kind of the fuel used.

I have now described in the foregoing my present invention on the lines of a preferred embodiment thereof, but my invention is not limited in all its aspects to the mode of carrying it out as described and shown, since the invention may be variously embodied within the scope of the following claims.

I claim:

1. In a method of continuously producing water-gas free of hydrocarbons from distillable solid fuels, which comprises: maintaining in a bed of continuously descending fuel aforesaid a lower water-gas reaction gasifying-zone and an upper predistillation degasifying zone; introducing the fuel to be gasified at the top of the bed and withdrawing the residue as solids from the bed below the water-gas reaction zone; and effecting said maintenance of the zones of the fuel bed by traversing the upper predistillation zone with a preheated gaseous heat carrier medium of water-gas and circulation of the same from the upper predistillation zone together with hydrocarbons therefrom and steam through a separate heating-up stage to reheat the medium and thence back to the fuel bed through the lower water-gas reaction zone for the water-gas reaction therewith; the improvement comprising: introducing the gaseous heat carrier medium for the upper predistillation and lower water-gas reaction zone to the bed intermediate the respective zones, and in quantities for the respective zones to supply the heat requirements for the respective zones; withdrawing the hydrocarbon-free water-gas from the fuel bed at a zone intermediate the lower water-gas reaction zone and the region of withdrawal of solid residue from below the water-gas reaction zone; the heat carrier for the respective zones being introduced to the fuel bed at a region in which the stream divides and the part for the upper zone traverses the upper zone independently of the lower zone and the other part of the stream for the lower water-gas reaction zone traverses predistilled fuel from the upper zone before the predistilled fuel and the heat carrier reaches the lower water-gas reaction zone.

2. A method as claimed in claim 1, and in which the heat carrier stream for the upper predistillation degasifying zone is led countercurrent through the fuel therein, and the head carrier stream for the lower water-gas reaction zone is led co-currently through the fuel of the water-gas reaction zone.

3. A method as claimed in claim 1, and which includes the step of generating part of the water-gas also in the upper predistillation degasifying zone.

4. A method as claimed in claim 1, and in which steam for water-gas reaction is injected directly into the fuel bed in the lower gasifying zone but above the lower offtake for hydrocarbon-free water-gas.

5. A method as claimed in claim 1, and in which steam necessary for the water-gas production is added to the heat carrier after it leaves the heating-up stage but before it enters the fuel bed, whereby part of the water-gas is generated also in the upper predistillation degasifying zone.

6. A method as claimed in claim 1, and in which additional steam is also led through the fuel residue in the region of the bed underneath the zone of withdrawal of hydrocarbon free water-gas, said steam transferring sensible heat of the fuel residue upwardly toward the lower water-gas reaction zone for the production of additional water-gas.

7. A method as claimed in claim 1, and in which free oxygen is added to the heat carrier medium that is to react in the lower water-gas reaction zone.

ROMAN RUMMEL.