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(54) PROCESS AND APPARATUS FOR THE PREPARATION OF GASES CONTAINING HYDROGEN AND CARBON MONOXIDE

(54)

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- Claims Image
- Disclosures Image

The invention relates to a process for the preparation of gases containing hydrogen and carbon monoxide by partial combustion of hydrocarbons, preferably with addition of steam, in which the conversion takes place in a reaction chamber which is provided on one side with one or more burners to which the hydrocarbons and the oxygen or the oxygen-containing gas and the steam, if any, are supplied and which reaction chamber is provided on the other side with a device for the discharge of the reaction product. The invention further relates to an apparatus suitable for carrying out that process.

Suitable for conversion are hydrocarbons in any state of aggregation. Substances in the solid state such as asphaltic bitumen, petroleum coke, soot or asphaltenes, will, however, first have to be brought to a condition in which they can be pumped, which may be done for instance by melting or by changing the solid into a slurry.

It is customary for this conversion to be made to take place in an empty reaction chamber enclosed by a mainly cylindrical wall. The oxygen required for the partial combustion is supplied as substantially pure oxygen or as air to which extra oxygen has been added. Air also can sometimes be used. Often steam is likewise added to the reaction mixture. The ratio by weight between steam and hydrocarbon may vary considerably, preferred values of this ratio being those in the range from 0.1 to 0.7. The steam may either be mixed with the oxygen or be introduced together with the hydrocarbons; if the hydrocarbons are in the liquid state the steam may promote the atomization thereof. Sometimes carbon dioxide also is added.

The pressure is the reaction chamber may vary from substantially atmospheric pressure to a pressure of 120 atm. Preferably the pressure is chosen to have a value between 20 and 60 atmospheres. The temperature may be 1200-1500 °C, a value of approx. 1300 °C being preferred.

The product always contains a certain quantity of soot which has to be removed from it. The formation of the soot makes it necessary to subject the gas to an extra treatment to effect separation of the soot from the gas and for this purpose rather expensive equipment is required. Another reason to prevent the formation of soot as far as possible is that the soot is formed at a sacrifice in gas yield.

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The invention provides a process and an apparatus which make it possible to obtain a product the soot content of which is considerably lower.

According to the invention the reaction mixture is passed through a first zone which is located on the side of the burner, or burners, and where a thorough mixing takes place which promotes the transfer of heat from the combustion gases to the hydrocarbons that have not yet been converted, and is subsequently passed through a second zone, which is located on the side of the discharge device and which comprises at least three theoretical mixing stages in which the reaction is completed while the conversion of soot to gaseous compounds is promoted.

In the present process for the formation of synthesis gas a part of the hydrocarbon feed is burnt with the oxygen. The heat formed in this combustion is transferred to the remaining hydrocarbons as a result of which these are being cracked. Conversions with the combustion gases formed in the partial combustion and with steam are of importance for these cracking reactions.

Mostly, in the cracking reactions a small quantity of soot is formed. This soot may be reconverted to gaseous compounds, for instance by reaction with carbon dioxide or steam present in the reaction mixture or added to it, whereby carbon monoxide or a mixture of carbon monoxide and hydrogen is formed.

It is of importance that the transfer of heat from the combustion gases to feed that has not yet or not yet completely been converted should take place as rapidly as possible in order that a uniform temperature distribution is obtained. This has a favourable effect on the course of the cracking process. A rapid heat transfer may be obtained by a thorough mixing of the reactor contents. Thorough mixing may be effected, for instance, by introducing one or more gas streams in such a way that they perform a rotational movement.

The rate at which the soot is converted to gaseous compounds is comparatively low. Thus, it is the residence time of the soot particles during the reaction which to a large extent determines the final soot content of the product gas. In this connection it is of great importance that the residence time of the soot particles is as homogeneous as possible, because an increase in the spread of the residence time at a specific average residence time results in a higher soot content of the product gas. A decrease in the spread of the residence time is effected by measures being conducive to the flow obtaining the characteristics of a plug flow.

The concept of a "theoretical mixing stage" serves to more exactly indicate the nature of the flow through a reaction zone. A reaction zone is said to have n theoretical mixing stages when the spread of the residence time of the volume elements of the stream supplied is in fact equal to that of n ideal mixers connected in series. By an ideal mixer is understood a system where mixing is such that the composition has the same value everywhere. These subjects are discussed in detail in Levenspiel "Chemical Reaction Engineering", New York, 1962, particularly on page 99 and following pages and in Chapter 9.

By carrying out the process in two zones it is possible to meet the - opposite - requirements concerning the mixing and the homogeneity of the residence time.

Owing to the mixing in the first zone the heat transfer can take place rapidly and a uniform temperature distribution develops. This has a favourable effect on the course of the cracking reactions and counteracts the formation of soot; in addition, this prevents the occurrence of local high temperatures, which might cause damage to the walls by which the zone is bounded.

The plug flow in the second zone ensures that the spread of the residence time is small. Thus, on the one hand it becomes possible to prepare, at a specific average residence time, a gas with a lower soot content at a smaller loss of starting material, while, on the other hand for the production of a gas with a specific soot content a lower average residence time may suffice. This may result in a simplification of the equipment for the separation of the soot and in a reduction of the size of the reactor required for the process. The said advantages are already obtained when the second zone comprises three theoretical mixing stages. Naturally, a much larger number of mixing stages, for instance several hundred, is favourable with a view to obtaining these advantages to a larger extent.

Existing reactors rather have the character of an ideal mixer.

A suitable apparatus for carrying out the process is obtained if the first zone consists of an essentially cylindrical chamber which is provided with devices for the supply of the reaction mixture and where the ratio between length and diameter is at most 6, preferably 1-3, and if the second zone consists of an essentially cylindrical chamber which communicates with the first chamber and is in a coaxial position relative to that chamber, whose diameter is 0.5-0.8 times the diameter of the first chamber and whose length has been chosen so that that zone comprises at least three mixing stages.

The length of the first zone is reckoned between the burner port and the extreme end of the wide cylindrical section. The length of the second zone is reckoned between the initial part of the narrower cylindrical section and the bottom of that section.

If the ratio between the length and the diameter of the chamber forming the first zone is at most 6, then a flow being promotive to a thorough mixing of all that is contained in that chamber can be maintained therein in a simple way. Such a flow can be achieved for instance by introducing the hydrocarbons and/or the oxygen, or the oxygen-containing gas, required for the combustion in such a way that these will perform a rotational movement about the centre line of the chamber. Also, as a result of this a vortex may be formed in which backflow of gases occurs along the centre line.

By taking the diameter of the chamber forming the second zone so as to be smaller than that of the first zone, the condition of the second comprising at least three theoretical mixing stages can easily be met. Although the length required for this is in the first place dependent on the diameter, other factors, such as, for instance, the way in which the gas flows into that chamber, may also have an influence in this respect. This length may lie in the range between 1 and 5 times the diameter of the first zone. However, it will always be possible to determine the required length by means which in themselves are known, while, in addition, model tests may be used for this purpose. In this connection the reader is referred to the aforementioned book by Levenspiel, Chapter 9.

It is advantageous for a conical chamber to be present as a connection between the chambers forming the first and the second zone. As a result, the change in the cross section of the reactor will be more gradual so that, for instance, the formation of vortices in the chamber of the second zone, which would make it difficult to achieve the desired plug flow, is counteracted. A length of the conical chamber that is suitable for this purpose is equal to 0.2-0.6 times the diameter of the chamber forming the first zone. The length of this connecting chamber is not included in the aforementioned lengths of the first and the second zone.

The invention will now be further elucidated with the aid of the drawing in which is represented a longitudinal section through an embodiment of an apparatus according to the invention. Here item 1 is the chamber forming the first zone, item 2 the chamber forming the second zone. The reaction mixture is supplied to a burner 3 which via the opening 4 communicates with the chamber 1. The burner is provided with a tube 5 for the supply of hydrocarbons and with openings 6 for the supply of oxygen or of an oxygen-containing gas. The openings 6 are so arranged that the gas introduced will perform a rotational movement about the centre line of the burner. The chamber 2 is provided with a device 7 for the discharge of the product gas; a conical connecting section 8 is located between the chambers 1 and 2.

EXAMPLE

For the partial combustion according to the invention of 100 tons hydrocarbons a day with the aid of approx. 120 tons oxygen and approx. 50 tons of steam at a reaction temperature of 1300 °C and a pressure of 35 atm. use may be made of a reactor as illustrated in the figure, where the first zone has a diameter of 1 m and a length of 1.35 m and the second zone a diameter of 0.6 m and a length of 3 m, the conical connecting section having a length of 0.25 m. There is thus obtained approx. 300,000 normal m^3 gas per day consisting of carbon monoxide and hydrogen, the product gas containing only a few percent soot.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

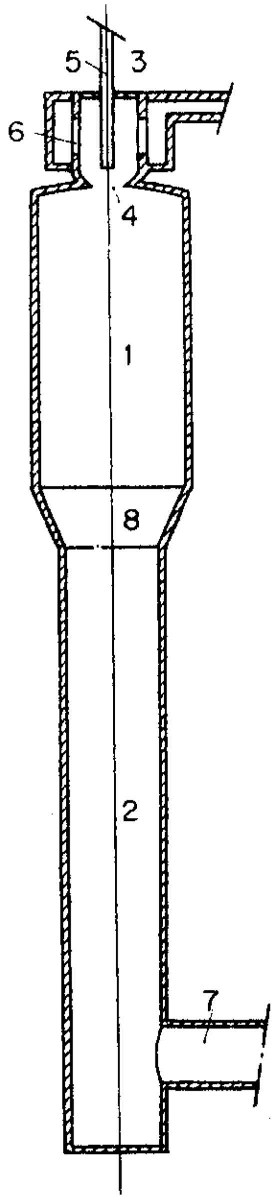
1. A process for the preparation of gases containing hydrogen and carbon monoxide by partial combustion of hydrocarbons, with or without the addition of steam, in which the conversion takes place in a reaction chamber which is provided on one side with one or more burners to which the hydrocarbons and the oxygen or the oxygen-containing gas and the steam, if any, are supplied and which reaction chamber is provided on the other side with a device for the discharge of the reaction product, characterized in that the reaction mixture is passed through a first zone, which is located on the side of the burner, or burners, and where a thorough mixing takes place which promotes the transfer of heat from the combustion gases to the hydro-carbons that have not yet been converted, and is subsequently passed through a second zone which is located on the side of the discharge device and which comprises at least three theoretical mixing stages in which the reaction is completed while the conversion of soot to gaseous compounds is promoted.

2. An apparatus suitable for carrying out the process according to Claim 1, characterized in that the first zone consists of an essentially cylindrical chamber which is provided with devices for the supply of the reaction mixture and where the ratio between length and diameter is at most 6 and that the second zone consists of an essentially cylindrical chamber which communicates with the first chamber and is in a coaxial position relative to that chamber, whose diameter is 0.5-0.8 times the diameter of the first chamber and whose length has been chosen so that the zone comprises at least three mixing stages.

3. An apparatus as claimed in claim 2 in which the ratio between length and diameter is 1:3.

4. An apparatus according to claims 2 and 3, characterized in that the chambers of the first and second zone are connected by a conical chamber.

5. An apparatus according to claim 4, characterized in that the length of the conical chamber is 0.2 - 0.6 times the diameter of the chamber forming the first zone.



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