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(54) PROCESS AND APPARATUS FOR THE PARTIAL COMBUSTION OF LIQUID HYDROCARBONS FOR THE PRODUCTION OF GASEOUS MIXTURES CONTAINING HYDROGEN AND CARBON MONOXIDE

(54)

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The present invention relates to a process and apparatus for producing gas mixtures containing hydrogen and carbon monoxide by partial combustion of liquid hydrocarbons with a gaseous oxidizer being oxygen or an oxygen-containing mixture, to which steam may be added. In this process and apparatus both the liquid fuel and the gaseous oxidizer are introduced separately into a reaction vessel so as to have the intimate mixing necessary to the combustion process within the reaction vessel itself. The process to which the invention relates is, therefore, of the so-called diffusion type, as distinguished from the process with pre-mixing.

The term gaseous oxidizer is here intended to define a gaseous oxidizer plus inert gases (e.g. air, oxygen-enriched air, pure oxygen and mixtures of these gases with steam).

The liquid fuel may consist of crude oil and its distillation and cracking products ranging from the lighter to the heavier fractions.

It is known that usually the liquid fuel is atomized or nebulized for instance by means of liquid pressure atomizers, before mixing, within the reaction vessel, with the gaseous oxidizer which is fed at a low velocity into the said vessel in the proximity of the zone of introduction of the nebulized fuel; namely, a process for nebulizing the liquid fuel is carried out, followed by a mixing and combustion process with the gaseous oxidizer, fed at a low velocity.

That process derives from conventional methods suggested by the technique of the combustion with air in furnaces, in which, however, the conditions within the combustion vessel widely differ from the ones existing in partial combustion reaction vessel for the production of hydrogen-and carbon monoxide containing gases.

Therefore the requirements concerning the flame stability and the attachment of the flame, which, the fuel being the same, depend chiefly on the nature and amount of gaseous oxidizer, on the composition outside the flame zone, on the temperature of the walls of the reaction chamber, are not identical in the two cases under consideration; they are on the contrary very different. As a consequence, partial combustions for the production of hydrogen and carbon monoxide-containing gases can be carried out operating in a way differing from the ones suggested by the conventional combustion technique.

More particularly, in reaction chambers for the production of hydrogen and carbon monoxide containing gases, contrarily to what takes place in conventional air furnaces, it is possible to obtain a flame, or combustion zone which is perfectly attached to the combustion apparatus, namely at the beginning of the mixing zone, also when the gaseous oxidizer has in the inlet section of the reaction chamber, a very high velocity, above 400 m/sec.

On the other hand, it is known that in a process for nebulizing a liquid performed by means of a gas stream, which is the best of all processes when the gas velocity is sufficiently high, the nebulization degree of the liquid increases with increasing not only the velocity but also the amount of nebulizing gas. It is known as well that to an increase in the atomization degree of the liquid fuel, corresponds an increase in the efficiency of the plant producing hydrogen and carbon monoxide containing gases, both because the amount of carbon black formed is lower and because the yield of the gasification process is, consequently, higher.

From what is set forth above, it is clear that it is possible to utilize the feed of the gaseous oxidizer as a high velocity atomizing agent with the consequent advantage of carrying out an atomization process at a high ratio of (atomizing agent) to (liquid fuel) and avoiding the atomization process of the liquid before contacting the gaseous oxidizer, and all the drawbacks connected thereto.

The present invention allows to obtain the above mentioned advantages and is characterized in that the gaseous oxidizer consisting of all the process gas is accelerated immediately before the introduction into the reaction chamber, and therein injected at a high velocity against the liquid fuel stream which, immediately after introduction into the chamber, is suitably distributed in the form of a continuous film, that is, in the non-atomized state, on which the high velocity stream of gaseous oxidizer impinges. Immediately after the impinging zone, both the atomization and the mixing processes take place simultaneously along with consequent combustion.

The liquid, non-atomized fuel can be brought into contact with the high velocity stream of gaseous oxidizer in various ways, e.g. by means of a device provided with holes or openings for the introduction of the liquid or the filming device which will be illustrated hereinbelow.

The present invention relates also to an apparatus suitable for carrying out the process described above. It consists of a reaction chamber wherein the high velocity stream of gaseous oxidizer is introducted through an annular opening forming the end section of an annular expansion nozzle, where the gaseous oxidizer fed from a chamber of the combustion apparatus is subjected to a pressure drop and to a consequent increase in velocity suitable for atomizing or nebulizing one or more jets of liquid fuel on which the high velocity gas stream impinges immediately downstream from the opening for the introduction of the liquid into the reaction chamber.

An example of a particularly advantageous application of said apparatus, which is not to be intended as limitative, will be now described also in order to illustrate the object of the invention more clearly. Reference is made to figure 1, representing the cross-section of the apparatus and to figure 2 showing the central body of figure 1 in more detail and, schematically, both the stream of gaseous oxidizer and the stream of liquid fuel.

In the drawings, 1 is the reaction chamber, into which through annular opening 7 is introduced the gaseous oxidizer having a high velocity reached in expansion nozzle 6, where the pressure falls from the value existing in chamber 5, to the value existing in reaction chamber 1. The ratio between these two pressures will be called expansion ratio. Chamber 5 is provided with opening 4 for feeding the pre-mixed gaseous oxidizer, when it consists of more gaseous fluids, or with several feed openings, always indicated by 4, for the gases forming the gaseous oxidizer in case it is desired that the mixing takes place inside chamber 5. Annular opening 7 is limited, in the central part, by the device for feeding the liquid fuel, which in the example now described consists essentially of a vortex chamber 12, to which the liquid is carried through the swirl device 10 fed by tube 9. The swirl device imparts to the liquid a rotatory movement, thereby the liquid overflows from the circular weir 13 and licks the terminal part 14 of the feeding device, which is thus protected from the action of high temperature gases.

At the end, the liquid at the external perimeter of the feeding device impinges on an anular jet of the gaseous oxidizer coming out of opening 7. The non-nebulized liquid impinges on the gaseous jet in the state of a continuous film, which may be some tenths of millimeter to some millimeters thick. The outside part of said filming device constitutes the inside part of annular expansion nozzle 6.

In the example reported in figure 1, also an adjusting device for the liquid has been indicated, which allows, by means of valve 3, to obtain strong variations in the flow rate of the fuel, the feeding pressure of the fuel being the same. Namely, the liquid coming out of opening 8 is divided into a current 15 by-passing the swirl device 10 which is mixed, without undergoing any rotatory movement, with the main stream in the mixing chamber 11 feeding the vortex chamber 12.

Of course, this device for adjusting and dividing the liquid stream into two streams can also not be present. In this case it is evident that the liquid coming out of 8 has to be conveyed through one tube corresponding to tube 9 of figure 1 to the swirl device 10.

Body 2 of the device for feeding the liquid is movable in axial direction, as clearly shown by figure 1 so that, owing to the particular shape of annular expansion nozzle 6, variations of outlet cross-section 7 are obtained. That is, nozzle 6 is an expansion nozzle having variable outlet cross-section. This possibility of movement allows to control the velocity of the gaseous oxidizer coming out of 7, under the various loads, and consequently, for the above mentioned reasons, the production of hydrogen and carbon monoxide containing gases under conditions of optimum yields.

In order to show the advantages of this process, two examples taken from the industrial applications of this invention will now be reported.

In the gasification of fuel oil through partial combustion with atmospheric air at about 1,300°C and at 2 Kg/cm^2, the amount of carbon black formed in the gasification process was found to be 3% of the entering carbon at expansion ratio 1.10 and about 0.8% at expansion ratio 1.60.

The increase of the yield corresponding to a decrease of carbon black clearly shows the important role played by the velocity value of the gaseous oxidizer impinging on the liquid fuel oil and justifies the use of the solution provided by the movable body 2 (see figure 1), in order to meet the unavoidable load variations in industrial plants. In the gasification of fuel oil by partial combustion with oxygen and steam at about 1,300°C and at about 20 kg/cm^2, the amount of carbon black formed in the gasification process, all conditions being the same with the exception of the gaseous oxidizer pressure, is such as to cause an increase in the yield of gas $CO+H_2$ of about 3% with respect to the yield obtainable with a conventional diffusion type process, in which the liquid fuel is atomized by steam and then mixed with low rate oxygen stream.

The invention is based on these fundamental points:

In order to have a high efficiency of the plant the carbon black production must be the minimum obtainable - in order to achieve this, it is necessary to atomize the liquid fuel properly - a good atomization requires two conditions:

(a) a large amount of atomizing gaseous fluid

(b) a high velocity of the atomizing gaseous fluid.

In conventional burners fitted with steam atomizers, the liquid is atomized with a high velocity stream consisting of the process steam, the ratio of atomizing gaseous fluid to liquid is on the average 0.5 kg/kg and this ratio is too low.

In the burner according to the present invention oxygen is mixed with steam and this mixture is utilized to atomize the liquid fuel; the ratio between atomizing gaseous fluid and liquid becomes 1.6 kg/kg on the average.

Under condition (a) the atomization proves clearly better, provided of course, that condition (b) is satisfied. Condition (b) is satisfied by accelerating the mixture in the expansion nozzle in order to obtain a jet at the inlet of the reaction chamber, having a velocity usually in the range of from 200 to 500 m/sec. Now in this case, it is convenient to eliminate the nebulization of the liquid before it is mixed with gaseous oxidizer; though the said nebulization may also be carried out, it should be avoided in order to eliminate serious drawbacks due to the presence of the atomizer (melting, overheating of the material, clogging etc.). From the above mentioned points, it follows that the essential features of the process according to the present invention are:

1. Mixing of all the process gaseous fluids (e.g. O_2 and steam) so as to dispose of a large amount of atomizing gaseous fluid.
2. Expansion of the gaseous fluid referred to under 1, in order to produce a high velocity jet, at the inlet of the reaction chamber.
3. Feeding of the liquid fuel up to the impinging zone in the continuous state, that is in the non-nebulized state.

Furthermore, an important element could be the following:

4. Feeding of the liquid fuel as under 3 accomplished in such a way that the terminal part of the filming device, is licked by the liquid fuel.

From the above considerations, it follows that the essential features of the apparatus according to the present invention are:

1. Expansion nozzle (for all the gaseous fluid)
2. The filming device of the liquid which licks its terminal part and then impinges on the high velocity annular jet of the gaseous oxidizer in the continuous state, namely in the non-nebulized state.

It is further to be noted that the expansion nozzle is so shaped as to be licked by a gaseous film on the inside surface up to the contact zone with the liquid fuel. As a consequence the terminal part of the internal piece of the device is licked on both sides by fluids protecting its surfaces.

The present invention allows to obtain the following advantages beside the above mentioned ones:

1. Great load variations on both gas and liquid streams, when the apparatus is built as shown in the figure (namely, fitted with axially movable internal body and with liquid adjusting device. The ratio between maximum and minimum load can exceed value 5/1 for large potentialities (more than 200 t/d NH_3).
2. The particular shape of the flame generated by the feeding device (burner) which is approximately cylindrical, and the stability of the flame due to the vortex motion therein produced by the momentum imparted to the entering liquid. This allows to obtain gasification units having very large throughputs; (1,000 t/d NH_3).

In summary, the object of the invention consists essentially of:

a) a method for partial combustion of liquid hydrocarbons at high pressure to produce gas mixtures containing H_2 and CO, in which the streams of gaseous oxidizer and fuel are introduced separately into the reaction chamber, so as to obtain, immediately after the inlet of the two streams into the reaction chamber, the nebulization of the fuel by the impinging of the high velocity stream of gaseous oxidizer consisting of all the process gas on the liquid which is fed in the continuous state, that is, non-nebulized. This method achieves the nebulization of the liquid fuel by means of a high ratio between the amounts of nebulizing gas and of liquid fuel and, furthermore, avoids the presence of any kind of conventional atomizers.

b) An apparatus suitable for carrying out said partial combustion formed essentially by two coaxial cylindrical chambers feeding the reaction vessel. The external one feeds the gaseous oxidizer accelerated to a high velocity by means of the terminal throttling action; the internal one feeds the liquid fuel having a high tangential momentum obtained by means of a swirl device. The terminal enlargement of the internal cylindrical chamber and the rotatory movement of the liquid fuel stream are so arranged as to have the high velocity stream of gaseous oxidizer impinging on the liquid stream still in the continuous state, namely, in the non-nebulized state, that licks all the terminal surface of the internal chamber. That is, the essential elements in the apparatus are both the acceleration nozzle for the gaseous oxidizer and the shape of the overflowing surface for the liquid fuel (13 and 14 in the figures) that must lick the surface till the impingement region with the annular jet of gaseous oxidizer.

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 gaseous mixtures containing hydrogen and carbon monoxide by partial combustion at high pressures of a liquid hydrocarbon with a process gas consisting essentially of an oxygen containing gaseous oxidizer mixed with steam which comprises separately introducing the liquid hydrocarbon fuel and the process gas into a reaction chamber accelerating the process gas immediately before said introduction into the reaction chamber and impinging the process gas at high velocity upon the liquid fuel immediately after introduction of the liquid into the chamber as a continuous conical film whereby the liquid film is atomized by the high velocity process gas stream.

2. The process of claim 1 wherein the velocity of the process gas is controlled by axial motion of an internal body.

3. The process of claim 1 wherein all of the process gas is intoduced into the reaction chamber by an annular expansion nozzle to form a hollow jet of a nearly cylindrical shape; feeding the liquid fuel in a nearly conical film coaxial with the annular jet of the process gas from the inside of the cylindrical jet upon which the liquid stream impinges in the form of a continuous film.

4. The process of claim 4, wherein a thin conical-shaped jet of liquid is produced by overflow from a circular weir fed by a vortex chamber with a high centrifugal field, in order to have the liquid film lick the surface of the internal device and to form a continuous film on the terminal surface thereof up to the impingement region with the annular jet of process gas.

5. The process of claim 5, in which the fuel stream is di-

Claim 5 continued ...

vided into two streams before entering the vortex chamber, giving the main stream a rotatory movement by means of a swirl device and mixing said stream with the other one, to which no rotation has been imparted, in a mixing chamber feeding the vortex chamber of the liquid supplying device.

6. Apparatus for producing gaseous mixture containing hydrogen and carbon monoxide by partial combustion at high pressures of a liquid hydrocarbon and a process gas comprising an oxygen-containing gaseous oxidizer mixed with steam, which comprises two coaxial concentric cylindrical chambers, a reaction vessel downstream of said coaxial chambers, and, fed thereby, the external chamber adapted to convey all the process gas and the internal chamber adapted to convey the liquid hydrocarbon, throttling means at the end of said external chamber for accelerating the process gas, swirl means for imparting a fast rotatory movement to the liquid hydrocarbon to make it form a conical film flowing down and licking the inner walls of said internal chamber, and a weir means and a conical enlargement at the end of said internal chamber, said end projecting into the reaction vessel beyond the annular opening of said external chamber.

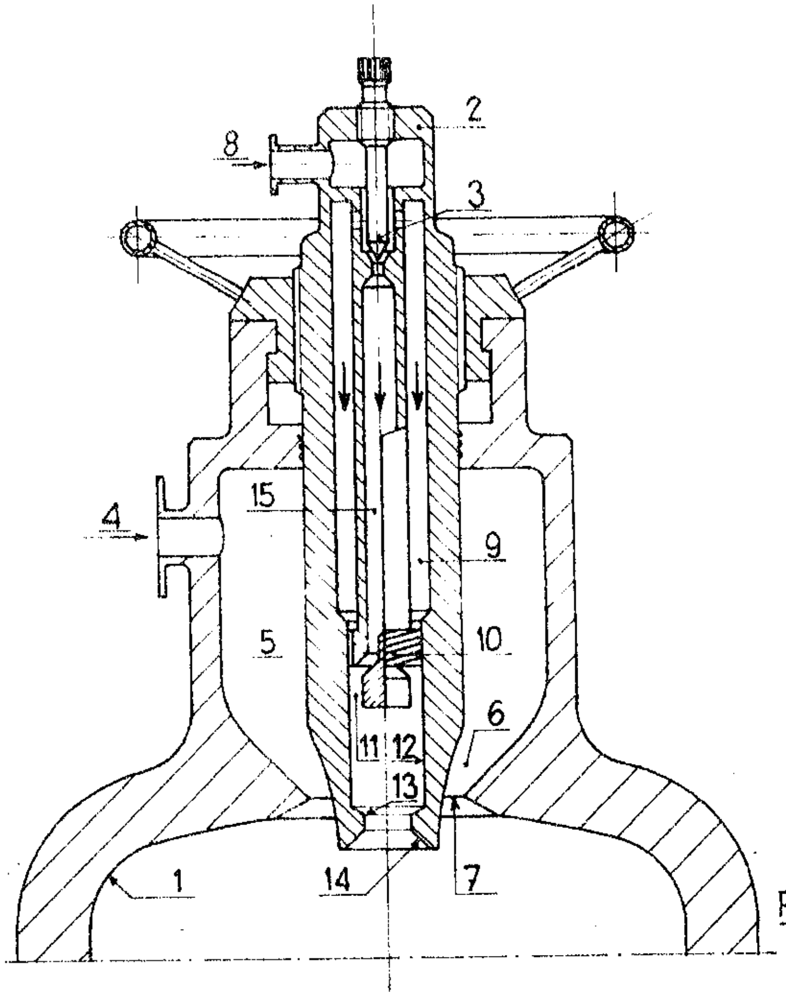

Fig. 1

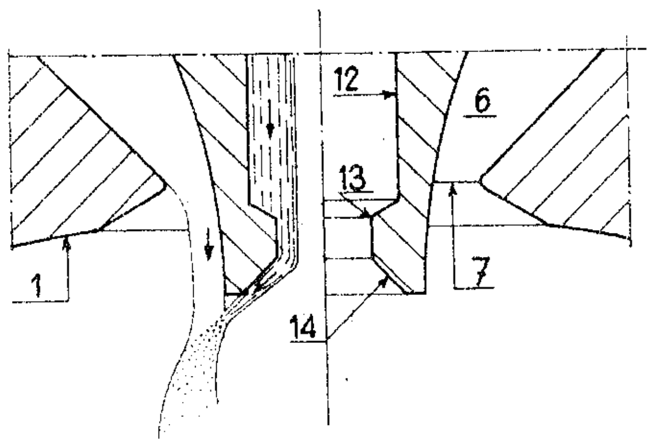

Fig. 2

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