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(57) **ABSTRACT**

A gasification system that comprises a gasification reactor and a synthesis gas cooling vessel, and its use. The gasification reactor comprises a pressure shell for maintaining a pressure higher than atmospheric pressure; a slag bath located in a lower part of the pressure shell; and a gasifier wall arranged inside the pressure shell. The gasifier wall defines a gasification chamber wherein during operation the synthesis gas can be formed, a lower open part of the gasifier wall which is in fluid communication with the slag bath and an open upper end of the gasifier wall which is in fluid communication with the synthesis gas cooling vessel via a connecting conduit. The synthesis gas cooling vessel comprises an inlet for hot synthesis gas; an outlet for cooled synthesis gas; and means to directly contact liquid water with the hot synthesis gas as formed in the gasification reactor in use.

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SHELL OIL COMPANY**P O BOX 2463****HOUSTON, TX 772522463**(21) Appl. No.: **11/742,463**(22) Filed: **Apr. 30, 2007****Related U.S. Application Data**

(63) Continuation-in-part of application No. 11/416,432, filed on May 2, 2006.

(60) Provisional application No. 60/865,131, filed on Nov. 9, 2006.

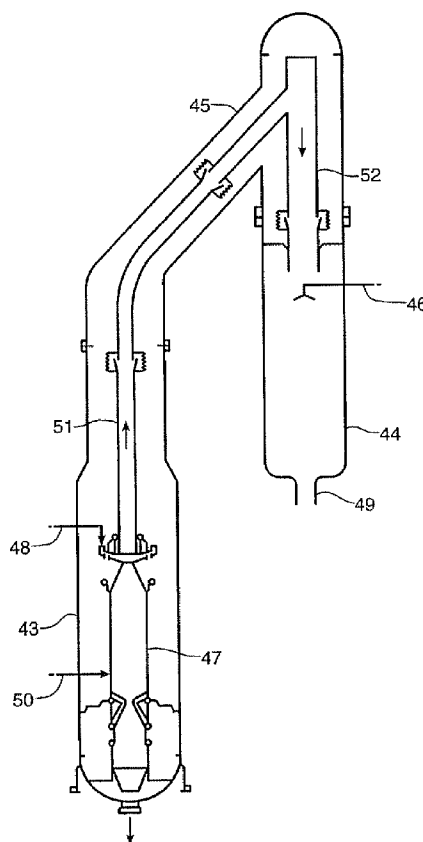


Fig. 1.

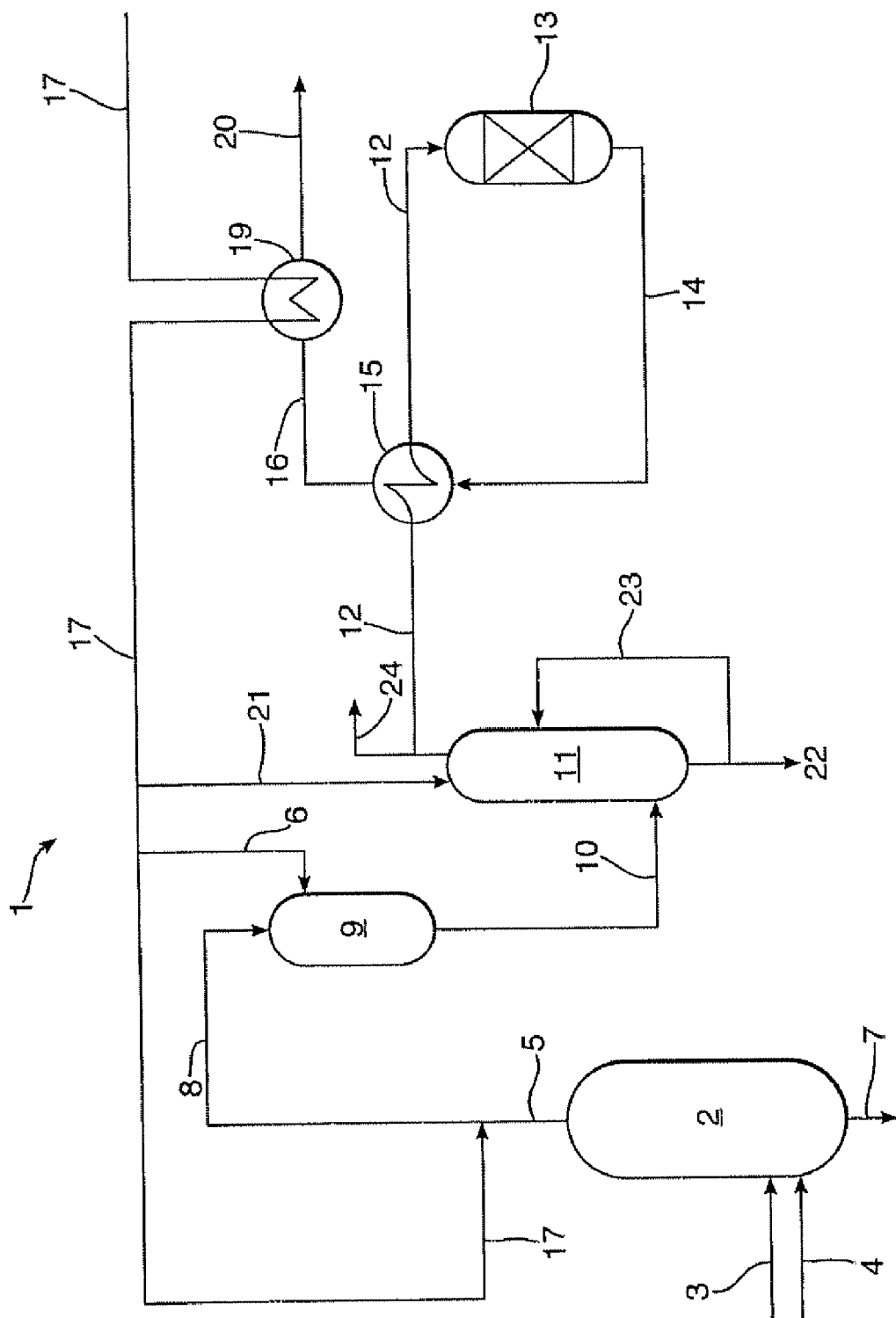


Fig.2.

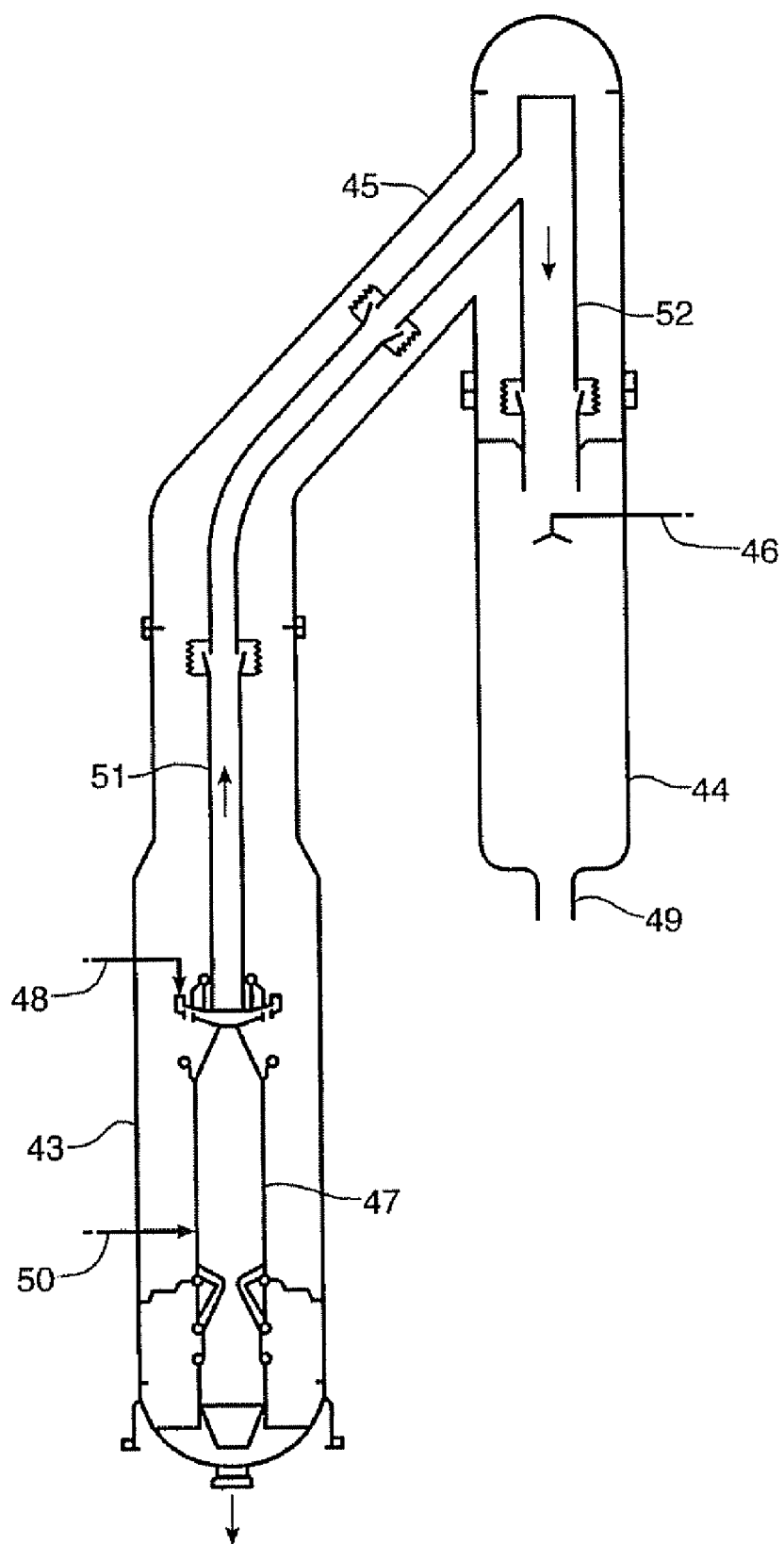
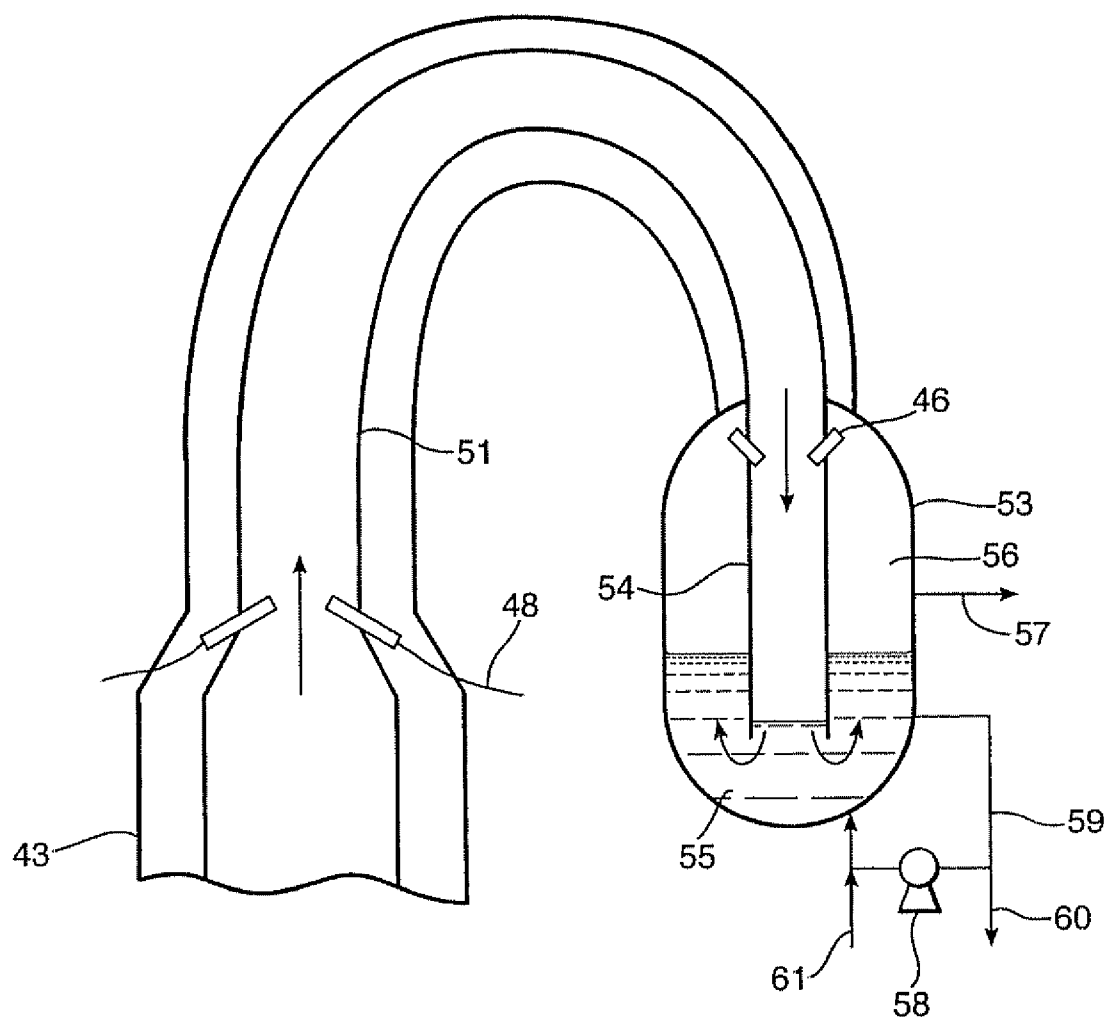


Fig.3.



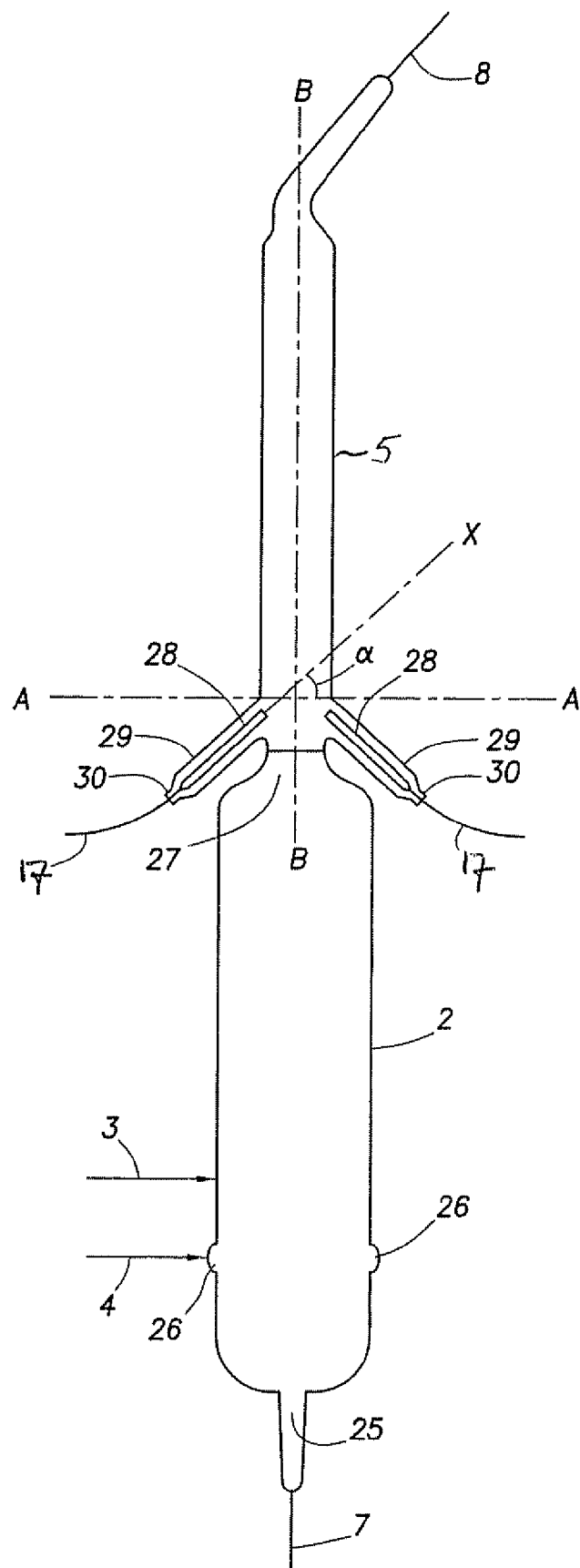


FIG. 4

GASIFICATION SYSTEM AND ITS USE

CROSS REFERENCE TO EARLIER APPLICATION

[0001] The present application is a continuation in part of U.S. application Ser. No. 11/416,432 filed 2 May 2006, incorporated herein by reference. The present application also claims priority under 35 USC §119(e) of U.S. Provisional application No. 60/865,131 filed 9 Nov. 2006, incorporated herein by reference.

FIELD OF THE INVENTION

[0002] In one aspect, the present invention relates to an improved gasification system for preparing a mixture comprising carbon monoxide and hydrogen from a carbonaceous stream using an oxygen containing stream.

[0003] In another aspect, the present invention relates to a process to prepare a mixture comprising carbon monoxide and hydrogen in a system according to the invention.

BACKGROUND OF THE INVENTION

[0004] Methods for producing synthesis gas are well known from practice. An example of a method for producing synthesis gas is described in EP-A-400740. Generally, a carbonaceous stream such as coal, brown coal, peat, wood, coke, soot, or other gaseous, liquid or solid fuel or mixture thereof, is partially combusted in a gasification reactor using an oxygen containing gas such as substantially pure oxygen or (optionally oxygen enriched) air or the like, thereby obtaining a.o. synthesis gas (CO and H_2), CO_2 and a slag. The slag formed during the partial combustion drops down and is drained through an outlet located at or near the reactor bottom.

[0005] The hot product gas in the reactor of EP-A-400740 flows upwardly. This hot product gas, i.e. raw synthesis gas, usually contains sticky particles that lose their stickiness upon cooling. These sticky particles in the raw synthesis gas may cause problems downstream of the gasification reactor where the raw synthesis gas is further processed. Undesirable deposits of the sticky particles on, for example, heat exchange surfaces, walls, valves or outlets may adversely affect the process. Moreover such deposits are hard to remove. Therefore, the raw synthesis gas is quenched in a quench section. In such a quench section a quench gas is injected into the upwardly moving raw synthesis gas in order to cool it.

[0006] WO-A-2004/005438 describes a gasification system comprising a gasification reactor and a synthesis gas cooling vessel. This publication describes a gasification combustion chamber and a tubular part fluidly connected to an open upper end of said combustion chamber. Both combustion chamber and tubular part are located in a pressure shell defining an annular space between said pressure shell and the combustion chamber and tubular part respectively. In the tubular part a quench gas is injected into the hot synthesis gas. This publication also describes a separate cooling vessel provided with three banks of heat exchange surfaces located one above the other.

[0007] U.S. Pat. No. 5,803,937 describes a gasification reactor and a syngas cooler within one pressure vessel. In this reactor a tubular part is fluidly connected to an open

upper end of a combustion chamber. At the upper end of the tubular part the gas is deflected 180° to flow downwardly through the annular space between the tubular part and the wall of the pressure shell. In said annular space heat exchanging surfaces are present to cool the hot gas.

[0008] U.S. Pat. No. 4,836,146 describes a gasification system for a solid particulate comprising a gasification reactor and a synthesis gas cooling vessel as in WO-A-2004/005438. In this publication a method and apparatus described for controlling rapping of the heat exchange surfaces as present in the separate cooling vessel. Rapping is required to prevent deposits from accumulating on the surfaces of the heat exchangers.

[0009] The afore discussed gasification reactors have in common that the synthesis gas as produced flows substantially upwards and the slag flows substantially downwards relative to the gasification burners as present in said reactors. Thus, all these reactors have an outlet for slag, which is separate from the outlet for synthesis gas. This in contrast to a class of gasification reactors as for example described in EP-A-926441 where both slag and synthesis gas flow downwardly and wherein both the outlet for slag and synthesis gas are located at the lower end of the reactor.

[0010] The present invention is directed to an improved reactor of the type where slag flows downwardly and is discharged at the bottom end of the reactor and wherein synthesis gas flows upwardly and is discharged at the upper end of said reactor.

[0011] A problem with the syngas cooler of WO-A-2004/005438 and U.S. Pat. No. 4,836,146 and also with the apparatus of U.S. Pat. No. 5,803,937 is that the heat exchanging surfaces introduce a large complexity to the design of said apparatuses. Furthermore, extensive measures like rapping are required to avoid deposits on the heat exchanger surfaces. Another problem is that the heat exchanging surfaces are even more vulnerable to fouling from feedstocks with for instance a high alkaline content. There is thus a desire to process high alkaline feedstocks as well as a desire to provide more simple gasification systems. These and other objects are achieved with the reactor as described below.

SUMMARY OF THE INVENTION

[0012] In one aspect, the invention provides a gasification system comprising a gasification reactor and a synthesis gas cooling vessel.

[0013] In this gasification system, the gasification reactor comprises:

[0014] a pressure shell for maintaining a pressure higher than atmospheric pressure;

[0015] a slag bath located in a lower part of the pressure shell;

[0016] a gasifier wall arranged inside the pressure shell defining a gasification chamber wherein during operation the synthesis gas can be formed, a lower open part of the gasifier wall which is in fluid communication with the slag bath and an open upper end of the gasifier wall which is in fluid communication with the synthesis gas cooling vessel via a connecting conduit;

[0017] In this gasification system, the synthesis gas cooling vessel comprises an inlet for hot synthesis gas; an outlet for cooled synthesis gas; and means to directly contact liquid water with the hot synthesis gas as formed in the gasification reactor when in use.

[0018] Applicants found that, by using such a gasification system, the use of complicated heat exchange surfaces could be avoided. A further advantage is that high alkaline feedstocks can be more easily processed. Other advantages and preferred embodiments will be discussed hereafter.

[0019] The invention also provides a process of preparing a mixture comprising carbon monoxide and hydrogen by partial oxidation of a solid carbonaceous feed in the gasification system according to the invention. In the gasification chamber the solid carbonaceous feed is partially oxidized with an oxygen comprising gas to form an upwardly moving gas mixture having a temperature of between 1200 and 1800° C., preferably between 1400 and 1800° C., and a pressure of between 20 and 100 bar, cooling said gas mixture in the connecting conduit to a temperature of between 500 and 900° C. by injecting a gaseous or liquid cooling medium and subsequently further cooling the gas in the synthesis gas cooling vessel to below 500° C. by contacting the gas with water.

[0020] It has been found that the raw synthesis gas is cooled very efficiently, as a result of which the risk of deposits of sticky particles downstream of the gasification reactor is reduced.

[0021] The invention will now be described by way of example in more detail, with reference to the accompanying non-limiting drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] In the accompanying drawings:

[0023] FIG. 1 schematically shows a process scheme for a system for preparing a purified mixture comprising carbon monoxide and hydrogen;

[0024] FIG. 2 schematically shows a longitudinal cross-section of a preferred gasification system comprising a reactor vessel and a cooling vessel;

[0025] FIG. 3 schematically shows a possible further embodiment for the cooling vessel; and

[0026] FIG. 4 schematically shows a more detailed longitudinal cross section of a gasification reactor.

[0027] The same reference numbers are used below to refer to similar structural elements.

DETAILED DESCRIPTION OF THE INVENTION

[0028] Disclosed is an improved gasification system for preparing a synthesis gas comprising CO, CO₂ and H₂, from a carbonaceous stream using an oxygen containing stream.

[0029] The gasification reactor according to the present invention is suitably used to prepare a mixture comprising carbon monoxide and hydrogen by partial oxidation of a solid carbonaceous feed in a gasification reactor according to the present invention or in a system according to the present invention. In such a process a solid carbonaceous

feed is partially oxidized in the gasification chamber with an oxygen comprising gas to form an upwardly moving gas mixture having a temperature of between 1200 and 1800° C., preferably between 1400 and 1800° C. This mixture is preferably cooled, in a first cooling step. In a separate cooling vessel the gas is further cooled to preferably below 500° C.

[0030] The solid carbonaceous feed is partially oxidized with an oxygen comprising gas. Preferred carbonaceous feeds are solid, high carbon containing feedstocks, more preferably it is substantially (i.e. >90 wt. %) comprised of naturally occurring coal or synthetic (petroleum)coke, most preferably coal. Suitable coals include lignite, bituminous coal, sub-bituminous coal, anthracite coal, and brown coal.

[0031] In general, this so-called gasification is carried out by partially combusting the carbonaceous feed with a limited volume of oxygen at an elevated temperature in the absence of a catalyst. In order to achieve a more rapid and complete gasification, initial pulverisation of the coal is preferred to form fine coal particulates. The term fine particulates is intended to include at least pulverized particulates having a particle size distribution so that at least about 90% by weight of the material is less than 90 µm and moisture content is typically between 2 and 8% by weight, and preferably less than about 5% by weight.

[0032] The gasification is preferably carried out in the presence of oxygen and optionally some steam, the purity of the oxygen preferably being at least 90% by volume, nitrogen, carbon dioxide and argon being permissible as impurities. Substantially pure oxygen is preferred, such as prepared by an air separation unit (ASU). The gas may contain some steam. Steam acts as moderator gas in the gasification reaction. The ratio between oxygen and steam is preferably from 0 to 0.3 parts by volume of steam per part by volume of oxygen. The oxygen used is preferably heated before being contacted with the coal, preferably to a temperature of from about 200 to 500° C.

[0033] If the water content of the carbonaceous feed, as can be the case when coal is used, is too high, the feed is preferably dried before use.

[0034] The partial oxidation reaction is preferably performed by combustion of a dry mixture of fine particulates of the carbonaceous feed and a carrier gas with oxygen in a suitable burner as present in the gasification chamber of the reactor according to the invention. Examples of suitable burners are described in U.S. Pat. No. 4,887,962, U.S. Pat. No. 4,523,529 and U.S. Pat. No. 4,510,874. The gasification chamber is preferably provided with one or more pairs of partial oxidation burners, wherein said burners are provided with supply means for a solid carbonaceous feed and supply means for oxygen. With a pair of burners is here meant two burners, which are directed horizontal and diametric into the gasification chamber. This results in a pair of two burners in a substantially opposite direction at the same horizontal position. The reactor may be provided with 1 to 5 of such pairs of burners. The upper limit of the number of pairs will depend on the size of the reactor. The firing direction of the burners may be slightly tangential as for example described in EP-A-400740.

[0035] Examples of suitable carrier gasses to transport the dry and solid feed to the burners are steam, nitrogen,

synthesis gas and carbon dioxide. Preferably nitrogen is used when the synthesis gas is used for power generation and as feedstock to make ammonia. Carbon dioxide is preferably used when the synthesis gas is subjected to downstream shift reactions. The shifted synthesis gas may for example be used to prepare hydrogen, methanol and/or dimethyl ether or as feed gas of a Fischer-Tropsch synthesis.

[0036] The synthesis gas discharged from the gasification reactor comprises at least H_2 , CO, and CO_2 . The suitability of the synthesis gas composition for especially the methanol forming reaction is expressed as the stoichiometric number SN of the synthesis gas, whereby expressed in the molar contents $[H_2]$, $[CO]$, and $[CO_2]$, $SN = ([H_2] - [CO_2]) / ([CO] + [CO_2])$. It has been found that the stoichiometric number of the synthesis gas produced by gasification of the carbonaceous feed is lower than the desired ratio of about 2.05 for forming methanol in the methanol forming reaction. By performing a water shift reaction and separating part of the carbon dioxide the SN number can be improved. Preferably hydrogen separated from methanol synthesis offgas can be added to the synthesis gas to increase the SN.

[0037] In one embodiment of the present invention the hot synthesis gas is first cooled in a first cooling step to a temperature of between 500 and 900° C. before it enters the separate cooling vessel. This first cooling step is preferred to achieve a gas temperature below the solidification temperature of the non-gaseous components present in the hot synthesis gas. The solidification temperature of the non-gaseous components in the hot synthesis gas will depend on the carbonaceous feed and is usually between 600 and 1200° C. and more especially between 500 and 1000° C., for coal type feedstocks. The first cooling step is preferably performed in the connecting conduit that fluidly connects the gasification chamber and the cooling vessel. Cooling may be performed by injecting a quench gas. Cooling with a gas quench is well known and described in for example EP-A-416242, EP-A-662506 and WO-A-2004/005438. Examples of suitable quench gases are recycle synthesis gas and steam.

[0038] More preferably this first cooling and/or the cooling performed in the cooling vessel is performed by injecting a mist of liquid droplets into the gas flow as will be described in more detail below. The use of the liquid mist as compared to a gas quench is advantageous because of the larger cooling capacity of the mist.

[0039] The liquid may be any liquid having a suitable viscosity in order to be atomized. Non-limiting examples of the liquid to be injected are a hydrocarbon liquid, a waste stream etc. Preferably the liquid comprises at least 50% water. Most preferably the liquid is substantially comprised of water (i.e. >95 vol %). In a preferred embodiment the wastewater, also referred to as black water, as obtained in a possible downstream synthesis gas scrubber is used as the liquid. Even more preferably, the process condensate of an optional downstream water shift reactor is used as the liquid.

[0040] With the term hot synthesis gas is meant the gas mixture as directly obtained in the gasification chamber.

[0041] With the term 'mist' is meant that the liquid is injected in the form of small droplets. If water is to be used as the liquid, then preferably more than 80%, more preferably more than 90%, of the water is in the liquid state.

[0042] Preferably the injected mist has a temperature of at most 50° C. below the bubble point at the prevailing

pressure conditions at the point of injection, particularly at most 15° C., even more preferably at most 10° C. below the bubble point. To this end, if the injected liquid is water, it usually has a temperature of above 90° C., preferably above 150° C., more preferably from 200° C. to 230° C. The temperature will obviously depend on the operating pressure of the gasification reactor, i.e. the pressure of the raw synthesis gas specified further below. Hereby a rapid vaporization of the injected mist is obtained, while cold spots are avoided. As a result the risk of ammonium chloride deposits and local attraction of ashes in the gasification reactor is reduced.

[0043] Further it is preferred that the mist comprises droplets having a diameter of from 50 to 200 μm , preferably from 100 to 150 μm . Preferably, at least 80 vol. % of the injected liquid is in the form of droplets having the indicated sizes.

[0044] To enhance quenching of the hot synthesis gas, the mist is preferably injected with a velocity of 30-90 m/s, preferably 40-60 m/s.

[0045] Also it is preferred that the mist is injected with an injection pressure of at least 10 bar above the pressure of the raw synthesis gas as present in the gasification reactor, preferably from 20 to 60 bar, more preferably about 40 bar, above the pressure of the raw synthesis gas. If the mist is injected with an injection pressure of below 10 bar above the pressure of the raw synthesis gas, the droplets of the mist may become too large. The latter may be at least partially offset by using an atomization gas, which may e.g. be N_2 , CO_2 , steam or synthesis gas, more preferably steam or synthesis gas. Using atomization gas has the additional advantage that the difference between injection pressure and the pressure of the raw synthesis gas may be reduced to a pressure difference of between 5 and 20 bar.

[0046] Further it has been found especially suitable when the mist is injected in a direction away from the gasification reactor, or said otherwise when the mist is injected in the flow direction of the raw synthesis gas, more preferably under an angle. Hereby no or less dead spaces occur which might result in local deposits on the wall of the connecting conduit. Preferably the mist is injected from the wall of the connecting conduit or from the wall of the cooling vessel in the direction of the flow of hot synthesis gas and under an angle of between 30-60°, more preferably about 45°, with respect to a plane perpendicular to the longitudinal axis of the connecting conduit or cooling vessel. Alternatively the injection of the mist in the cooling vessel may be performed by injecting the mist in the same, suitably downwardly, direction as the flow path of the synthesis gas.

[0047] According to a further preferred embodiment, the injected mist is at least partially surrounded by a shielding fluid. Herewith the risk of forming local deposits is reduced. The shielding fluid may be any suitable fluid, but is preferably selected from the group consisting of an inert gas such as N_2 and CO_2 , synthesis gas, steam and a combination thereof.

[0048] According to an especially preferred embodiment, the amount of injected mist is selected such that the raw synthesis gas leaving the cooling vessel comprises at least 40 vol. % H_2O , preferably from 40 to 60 vol. % H_2O , more preferably from 45 to 55 vol. % H_2O .

[0049] In another preferred embodiment the amount of water added relative to the raw synthesis gas is even higher than the preferred ranges above if one chooses to perform a so-called overquench. In an overquench type process the amount of water added, preferably the amount added in the cooling vessel, is such that not all liquid water will evaporate and some liquid water will remain in the cooled raw synthesis gas. Such a process is advantageous because a downstream dry solid removal system can be omitted. In such a process the raw synthesis gas leaving the cooling vessel is saturated with water. The weight ratio of the raw synthesis gas and water injection can be 1:1 to 1:4.

[0050] Overquench type process conditions may be achieved by injecting a large amount of water into the flow path of the synthesis gas, by passing the flow of synthesis gas through a water bath positioned at the lower end of the cooling vessel or combinations of these measures.

[0051] It has been found that herewith the capital costs can be substantially lowered, as no further or significantly less addition of steam in an optional downstream water shift conversion step is necessary. With capital costs is here meant the capital costs for steam boilers.

[0052] In a preferred method of the present invention, the synthesis gas or a part thereof, and especially the synthesis gas as saturated with water, leaving the quenching section is preferably shift converted whereby at least a part of the water is reacted with CO to produce CO₂ and H₂ thereby obtaining a shift converted synthesis gas stream. As the person skilled in the art will readily understand what is meant with a shift converter, this is not further discussed. Preferably, before shift converting the raw synthesis gas, the raw synthesis gas is heated in a heat exchanger against the shift converted synthesis gas stream. Herewith the energy consumption of the method is further reduced. In this respect it is also preferred that the liquid is heated before using the liquid injecting it as a mist in the process of the present invention. Preferably heating of this liquid is performed by indirect heat exchange against the shift converted synthesis gas stream.

[0053] Any desired molar ratio of H₂/CO may be obtained by subjecting one part of the synthesis gas to a water shift reaction obtaining a CO depleted stream and by-passing the water shift unit with another part of the synthesis gas and combining the CO depleted stream and the by-pass stream. By choosing the ratio of by-pass and shift feed one may achieve most desired ratios for the preferred downstream processes.

[0054] Reference is made to FIG. 1. FIG. 1 schematically shows a system 1 for producing synthesis gas. In a gasification reactor a carbonaceous stream and an oxygen-containing stream may be fed via lines 3, 4, respectively to a gasification chamber 2. In gasification chamber 2 a raw synthesis gas and a slag is obtained. To this end usually several burners (not shown) are present in the gasification chamber 2. Usually, the partial oxidation in the gasification chamber 2 is carried out at a temperature in the range from 1200 to 1800° C., preferably between 1400 and 1800° C., and at a pressure in the range from 1 to 200 bar, preferably between 20 and 100 bar, more preferably between 40 and 70 bar.

[0055] The produced raw synthesis gas is fed via a connecting conduit 5 to a cooling vessel 9. Water 17 is injected

in the form of a mist in connecting conduit 5, wherein the synthesis gas is cooled to below 500° C., for example to about 400° C.

[0056] The ash components as are present in most of the preferred feeds will form a so-called liquid slag in gasification chamber 2 at these temperatures. The slag will preferably form a layer on the inner side of the wall of gasification chamber 2, thereby creating an isolation layer. The temperature conditions are so chosen that the slag will create on one hand such a protective layer and on the other hand will still be able to flow to a lower positioned slag outlet 7 for optional further processing.

[0057] As shown in the embodiment of FIG. 1, the partly cooled synthesis gas 8 enters a cooling vessel 9. In cooling vessel 9 the synthesis gas 8 is contacted with an amount of water 6 in an overquench process mode to obtain a water saturated synthesis gas 10.

[0058] Water saturated synthesis gas 10 is directly fed to a wet gas scrubber 11 and subsequently via line 12 to a shift converter 13 to react at least a part of the water with CO to produce CO₂ and H₂, thereby obtaining a shift converted gas stream in line 14. Part of the scrubbed gas 24 may by-pass the shift converter 13. This gas and stream 20 may be combined, optionally after both streams have been subjected to a further gas treating (not shown). As the wet gas scrubber 11 and shift converter 13 are already known per se, they are not further discussed here in detail. Waste water from gas scrubber 11 is removed via line 22 and optionally partly recycled to the gas scrubber 11 via line 23. Part of the wastewater, black water, from gas scrubber 11 may be preferably used as liquid water as injected via line 17 or 6. In a non-overquench mode the synthesis gas 10 is suitably fed to a dry-solids removal unit to at least partially remove dry ash. Preferred solids removal units are cyclones or filter units as for example described in EP-A-551951 and EP-A-1499418.

[0059] Further improvements are achieved when the raw synthesis gas in line 12 is heated in a heat exchanger 15 against the shift converted synthesis gas in line 14 that is leaving the shift converter 13.

[0060] Further it is preferred according to the present invention that energy contained in the stream of line 16 leaving heat exchanger 15 is used to warm up the water in line 17 prior to be used in a first or second cooling step. To this end, the stream in line 16 may be fed to an indirect heat exchanger 19, for indirect heat exchange with the stream in line 17.

[0061] As shown in the embodiment in FIG. 1, the stream in line 14 is first fed to the heat exchanger 15 before entering the indirect heat exchanger 19 via line 16. However, the person skilled in the art will readily understand that the heat exchanger 15 may be dispensed with, if desired, or that the stream in line 14 is first fed to the indirect heat exchanger 19 before heat exchanging in heat exchanger 15.

[0062] The CO depleted synthesis gas leaving the indirect heat exchanger 19 in line 20 may be further processed, if desired, for further heat recovery and gas treatment.

[0063] If desired the heated stream in line 17 may also be partly used as a feed (line 21) to the gas scrubber 11.

[0064] FIG. 2 shows a longitudinal cross-section of a gasification system, which may be part of the system 1 of FIG. 1. FIG. 2 shows the gasification reactor 43 of FIG. 1 of WO-A-2004/005438 in combination with a downstream cooling vessel or quench vessel 44 fluidly connected by a connecting conduit, i.e. transfer duct 45. Shown in FIG. 2 is the gasification chamber 47, which is connected to a tubular part 51, which connects, by means of a connecting conduit, gasification chamber 47 via an upper wall part 52 to the interior of cooling vessel 44. At the lower end of the tubular part 51 injecting means 48 are present for injecting a liquid or gaseous cooling medium. Cooling vessel 44 is further provided with an outlet 49 for cooled synthesis gas.

[0065] The system of FIG. 2 differs from the system disclosed in FIG. 1 of WO-A-2004/005438 in that the cooling vessel 3 of said FIG. 1 is omitted and replaced by a simple vessel comprising means 46 to add liquid water. A further difference is that injecting means 48 may be suited for injecting a mist of liquid water.

[0066] Preferably the wall of the gasification chamber 43 and/or the wall of the connecting conduit 51 are provided with cooling means. Preferably the cooling means are an arrangement of water-cooled tubes, more preferably in the form of a membrane wall.

[0067] FIG. 2 also shows a burner 50. The burner configuration may suitably be as described in EP-A-0400740, which reference is hereby incorporated by reference. The various other details of the gasification reactor 43 and the transfer duct 45 as well as the upper design of the cooling vessel 44 are preferably as disclosed for the apparatus of FIG. 1 of WO-A-2004/005438.

[0068] The embodiment of FIG. 2 is preferred when retrofitting existing gasification reactors by replacing the syngas cooler of the prior art publications with a cooling vessel 44 or when one wishes to adopt the process of the present invention while maintaining the actual gasification reactor of the prior art.

[0069] The invention is thus preferably directed to a system, wherein the inlet for receiving hot synthesis gas of the cooling vessel is at its upper end and the outlet for cooled synthesis gas is at its lower end, such that in use, a substantially downwardly directed flow path of synthesis gas will result and wherein in the flow path downwardly directed injecting means are present, said injecting means suited to inject a mist of water.

[0070] FIG. 3 shows the upper end of gasification reactor 43 and the upper end of gasification chamber 47. This upper end is fluidly connected by means of connecting conduit 51 to separate cooling vessel 53. Injecting means 48 are present to inject a gaseous or liquid quenching medium in accordance with the process of the present invention.

[0071] In cooling vessel 53 a dip tube 54 is present to create a downwardly directed flow path for synthesis gas. At the upper end of the dip-tube 54 injecting means 46 are present to inject a mist of liquid water into the synthesis gas. The dip-tube is partly submerged in a water bath 55. In use the synthesis gas will flow through water bath 55 to an annular space 56 as present between dip-tube 54 and the wall of the cooling vessel 53. From said annular space 56 the water saturated synthesis gas is discharged from said cooling vessel via conduit 57.

[0072] FIG. 3 also shows a pump 58 to recirculate water 59, providing a bleed stream 60 and a supply stream 61 for fresh water.

[0073] The invention is thus also directed to a system, wherein the synthesis gas cooling vessel has an opening for receiving hot synthesis gas at its upper end and an outlet for cooled synthesis gas defining a flow path for synthesis gas there between, and wherein a water bath is present in the flow path of the synthesis gas.

[0074] More preferably the invention is directed to a system, wherein in the connecting conduit injecting means are present for injecting a liquid or gaseous cooling medium into the synthesis gas. Even more preferably wherein the injecting means are injecting means for injecting a liquid cooling medium in the form of a mist of water droplets.

[0075] FIG. 4 shows a more detailed longitudinal cross-section of a gasification reactor 2 used in the system 1 of FIG. 1. The gasification reactor 2 has an inlet 3 for a carbonaceous stream and an inlet 4 for an oxygen containing gas.

[0076] One or several burners (schematically denoted at 26) are present in the gasification reactor 2 for performing the partial oxidation reaction. For reasons of simplicity, two burners 26 are shown here but a different number may be provided.

[0077] Further, the gasification reactor 2 comprises an outlet 25 for removing the slag formed during the partial oxidation reaction via line 7.

[0078] Also, the gasification reactor 2 comprises an outlet 27 for the raw synthesis gas produced, which outlet 27 is connected with the connecting conduit 5. The skilled person will readily understand that between the outlet 27 and the connecting conduit, some additional tubing may be present. However, usually the connecting conduit 5 is directly connected to the gasification reactor 2, as shown in FIG. 4.

[0079] The connecting conduit 5 comprises a first injector 28 that is adapted for injecting a water containing stream in the form of a mist in a quenching section of connecting conduit 5. The first injector 28 is connected to line 17. The person skilled in the art will readily understand how to select the first injector to obtain the desired mist. Also more than one first injector may be present.

[0080] The first injector injects the mist in a direction away from the gasification reactor, usually in a partially upward direction. As shown in FIG. 4, the first injector in use injects the mist in a direction away from the outlet 27 of the gasification reactor 2. To this end the centre line X of the mist injected by the first injector 28 forms an angle α of between 30-60°, preferably about 45°, with respect to the plane A-A perpendicular to the longitudinal axis B-B of the quenching section in connecting conduit 5.

[0081] As shown in the embodiment of FIG. 4, the quenching section may further comprise a second injector 29 adapted for injecting a shielding fluid at least partially surrounding the mist injected by the at least one first injector 28. The second injector 29 is connected via line 30 to a source of shielding gas.

[0082] Also in this case the person skilled in the art will readily understand how to adapt the second injector to

achieve the desired effect. For instance, the nozzle of the first injector may be partly surrounded by the nozzle of the second injector. As shown in the embodiment of FIG. 4 the first injector 28 is to this end partly surrounded by second injector 29.

[0083] The quenching section of connecting conduit 5, wherein the liquid mist is injected, may be situated above, below or next to the gasification reactor, provided that it is downstream of the gasification reactor 2. Preferably the quenching section of connecting conduit 5 is placed above the gasification reactor 2; to this end the outlet of the gasification reactor 2 may be placed at the top of the gasification reactor.

[0084] The person skilled in the art will readily understand that the present invention may be modified in various ways without departing from the scope as defined in the claims. Features in each claim may be combined with features of any other claim.

We claim:

1. A gasification system comprising a gasification reactor and a synthesis gas cooling vessel, wherein the gasification reactor comprises:

a pressure shell for maintaining a pressure higher than atmospheric pressure;

a slag bath located in a lower part of the pressure shell;

a gasifier wall arranged inside the pressure shell defining a gasification chamber wherein during operation the synthesis gas can be formed, a lower open part of the gasifier wall which is in fluid communication with the slag bath and an open upper end of the gasifier wall which is in fluid communication with the synthesis gas cooling vessel via a connecting conduit;

and wherein the synthesis gas cooling vessel comprises:

an inlet for hot synthesis gas;

an outlet for cooled synthesis gas; and

means to, in use, directly contact liquid water with the hot synthesis gas as formed in the gasification reactor.

2. The system according to claim 1, wherein the synthesis gas cooling vessel has the inlet for receiving hot synthesis gas at its upper end and the outlet for cooled synthesis gas at its lower end, such that in use, a substantially downwardly directed flow path of synthesis gas will result and wherein in the flow path downwardly directed injecting means are present, said injecting means suited to inject a mist of water.

3. The system according to claim 1, wherein the synthesis gas cooling vessel has an opening for receiving hot synthesis gas at its upper end and an outlet for cooled synthesis gas defining a flow path for synthesis gas there between, and wherein a water bath is present in the flow path of the synthesis gas.

4. The system according to claim 3, wherein the outlet for cooled synthesis gas is fluidly connected to an inlet of a wet gas scrubber.

5. The system according to claim 4, wherein the gas outlet of the wet gas scrubber is fluidly connected to an inlet of a water shift converter.

6. The system according to claim 1, wherein in the connecting conduit injecting means are present for injecting a liquid or gaseous cooling medium into the synthesis gas.

7. The system according to claim 6, wherein the injecting means are injecting means for injecting a liquid cooling medium in the form of a mist of water droplets.

8. The system according to claim 1, wherein the wall of the combustion chamber and the wall of the connecting conduit are provided with cooling means.

9. The system according to claim 8, wherein the cooling means is an arrangement of water-cooled tubes, preferably in the form of a membrane wall.

10. The system according to claim 1, wherein the gasification chamber is provided with one or more pairs of partial oxidation burners, wherein said burners are provided with supply means for a solid carbonaceous feed and supply means for an oxygen containing gas.

11. A process of preparing a mixture comprising carbon monoxide and hydrogen by partial oxidation of a solid carbonaceous feed, the process comprising:

partially oxidizing a solid carbonaceous feed with an oxygen comprising gas in a gasification chamber of a gasification reactor, to form an upwardly moving gas mixture having a temperature of between 1200 and 1800° C. and a pressure of between 20 and 100 bar;

cooling said gas mixture in a connecting conduit to a temperature of between 500 and 900° C. by injecting a gaseous or liquid cooling medium; and

subsequently further cooling the gas mixture in a synthesis gas cooling vessel to below 500° C. by contacting the gas with liquid water;

wherein the gasification chamber is defined by a gasifier wall, a lower open part of which gasifier wall being in fluid communication with a slag bath and an open upper end of which gasifier wall being in fluid communication with the synthesis gas cooling vessel via the connecting conduit.

12. The process according to claim 11, wherein said cooling in the connecting tube and/or in the synthesis gas cooling vessel is performed by injecting a mist of water droplets into the gas flow.

13. The process according to claim 12, wherein the injected water mist has a temperature of at most 50° C. below the bubble point of water at the pressure of the hot synthesis gas.

14. The process according to claim 12, wherein the mist comprises droplets having a diameter of from 50 to 200 µm.

15. The process according to claim 12, wherein the mist is injected at a velocity of between 30-100 m/s.

16. The process according to claim 15, wherein the mist is injected at a velocity of between 40-60 m/s.

17. The process according to claim 12, wherein the mist is injected using an atomizing gas with an injection pressure between 5 and 20 bar above the pressure of the raw synthesis gas.

18. The process according to claim 12, wherein the mist is injected from a wall of the connecting conduit or the cooling vessel, in the direction of the flow of hot synthesis gas, under an angle of between 30-60° with respect to a plane perpendicular to the longitudinal axis of the connecting tube or the cooling vessel.

19. The process according to claim 11, wherein a downwardly moving slag stream is formed during the partial oxidizing.

20. The process according to claim 11, wherein the gasification reactor further comprises:

a pressure shell for maintaining the pressure higher than atmospheric pressure, wherein the slag bath is located in a lower part of the pressure shell;

and wherein the synthesis gas cooling vessel comprises:

an inlet for hot synthesis gas, an outlet for cooled synthesis gas and means to, in use, directly contact liquid

water with the hot synthesis gas as formed in the gasification reactor.

21. The process according to claim 20, wherein the gasifier wall is arranged inside the pressure shell defining the gasification chamber wherein during operation the synthesis gas is formed.

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