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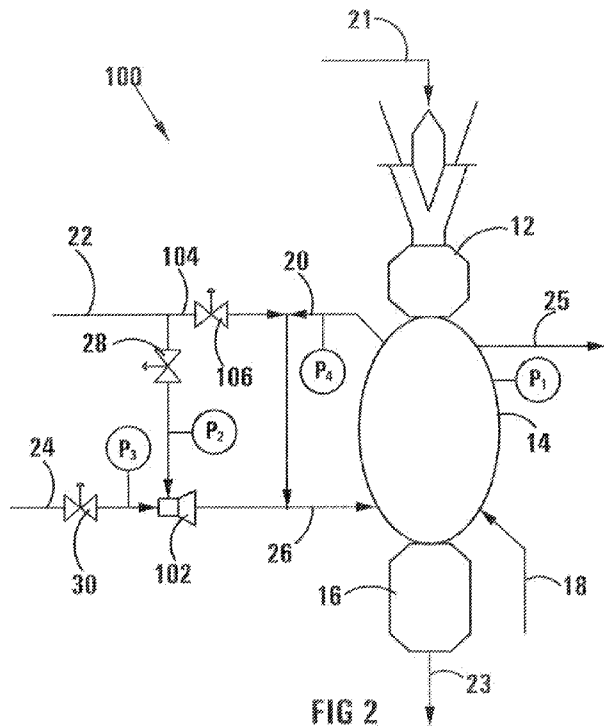
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(54) Title: GASIFICATION OF A CARBONACEOUS MATERIAL



(57) Abstract: A method of operating a pressurized gasifier (100) includes feeding a carbonaceous material (21) into a pressurized gasification vessel (14) of the gasifier (100) where the gasification vessel is at a pressure P1. Steam (22) as a temperature moderating and gasification agent is fed through a steam ejector (102) into the gasification vessel (14), the steam entering the ejector (102) at a pressure P2 and acting as a motive fluid for the steam ejector (102). Oxygen (24) is also fed into the gasification vessel through the steam ejector (102), the oxygen entering the steam ejector (102) at a pressure P3, where P2 > P1 > P3. The carbonaceous material is gasified in the presence of steam and oxygen at the pressure P1 to produce ash and synthesis gas which includes at least CO and H2, with ash (23) and synthesis gas (25) being removed from the gasification vessel.

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GASIFICATION OF A CARBONACEOUS MATERIAL

5 THIS INVENTION relates to gasification of a carbonaceous material. In particular, the invention relates to a method of operating a pressurized gasifier, to a method of upgrading a pressurized gasifier employing steam and oxygen, to a method of operating a gasifier upgraded in accordance with the invention, and to a pressurized gasifier.

10 Numerous kinds of pressurized gasifiers are known in the art and it is recognized that, for pressurized gasifiers, higher operating gasification pressures generally increase the production capacity of the gasifiers. Pressurized gasifiers typically employ a gasification agent comprising an admixture of oxygen and high pressure steam (often high pressure steam from a steam header and steam generated
15 in a jacket of the gasifier itself). Typically, the high pressure steam is available at a steam pressure which is higher than the oxygen pressure and the limit on the gasification agent pressure is therefore the oxygen pressure available at the gasification battery limit. For some kinds of gasifiers, such as fixed bed dry bottom gasifiers, the
20 mass flow rate of the steam is significantly higher than the mass flow rate of the oxygen to the gasifier.

 Conventionally, the oxygen and steam are mixed by controlling the flow of steam and the flow of oxygen to a common mixing point. When the steam is available
25 at a pressure significantly higher than that of the oxygen, as is often the case, the steam must be let down from a high pressure across a valve and the excess energy in the steam is not used to perform work.

 In modern air separation plants, oxygen is produced as a liquid at some
30 point in the process, at which point the liquid oxygen is pumped to achieve a desired pressure increase. The high pressure liquid oxygen is heat exchanged with a relatively hot process or utility stream so that the liquid oxygen is vaporised and sent to the battery limit of the air separation plant as a high pressure gaseous product. The separation of oxygen from air and the supply of high pressure oxygen to a gasification

process require large compression and pumping duties. If the required oxygen delivery pressure can be reduced, a saving on utilities in the air separation unit or plant can thus be achieved.

5 In short, in many integrated coal-to-liquids facilities, the steam and oxygen pressures are mismatched, with the steam pressure being substantially higher than the oxygen pressure leading to an energy-inefficient operation. Reduction or mitigation of this inefficiency would be desirable.

10 According to one aspect of the invention, there is provided a method of operating a pressurized gasifier, the method including

 feeding a carbonaceous material into a pressurized gasification vessel of said pressurised gasifier where the gasification vessel is at a pressure P1;

 feeding steam as a temperature moderating and gasification agent through a steam ejector into the gasification vessel, the steam entering the ejector at a pressure P2 and acting as a motive fluid for the steam ejector;

 feeding oxygen into the gasification vessel through said steam ejector, the oxygen entering the steam ejector at a pressure P3, where $P2 > P1 \geq P3$;

 gasifying the carbonaceous material in the presence of said steam and oxygen at said pressure P1 to produce ash and synthesis gas which includes at least CO and H₂;

 and
 removing said ash and synthesis gas from the gasification vessel.

 Typically, the gasifier is a fixed bed dry bottom gasifier, also known as a moving bed dry ash gasifier, so that dry ash is removed from the gasification vessel. As will be appreciated, the operating method of the invention is well-suited to gasifiers with a high steam requirement to moderate gasification temperatures, such as fixed bed gasifiers, and is thus unlikely to find application in the operation of gasifiers with a low steam requirement, such as entrained bed gasifiers. It may however be possible to employ the operating method of the invention with gasifiers with a moderate steam requirement, such as fluidized bed gasifiers.

 In principle, the carbonaceous material may be any carbonaceous material suitable for gasification in a pressurized gasifier, particularly a fixed bed or

fluidised bed gasifier, such as waste, biomass, petcoke or coal. Typically however, the carbonaceous material will be coal, e.g. lignite, bituminous coal or anthracite.

5 Preferably, P1 is at least about 20 bar(g), more preferably between about 25 bar(g) and about 100 bar(g), e.g. about 29 bar(g).

Preferably, P2 is at least about 35 bar(g), more preferably between about 45 bar(g) and about 170 bar(g), e.g. about 60 bar(g).

10 P3 is typically at least about 25 bar(g), more typically between about 28 bar(g) and about 110 bar(g), e.g. about 29 bar(g).

Typically, the method of the invention includes generating steam from heat provided by the gasification of the carbonaceous material in the gasifier. The steam
15 may for example be generated in a jacket of the gasification vessel of the gasifier. The steam generated by the gasifier may be at a pressure P4, where $P4 > P1$. Typically $P4 \leq P2$.

20 Steam generated by the gasifier may be used as temperature moderating agent and gasification agent in the gasification vessel. Typically, the steam generated by the gasifier is thus mixed with an admixture of steam and oxygen from the steam ejector before being fed into the gasification vessel.

25 The method may include allowing some steam not generated by the gasifier to bypass the steam ejector. Typically, steam bypassing the steam ejector is mixed with the steam generated from heat provided by the gasification of the carbonaceous material in the gasifier and is also mixed with the admixture of steam and oxygen from the steam ejector before being fed into the gasification vessel.

30 If the steam to the ejector is available at a supply pressure higher than P2, the method may include letting the steam pressure down, for example across a valve, to reduce the steam pressure to P2. As will however be appreciated, for the same steam supply pressure and for the same operating pressure P1, the amount by which the steam pressure will have to be let down for the method of the invention would be less

than for a prior art gasification process in which a steam ejector is not used for feeding oxygen to the gasifier.

5 The method may include operating the gasification vessel at said pressure P1, where said pressure P1 is higher than said pressure P3. For example, said pressure P1 may be between about 0.5 bar and about 1.5 bar, typically between 0.9 bar and 1.3 bar higher than said pressure P3.

10 According to another aspect of the invention, there is provided a method of upgrading a pressurized gasifier employing steam and oxygen in a mass/volume ratio of at least 4.8 kg/m_n^3 , the method including

providing a steam ejector in flow communication with a steam supply so that steam flowing through the steam ejector can act as a motive fluid;

15 connecting a gaseous oxygen supply to the steam ejector so that the steam ejector can draw oxygen from the oxygen supply and compress it to a pressure higher than a supply pressure of the oxygen supply to the steam ejector; and

connecting an outlet of the steam ejector in flow communication with a gasification vessel of the gasifier so that an admixture of steam and oxygen from the steam ejector can be injected into the gasification vessel.

20

The gasifier may be as hereinbefore described, and may in particular be a fixed bed dry bottom gasifier.

25 Preferably the steam supply to the ejector is at a pressure of at least about 35 bar(g), more preferably between about 45 bar(g) and about 170 bar(g), e.g. about 60 bar(g).

30 The gaseous oxygen supply pressure to the steam ejector is typically at least 25 bar(g), more typically between about 28 bar(g) and about 110 bar(g), e.g. about 29 bar(g).

The gasification vessel may be a jacketed gasification vessel configured to generate steam from heat released during gasification of a carbonaceous material in the

jacketed gasification vessel. The method may include connecting the jacket of the gasification vessel in steam flow communication with said outlet of the steam ejector.

5 The invention extends to a method of operating a gasifier upgraded in accordance with the invention, the method including maintaining or operating the gasification vessel of the gasifier at its design operating pressure whilst reducing the oxygen supply pressure to the steam ejector, compared to the oxygen supply pressure to the gasifier prior to upgrading of the gasifier.

10 The invention further extends to a method of operating a gasifier upgraded in accordance with the invention, the method including operating the gasification vessel of the gasifier at a higher pressure than the operating pressure used for the gasification vessel of the gasifier prior to upgrading of the gasifier whilst maintaining the oxygen supply pressure to the steam ejector at least the same as or even higher than the
15 oxygen supply pressure to the gasifier prior to upgrading of the gasifier.

The method may include applying a pressure gain of at least 0.5 bar to the oxygen supplied to the steam ejector, by means of the steam ejector. Preferably, the pressure gain is between 0.5 bar and 1.5 bar, typically between 0.9 bar and 1.3 bar.

20 According to yet another aspect of the invention, there is provided a pressurized gasifier which includes

a gasification vessel which is a pressure vessel; and

25 a steam ejector in flow communication with a steam supply facility, the steam ejector being configured to use steam from the steam supply facility as a motive fluid, the steam ejector also being in flow communication with a gaseous oxygen supply facility and being configured to compress oxygen from the oxygen supply facility to a higher pressure and to deliver an admixture of steam and oxygen to the gasification vessel.

30 The gasifier may be as hereinbefore described, and may in particular be a fixed bed dry bottom gasifier.

The gasifier may be a jacketed gasifier configured to generate steam from heat released during gasification of a carbonaceous material. The jacket of the gasifier may be in steam flow communication with an outlet of the steam ejector in use to add steam generated in the jacket to the admixture of steam and oxygen delivered by the steam ejector.

The oxygen supply facility may include an air separation plant or unit configured to produce gaseous oxygen at the battery limit of the air separation unit.

The gasifier may include a bypass line for steam from the steam supply facility to bypass the steam ejector before entering the gasification vessel. The steam bypass line may be in flow communication with an outlet of the steam ejector, either directly or via a flow line which conveys a mixture of bypass steam and steam generated in the jacket.

The invention will now be described, by way of the non-limiting example and with reference to the accompanying diagrammatic drawings in which

Figure 1 shows a conventional fixed bed dry bottom gasifier employing an admixture of high pressure steam and oxygen as a gasification agent; and

Figure 2 shows a fixed bed dry bottom gasifier employing a steam ejector in accordance with an embodiment of the invention to provide an admixture of high pressure steam and oxygen as gasification agent to a gasification vessel.

Referring to Figure 1 of the drawings, reference numeral 10 generally indicates a conventional fixed bed dry bottom gasifier. The gasifier 10 includes a coal lock 12, a gasification vessel 14 and an ash lock 16. The gasification vessel 14 has a jacket (not shown) receiving high pressure boiler feed water by means of a boiler feed water line 18. A jacket steam line 20 is provided to remove steam from the jacket. A coal line 21 delivers coal to the coal lock 12, an ash line 23 removes ash from the ash lock 16 and a synthesis gas line 25 removes raw synthesis gas from the gasification vessel 14.

A high pressure steam line 22 and a gaseous oxygen line 24 join together to form a gasification agent line 26 which leads into the gasification vessel 14. The high

pressure steam line 22 is provided with a flow control valve 28 and the gaseous oxygen line 24 is provided with a flow control valve 30. The jacket steam line 20 joins the high pressure steam line 22 downstream of the flow control valve 28.

5 In use, a sized coal feed is fed by means of the coal line 21 into the gasification vessel 14 through the coal lock 12 and moves down through a bed formed inside the gasification vessel 14. Typically, the coal feed has coal particles greater than 5mm. Gasification agent, comprising an admixture of oxygen and steam enters at a bottom of the bed through a rotating grate (not shown) from the gasification agent line 10 26. Oxygen is required to combust some of the coal to supply energy for the endothermic gasification reactions. Steam is required to moderate the temperatures inside the gasification vessel 14, as well as to act as gasification agent. Part of the steam that is used is generated in the gasifier jacket from boiler feed water fed into the jacket by means of the boiler feed water line 18. Typically, the steam generated in the 15 gasifier jacket is saturated and has a pressure of about 29 bar(g) and the gaseous oxygen is available at a pressure of about 30 bar(g) and a temperature of about 110°C. Within the gasifier bed, different reaction zones are distinguishable from top to bottom, namely a drying zone where moisture is released, a devolatilisation zone where pyrolysis takes place, a reduction zone or gasification zone where mainly endothermic reactions 20 occur, an exothermic oxidation or combustion zone, and an ash bed at the bottom of the gasifier bed. As a result of the counter-current mode of operation, hot ash exchanges heat with cold incoming reagents, such as steam and oxygen, while at the same time hot raw gas, i.e. raw synthesis gas, exchanges heat with cold incoming coal. This results in an ash stream removed from the ash lock 16 by means of the ash line 23 and 25 a raw gas or raw synthesis gas stream removed from the gasification vessel 14 by means of the synthesis gas line 25, at relatively low temperatures compared to other types of gasifiers, which improves the thermal efficiency and lowers the steam and oxygen consumption of the gasifier 10. Typically, the ash passes through a rotating grate and then the ash lock 16 before being removed.

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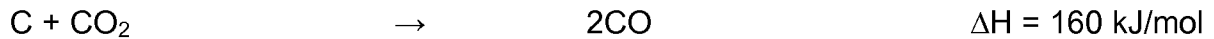
In the pyrolysis zone of the gasifier, tars, oils and pitches and the like are released. These pyrolysis products are not destroyed, in view of the relatively low operating temperature of the pressurized dry ash moving bed gasifier 10. The pyrolysis products can be used to create valuable co-products, such as ammonia, sulphur,

cresols and phenols. The following are some of the reactions that take place in the gasifier:

Combustion:



Reduction:



10

Water-gas shift:



Methane formation:



The temperature profile in the gasifier 10 varies between about 800°C and about 1350°C as the coal moves through the different zones in the gasification vessel 14. The raw gas or raw synthesis gas stream in the synthesis gas line 25 leaves the gasification vessel 14 typically at a temperature between about 460°C and 600°C, but may be lower. The maximum temperature in the gasification vessel 14 is limited by the ash fusion temperature of the coal feed as ash fusion creates removal problems of the ash at the bottom of the gasifier 10.

A detailed description of the operation of a fixed bed dry bottom gasifier is provided in the specification of WO 2006/061738, which is published and available to the public.

30

The high pressure steam in the high pressure steam line 22 is typically available at a much higher pressure than the gaseous oxygen pressure in the gaseous oxygen line 24. For example, the high pressure steam may be available at about 40 bar(g) whereas the gaseous oxygen is available at about 30 bar(g). Accordingly, the

high pressure steam is let down across the flow control valve 28 to about 29 bar(g). Similarly, the gaseous oxygen pressure is let down across the flow control valve 30 to about 29 bar(g) and the gasification agent formed by an admixture of the let down high pressure steam and the gaseous oxygen is then fed into the gasification vessel 14 at a pressure of about 29 bar(g), which is then also the operating pressure of the gasification vessel 14.

Steam generated in the jacket of the gasification vessel 14 is maintained at a pressure of about 29 bar(g) by being in flow communication with the let down high pressure steam downstream of the flow control valve 28 and the jacket steam from the jacket steam line 20 is thus fed with the let down high pressure steam and the gaseous oxygen as part of the gasification agent admixture into the gasification vessel 14.

As will be appreciated, by letting down the high pressure steam in the high pressure steam line 22 from a pressure of about 40 bar(g) to a pressure of about 29 bar(g), the excess energy in the steam is not used to perform any useful work and this thus introduces an energy-inefficient step in the conventional gasification process illustrated in Figure 1.

Referring to Figure 2, a fixed bed dry bottom gasifier upgraded in accordance with the invention, and operated in accordance with the invention, is shown and generally indicated by reference numeral 100. As the gasifier 100 is in many respects similar to the gasifier 10, the same components or features are indicated by the same reference numerals, unless otherwise indicated.

As will be noted, the gasifier 100 is provided with a steam ejector 102 (typically one of a few) downstream of the steam flow control valve 28 and the gaseous oxygen flow control valve 30. A high pressure steam bypass line 104 with a steam flow control valve 106 is provided to allow for high pressure steam to bypass the steam ejector 102 and to be let down to a lower pressure. The jacket steam line 20 and the high pressure steam bypass line 104 join the gasification agent line 26 downstream of the steam ejector 102.

The gasifier 100 is operated in similar fashion to the gasifier 10. However, an important difference is that the gaseous oxygen is supplied at a pressure of 29 bar(g) and not at a pressure of 30 bar(g), as is the case with the gasifier 10. The high pressure steam in the high pressure steam line 22, also supplied at a steam pressure of 40 bar(g), is let down to a lower pressure through the flow control valve 28, but not to the same extent as is the case for the gasifier 10. The high pressure steam, let down to a pressure P2 of about 39 bar(g), is supplied to the steam ejector 102 as a motive fluid and performs work in the steam ejector 102 to draw in the gaseous oxygen from the gaseous oxygen line 24 at a pressure P3 and to compress the gaseous oxygen to a pressure slightly higher than 29 bar(g). A mixture of steam and gaseous oxygen thus exits the steam ejector 102 and this mixture is fed as the gasification agent by means of the gasification agent line 26 into the gasification vessel 14. This mixture is at a pressure of about 29 bar(g), which is also the operating pressure P1 of the gasification vessel 14. As a result of the drawing action of the steam ejector 102 on the oxygen in the oxygen line 24, the flow of oxygen through the flow control valve 30 can be maintained even though the gaseous oxygen is supplied at a pressure of 29 bar(g) and not at a pressure of 30 bar(g).

Jacket steam at a pressure P4 of about 29 bar(g) from the jacket steam line 20 joins the gasification agent line 26, as is the case with the gasifier 10.

Typically, the gasifier 100 requires more steam than can be fed through the steam ejector(s) 102. The additional high pressure steam is let down by means of the steam flow control valve 106 to a pressure of about 29 bar(g) and is fed into the gasification agent line 26 to form part of the gasification agent being fed into the gasification vessel 14.

In use, it may be possible that the steam flow control valve 28 would not be required. In the case where a constant pressure differential exists across the steam ejector(s) 102, the steam flow through the steam ejector(s) 102 would remain fairly constant. Consequently, it would not be necessary to let the high pressure steam in the high pressure steam line 22 down to a lower pressure across the flow control valve 28, and thus the flow control valve 28 would not be required. In this scenario, the total steam to the gasifier 100 would be controlled via the steam flow control valve 106.

Should the flow of gaseous oxygen in the gaseous oxygen line 24 be reduced for any reason, the pressure increase of gaseous oxygen across the steam ejector 102 would simply be higher, thus resulting in the gasifier pressure P1 further being increased.

5 In the gasification process employing the gasifier 100, less energy is wasted by letting down high pressure steam, than is the case with the gasifier 10. Instead, some of the energy in the high pressure steam is used to increase the delivery pressure of the gaseous oxygen to the gasifier 10. As will be appreciated, if the gaseous oxygen is supplied to the gasifier 10 at a higher pressure, it is possible to
10 increase the operating pressure P1 of the gasification vessel 14 thereby increasing gasifier throughput. Alternatively, it is possible to maintain the operating pressure P1 of the gasification vessel 14 at its original operating pressure, but one can reduce the oxygen supply pressure thereby reducing utility consumption in an air separation plant which provides the gaseous oxygen, as illustrated in the embodiment described with
15 reference to Figure 2.

 The use of a steam ejector in accordance with the invention to provide gasification agent to a gasifier is ideally suited to gasifiers requiring a large ratio of steam to oxygen in the gasification agent, such as fixed bed and possibly fluidized bed
20 gasifiers.

Example

 Table 1 reflects the differences between the operation of a conventional
25 gasifier of the art as depicted in Figure 1 (the base case) and two simulated cases (case A and case B) of a gasifier operating in accordance with an embodiment of the invention as depicted in Figure 2.

 Case A reflects the method of operating the gasifier by applying a
30 pressure gain to the oxygen supplied to the steam ejector, by means of the steam ejector. Case B reflects the method of operating the gasifier by maintaining or operating the gasification vessel of the gasifier at its design operating pressure whilst reducing the oxygen supply pressure to the steam ejector, compared to the oxygen supply pressure to the gasifier prior to upgrading of the gasifier.

Table 1

Parameter	Units	Base Case	Case A	Case B
		<i>No ejector</i>	<i>Gasifier pressure increase</i>	<i>O₂ supply pressure decrease</i>
Normalised Steam flow to gasifier	kg/hr / kg/hr	1.0	1.0	1.0
Normalised O ₂ flow to gasifier	kg/hr / kg/hr	1.0	1.0	1.0
Suction Ratio (Oxygen/Steam)	kg/hr / kg/hr	-	0.33	0.33
O ₂ Supply pressure (P3)	bar(g)	30.0	30.0	28.9
Steam Feed pressure (P2)	bar(g)	40.0	40.0	40
Driving pressure	bar(g)	-	10.0	11.1
O ₂ pressure increase over ejector	bar(g)	-	1.1	1.1
Gasifier operating pressure (P1)	bar(g)	30.0	31.1	30.0
Gasifier pressure increase	%	-	3.7	0.0
Utility Saving	%	-	0.0	1.2

5 The oxygen pressure increases were estimated using vendor-supplied tables for commercially available steam ejectors and the utility savings were determined by proprietary simulation models describing and predicting the operation of a Sasol® FBDB™ gasifier and associated systems.

10 The normalized steam and oxygen flows depicted in Table 1 reflect the ratios of the steam mass flow and oxygen mass flow to the base case steam mass flow and oxygen mass flow respectively. The suction ratio is the ratio of the oxygen mass flow to the steam mass flow entering the steam ejector.

15 In the base case, steam and oxygen are fed to a normally operating gasifier without the use of a steam ejector. Steam is let down from a pressure of 40 bar(g) to a pressure of 30 bar(g) without using any of the energy of the steam as a motive force. The gasifier operating pressure is determined by the oxygen pressure available, that being 30 bar(g).

20 In case A, the energy contained in the high pressure steam is used in the steam ejector 102 to increase the pressure P3 of the oxygen supplied to the gasifier by approximately 1.1 bar(g). This increase in oxygen pressure P3 allows a corresponding increase in the operating pressure of the gasifier P1 from 30 bar(g) to 31.1 bar(g).

Although no utility savings are realized in this case, a 3.7% increase in gasifier operating pressure P1 is realised. A person skilled in the art will readily appreciate that, for pressurized gasifiers, a higher operating gasification pressure will generally increase the production capacity of the gasifier by a corresponding amount.

5

The same steam ejector 102 can also be employed in an alternative embodiment of the invention. As illustrated in case B, the gasifier operating pressure P1 is maintained at the design operating pressure of 30 bar(g), whilst the oxygen supply pressure P3 to the steam ejector is reduced to 28.9 bar(g), compared to the oxygen supply pressure of 30 bar(g) in the base case (i.e. prior to upgrading the gasifier). By maintaining the operating pressure P1 of the gasifier and reducing the oxygen supply pressure P3, the utility requirements (e.g. compression and pumping duties) in an air separation facility providing the oxygen are reduced by 1.2%. A person skilled in the art will readily appreciate that such a utility saving in a large commercial facility is substantial.

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The case selected for commercial implementation would be determined by the specific requirements of the facility. For example, should scope exist for greater production at higher gasifier pressures, case A would be selected. However, should there be no scope for pressure increase due, inter alia, to equipment design limitations, utility savings could still be realized in the air separation unit or plant through the implementation of case B.

20

CLAIMS:

- 5 1. A method of operating a pressurized gasifier, the method including
feeding a carbonaceous material into a pressurized gasification vessel of said
pressurised gasifier where the gasification vessel is at a pressure P1;
feeding steam as a temperature moderating and gasification agent through a
steam ejector into the gasification vessel, the steam entering the ejector at a pressure
10 P2 and acting as a motive fluid for the steam ejector;
feeding oxygen into the gasification vessel through said steam ejector, the
oxygen entering the steam ejector at a pressure P3, where $P2 > P1 \geq P3$;
gasifying the carbonaceous material in the presence of said steam and oxygen at
said pressure P1 to produce ash and synthesis gas which includes at least CO and H₂;
15 and
removing said ash and synthesis gas from the gasification vessel.
2. The method according to claim 1, which includes generating steam from
heat provided by the gasification of the carbonaceous material in the gasifier, the steam
20 generated by the gasifier being at a pressure P4, where $P1 < P4 \leq P2$.
3. The method according to claim 2, which includes allowing some steam not
generated by the gasifier to bypass the steam ejector with said steam bypassing the
steam ejector being mixed with the steam generated from heat provided by the
25 gasification of the carbonaceous material in the gasifier and being mixed with the
admixture of steam and oxygen from the steam ejector before being fed into the
gasification vessel.
4. The method as claimed in any of claims 1 to 3, wherein said pressure P1
30 is higher than said pressure P3.
5. A method of upgrading a pressurized gasifier employing steam and
oxygen in a mass/volume ratio of at least 4.8 kg/m_n³, the method including

providing a steam ejector in flow communication with a steam supply so that steam flowing through the steam ejector can act as a motive fluid;

connecting a gaseous oxygen supply to the steam ejector so that the steam ejector can draw oxygen from the oxygen supply and compress it to a pressure higher than a supply pressure of the oxygen supply to the steam ejector; and

connecting an outlet of the steam ejector in flow communication with a gasification vessel of the gasifier so that an admixture of steam and oxygen from the steam ejector can be injected into the gasification vessel.

6. The method according to claim 5, wherein the gasification vessel is a jacketed gasification vessel configured to generate steam from heat released during gasification of a carbonaceous material in the jacketed gasification vessel, the method including connecting the jacket of the gasification vessel in steam flow communication with said outlet of the steam ejector.

7. A method of operating a gasifier upgraded in accordance with claim 5 or claim 6, the method including maintaining or operating the gasification vessel of the gasifier at its design operating pressure whilst reducing the oxygen supply pressure to the steam ejector, compared to the oxygen supply pressure to the gasifier prior to upgrading of the gasifier.

8. A method of operating a gasifier upgraded in accordance with claim 5 or claim 6, the method including operating the gasification vessel of the gasifier at a higher pressure than the operating pressure used for the gasification vessel of the gasifier prior to upgrading of the gasifier whilst maintaining the oxygen supply pressure to the steam ejector at least the same as or even higher than the oxygen supply pressure to the gasifier prior to upgrading of the gasifier.

9. The method as claimed in claim 7 or claim 8, which includes applying a pressure gain of at least 0.5 bar to the oxygen supplied to the steam ejector, by means of the steam ejector.

10. A pressurized gasifier which includes a gasification vessel which is a pressure vessel; and

5 a steam ejector in flow communication with a steam supply facility, the steam ejector being configured to use steam from the steam supply facility as a motive fluid, the steam ejector also being in flow communication with a gaseous oxygen supply facility and being configured to compress oxygen from the oxygen supply facility to a higher pressure and to deliver an admixture of steam and oxygen to the gasification vessel.

10 11. The gasifier according to claim 10, which is a fixed bed dry bottom gasifier.

15 12. The gasifier according to claim 10 or claim 11, which is a jacketed gasifier configured to generate steam from heat released during gasification of a carbonaceous material, the jacket of the gasifier being in steam flow communication with an outlet of the steam ejector in use to add steam generated in the jacket to the admixture of steam and oxygen delivered by the steam ejector.

20 13. The gasifier according to any of claims 10 to 12, which includes a bypass line for steam from the steam supply facility to bypass the steam ejector before entering the gasification vessel, the steam bypass line being in flow communication with an outlet of the steam ejector.

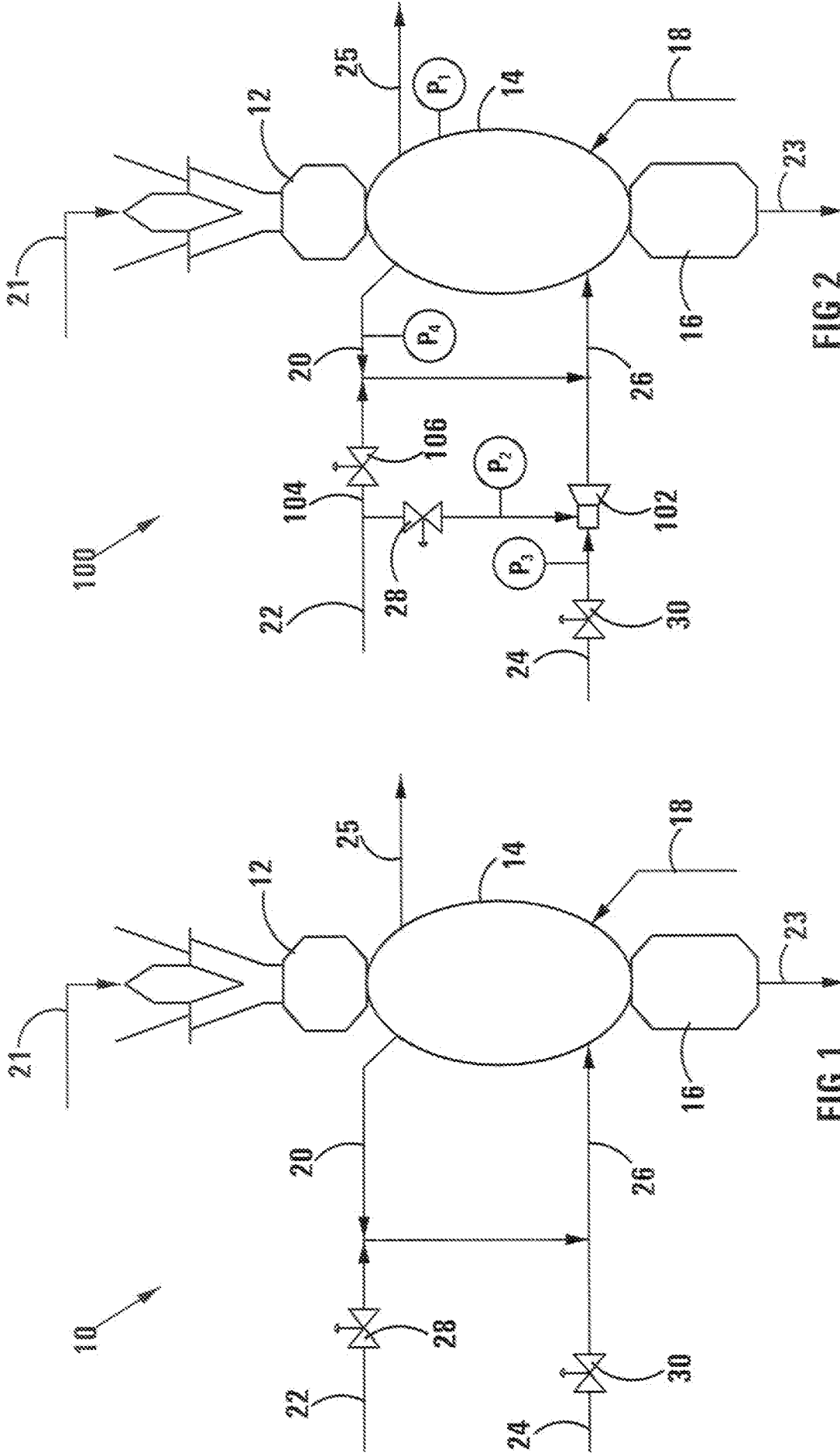


FIG 2

FIG 1