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(54) **Title**: GASIFICATION SYSTEM WITH WATER TREATMENT AND REUSE

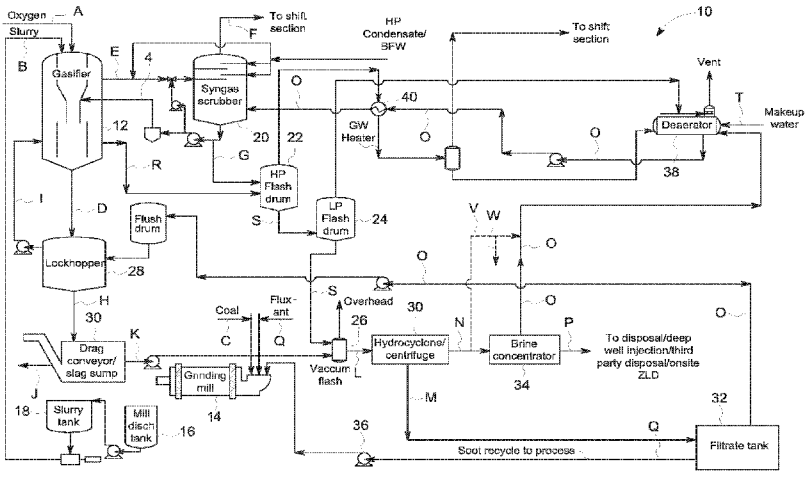


FIG. 1

(57) **Abstract**: In a gasification system, a desalination unit is used to treat the primary greywater stream. The desalination unit is preferably an evaporator. The desalination unit removes chlorides and produces a primary recycled grey water stream with a total dissolved solids concentration of 100 ppm or less. The desalination unit takes the place of the grey water settler in a conventional gasification system. The gasification system operates with a water recycle loop blowdown rate of 10% or less.

WO 2016/094612 A1

GASIFICATION SYSTEM WITH WATER TREATMENT AND REUSE

FIELD

[0001] This specification relates to water treatment and reuse in a gasification system.

BACKGROUND

[0002] In a typical gasification process, a feedstock such as coal is pulverized and fed to the reaction zone of a gasifier. Entrained flow gasification systems may feed the pulverized feedstock as a dry powder or mixed with water to form slurry. Other gasification systems such as fixed bed or fluidized bed systems typically feed the pulverized feedstock as a dry powder. In the reaction zone, the feedstock is heated with a sub-stoichiometric amount of oxygen. The reaction produces syngas, which is primarily made up of carbon monoxide and hydrogen, as well as slag, soot and various contaminants. In a typical gasification reactor, the reaction products travel to a quenching zone of the reactor where they are contacted with water. The reactor produces a quenching water blowdown stream and syngas. The syngas, along with some contaminants, flows from the gasifier to a syngas scrubber. In the syngas scrubber, the syngas is contacted with scrubbing water. The scrubbing water entrains fine solids and volatiles in the syngas. The syngas scrubber produces product syngas and a syngas scrubber blowdown stream.

[0003] Some water may be recovered from the syngas scrubber blowdown in one or more flash vessels. At least a portion of the syngas scrubber blowdown, for example flash vessel bottoms, is considered to be black water. In systems that use a water quenched gasification reactor, some un-gasified feedstock may be extracted from the quenching water blowdown along with some water to carry the solids. At least a portion of the quenching water blowdown is also considered to be black water. The black water is typically treated in a settler to produce an effluent, which may be called grey water. A portion of the grey water is returned to the syngas scrubber or gasifier thereby forming a primary water recycle loop. Another portion of the grey water is removed from the system as a grey water blowdown stream and replaced with make up water to prevent over-concentration of one or more contaminants in the primary water recycle loop.

[0004] The grey water blowdown stream contains various contaminants and must be treated before it can be discharged, stored in a brine pond or deep well disposal, or

processed to produce a zero liquid discharge. Some typical treatments include ammonia stripping, biological removal of organics, and solid-liquid separation, for example nanofiltration or reverse osmosis. Optionally, one or more of these treatment steps may produce treated water that can be returned to the gasifier or syngas scrubber in one or more supplementary water recycle loops. The settler bottoms may be treated, which may recover more water in a supplementary water recycle loop, or the settler bottoms may be returned to the gasifier as feedstock, or both.

INTRODUCTION

[0005] This specification describes a gasification system and process having a desalination step in the primary water recycle loop. Black water is treated to remove chlorides and other dissolved solids, optionally among other contaminants, before the treated water is recycled to the syngas scrubber or gasifier or both. The total dissolved solids of water continuing from the desalination step in the primary water recycle loop is preferably 100 ppm or less. The chloride concentration of water continuing from the desalination step in the primary water recycle loop is preferably 10 ppm or less. In one example, the desalination step is provided by a thermal evaporator.

[0006] One or more of a) substantially all (for example at least 80%) of the black water, or b) most (at least 50%) of the quenching water blowdown or c) most (at least 50%) of the syngas scrubber blowdown, is treated in a primary water recycle loop having a thermal evaporator or other desalination unit. Desalinated water, such as condensate from the evaporator, continues in the primary water recycle loop. The water treated in the desalination unit preferably includes quenching water blowdown.

[0007] The evaporator or other desalination unit is optionally the primary black water treatment unit for dissolved solids. In this sense, the desalination unit can be seen as replacing an aspect of the black water settler in a conventional gasification system allowing the settler (or other solid-liquid separation device) to be designed an operated primarily for soot removal. Optionally, the desalination unit may also allow one or more flash vessels in a conventional gasification system to be deleted. Compared to a settler, the evaporator is more expensive to build and operate. Possibly for that reason, evaporators have been considered in the past only to treat grey water blowdown. Even though some water from grey water blowdown treatment may return to the gasification system, the grey water blowdown treatment system is typically not considered to be part of the primary water recycle

loop of the gasification system. In an embodiment, the desalination unit treats black water within the gasification system.

[0008] In a process, chlorides are removed from recycled water in a gasification system. For example, chlorides may be removed in a blowdown stream from a desalination unit. The chloride removal rate may be selected to maintain a selected equilibrium chloride level in water recycled from a gasifier quench and/or scrubber in the gasification system. The selected equilibrium chloride concentration may be 500 ppm or less, for example, in the range of 150 to 200 or 300 ppm. The equilibrium chloride concentration may be selected in the design of the system, or it may be selected as a set point or other value in a controller or control process associated with the desalination unit.

[0009] When the evaporator is added to the primary water recycle loop, the primary water recycle loop blowdown rate is reduced. Despite the reduced blowdown rate, the equilibrium chloride concentration in the water loop is also reduced because the evaporator produces blowdown brine with a high concentration of dissolved solids. Reduced chloride concentration in the primary water recycle loop can reduce scaling and corrosion in the gasification system and reduce the syngas dew point. The need for make up water, and the cost of treating the water recycle loop blowdown, are both reduced. In an embodiment, the gasification system make up water demand is reduced by over 25% relative to a comparative system with only a settler.

[0010] A gasification system described in this specification operates with a primary water recycle loop blowdown rate of 10% or less of the black water. However, the total dissolved solids (TDS) concentration in the primary water recycle loop is maintained at 100 ppm or less through the use of a desalination unit, for example a thermal evaporator, in the primary black water treatment stream. At least a third, but optionally - all (for example 80% or more) of water recycled to the gasification reactor for quench water, or to the syngas scrubber, or both, has a TDS concentration of 100 ppm or less, or a chloride concentration of 10 ppm or less, or both.

BRIEF DESCRIPTION OF THE FIGURES

[0011] Figure 1 is a process flow diagram of a gasification system.

DETAILED DESCRIPTION

[0012] Figure 1 shows a gasification system 10. The system has an entrained bed gasifier 12 that receives oxygen A and slurry B. Oxygen A is provided to the gasifier 12 in a sub-stoichiometric amount, optionally as air. The gasifier 12 may operate, for example, at about 1250 to 1600 degrees C, at a pressure of about 30 to 80 atmospheres, and with a residence time of about 0.4 to 2 seconds. The slurry B in the example illustrated is coal slurry produced by feeding coal C and water Q to a grinding mill 14, mill discharge tank 16 and slurry tank 18. However, a gasification system 10 can also be configured to gasify any other hydrocarbon containing material such as wood, waste plastic, or petroleum coke. Further, the gasifier 12 may be fed with dry feedstock rather than slurry B. Alternatively, fixed bed or fluidized bed gasifiers may be used, which typically operate with a dry feedstock and at lower temperature and pressure, but longer residence time, relative to an entrained bed gasifier. The gasifier 12 produces syngas E, quenching water blowdown R and gasifier bottoms D. Syngas E is treated in syngas scrubber 20 to produce product syngas F, which is typically processed further before being used as a fuel. Syngas scrubber 20 also produces scrubber blowdown G. Gasifier bottoms D are treated in lockhopper 28 (alternatively called a bucket locker) to separate slag H from bottom water I. Slag H (which still has some water mixed with it) is separated further by drag conveyor 30 into coarse slag J and fine slag K. In another option, the gasifier 12 may be combined with a Radiant Syngas Cooler (RSC). In general, the raw syngas leaving the gasifier 12 can be cooled by a radiant and/or convective heat exchanger and/or by a direct quench system, wherein water or cool recycled gas is injected into the hot raw syngas. The syngas may pass through one or more flash vessels for heat recovery and to cool the syngas.

[0013] Quenching water blowdown R flows with scrubber blowdown G through a high pressure flash drum 22 and a low pressure flash drum 24. Flash drum bottoms S flows with fine slag K (along with some water mixed with it) through a vacuum flash tank 26 to form blackwater L. In some cases, a second vacuum flash tank may be added. Although some water is removed in flash drums 22 and 24 most (at least 50%, typically 80% or more) of the quenching water blowdown R and most (at least 50%, typically 80% or more) of the scrubber blowdown G is present in blackwater L. Most (at least 50%, typically 80% or more) of the water in slag H is also present in blackwater L. In the alternative, no more than half of the water (i.e. no more than half of the combination of the quenching water blowdown R and the scrubber blowdown G) is removed in any single treatment unit upstream of blackwater L.

Blackwater L is therefore considered part of the primary water recycle loop in the gasification system 10. In the gasification system 10 shown, the primary water recycle loop is made up of streams G, R, the stream between the flash drums, S, L, M, N, O and G and the intervening process units 20, 12, 2, 24, 26, 30, 34, 38 and 40.

[0014] Optionally, blackwater L is treated in solid-liquid separator 30, alternatively called a soot separator, to produce solids fraction M and pre-treated black water N, alternatively called grey water. Solid-liquid separator 30, if any, is used primarily to recycle soot or slag. The solids fraction M contains small particles of slag and soot, which can be added to slurry B to increase syngas production. If a solid-liquid separator 30 is used, the pre-treated black water N preferably includes 80% or more, or 90% or more, of black water L. A third or more, optionally all, of blackwater N or L continuing in the primary water recycle loop is fed to desalination device 34. Desalination device 34 produces effluent O and brine P.

[0015] The solid-liquid separator 30 is preferably a hydrocyclone or centrifuge but might also be a filter, gravity separator (alternatively called a settler or clarifier) or Voraxial separator or other device that produces a dewatered solids fraction M. As between a hydrocyclone and a centrifuge, the hydrocyclone is preferred. Depending on the type of solid-liquid separator 30 used, solids fraction M may be difficult to pump. In this case, the solids fraction M can be transferred to a soot tank 32 and diluted with some of the effluent O. A transfer pump Q can then be used to convey diluted soot Q to the grinding mill 14 to be combined into slurry B. Some of the effluent O can also be sent to the lockhopper 28. A flocculant or coagulant, for example 1-10 ppm of a polymeric flocculant, may be added to blackwater L treated in the solid-liquid separator 30.

[0016] Most of effluent O is re-circulated to syngas scrubber 20 or gasifier 12, optionally after passing through a deaerator 38 and heat exchanger 40. Deaerator 38 is not required if all of the effluent O has passed through a desalination device 34 such as an evaporator that produces a degassed effluent O. Some of effluent O may pass directly or through the syngas scrubber 20 to the gasifier 12 for use as gasifier quench water U. In this way, effluent O replaces at least a material fraction, for example one third to all, of the conventional recycle of non-desalinated grey water from a settler. With sufficient flow through desalination unit 34, the gasification system 10 may require only one vacuum flash tanks upstream of the settler.

[0017] Optionally, there may be a by-pass line V around the desalination device 34. The by-pass line V may have a blowdown outlet W and various valves not shown. In one option, the by-pass line 34 is kept normally closed but opened temporarily when required to service the desalination device 34. In another option, the by-pass line V is used to provide a path in the primary water recycle loop in parallel with one or more desalination units 34. For example, if an existing gasification system is to be retrofit with two or three desalination units 34 plumbed in parallel in the primary water recycle loop, the by-pass line V can be used continuously while only some, i.e. one or two, of the final number of desalination units 34 have been installed. After all desalination units 34 have been installed, the by-pass line V can be normally closed but opened temporarily when required to service a desalination device 34 in place of providing redundant desalination unit 34 capacity. In another option, a gasification system can be operated normally with only part of the black water L or N passing through the desalination device 34. In this option, at least one third, preferably at least one half, of the black water L or N passes through a desalination device 34. At some point below the one-third threshold, the amount of water flowing through the desalination device 34 would not materially affect the pH or chloride concentration of recycled water and would not be considered part the primary water recycle loop. In cases, or at times, where there is black water L or N flowing both through one or more desalination devices 34 and the by-pass line V, the blowdown outlet W is preferably kept closed such that all blowdown from the primary water recycle loop is extracted as brine P. In this way, blowdown from the primary water recycle loop is still withdrawn at a chloride concentration higher than the chloride concentration in blackwater L or N, and the required volume of make up water is correspondingly reduced.

[0018] Having at least one desalination device 34 in the primary water recycle loop, with or without a by-pass line V, allows the chloride concentration in effluent O to be adjusted by, for example, altering the ratio of effluent O to brine P or altering the flow in by-pass line V. The desalination device 34, particularly an evaporator, can also help manage the ammonia concentration in the primary water recycle loop. In one process, the chloride level in effluent O flowing to the syngas scrubber 20 is adjusted to provide the syngas dew point (alternatively called hydrocarbon dew point) within a desired range, for example below 250°C, or in a range of 230°C to 240°C. The syngas dew point increases with chloride concentration. Maintaining a reasonably low syngas dew point can, for example, allow lower cost alloys to be used in the syngas scrubber 20 or other components.

[0019] Desalination device 34 is preferably a thermal evaporator. The evaporator may be, for example, a vertical tube falling film evaporator with mechanical vapor compression (MVC), alternatively called mechanical vapor recompression (MVR). Alternatively, the evaporator may be a steam driven evaporator, optionally using waste steam from the gasification system 10, for example from a jacket around the gasifier 12. The evaporator may operate with a seeded slurry process to reduce scaling in the evaporator. In one example of a seeded slurry process, calcium sulfate crystals are encouraged to form in the evaporator. The evaporator may be seeded with calcium sulfate seed crystals or, despite the phrase "seeded slurry," the crystals may form spontaneously from compounds in the evaporator feed water even without seed crystals being added. In some cases a compound such as sodium sulfate or calcium chloride is added to the water in the evaporator (for example by adding the compound to the feed water or into the evaporator sump) to alter the relative concentration of calcium and sulfate ions to encourage crystal formation. The effluent O from the evaporator may also be called a condensate or distillate. The effluent O preferably has less than 100 ppm of total dissolved solids (TDS) and less than 10, or less than 5, ppm of chlorides. The low chloride concentration in the effluent O may allow for less corrosion resistant (and therefore less expensive) materials to be used in the gasification system 10 compared to conventional practice. The high chloride concentration in the brine P may allow for less blowdown (brine P) to be removed from the primary water recycle loop or for correspondingly less make up water T to be added compared to conventional practice. The low TDS concentration may reduce scaling problems in the gasification system 10. Including overheads from flash drums 22, 24 and 26, it is preferable, though optional, for all scrubber blowdown water or gasifier quench water to be recycled at less than 100 ppm TDS and less than 10 ppm chloride.

[0020] Brine P preferably has a flow rate that is 10% or less of the flow rate of one or more of blackwater L, pre-treated black water N, or effluent O. Each of flash drums 22, 24 and 26 are optional. However, at least one flash drum is useful for removing non-condensable gases such as H_2S. Brine P may optionally be treated further in a crystallizer (for example with a forced circulation evaporator), spray dryer, brine concentrator or other reduced or zero liquid discharge system. Alternatively, brine P may be removed for disposal or further treatment off site. The brine P flow rate, or other parameters affecting the removal of chlorides from the desalination device 34, can be designed or actively controlled to provide a selected chloride concentration in the effluent O or a selected equilibrium chloride

concentration in the water recycle loop, measured for example in the flash drum bottoms S. The selected equilibrium chloride concentration may be in the range of 500 ppm or less, for example 150 to 200 or 300 ppm. The selected equilibrium concentration may be implemented in the design of the gasification system 10 and its operating process or the selected equilibrium concentration may be implemented in real time, for example by connecting a chloride concentration sensor to a controller for the desalination device 34 or by otherwise adjusting operation of the desalination device 34 as required so that brine P removes enough chloride to keep the equilibrium chloride concentration below a selected value or within a range including the selected value.

[0021] In a modeled example of a coal gasification system as in Figure 1, black water has a flow rate is 120 m^3/hr. The black water is pretreated to remove soot, which removes 10 m^3/hr of a 10% solids soot mixture. The remaining pre-treated black water is treated in a vertical falling film mechanical vapor compression (MVR) evaporator. 105 m^3/hr of distillate is produced for return to the syngas scrubber or gasifier. The distillate has a TDS concentration of about 50 ppm, a chloride concentration of less than 1 ppm, and a pH of 8.5. 5 m^3/hr of blowdown is produced with a TDS concentration of about 75,000 ppm and a pH of about 5. Equilibrium chloride concentration in the low-pressure flash drum bottoms was less than 150 ppm. The system being modeled is generally as shown in Figure 1.

[0022] Soot removal factors for the model were predicted based on treating samples of black water in a laboratory scale centrifuge. The black water was obtained from a coal gasification plant that supplied coal slurry to an entrained bed gasifier. The black water contained a mixture of gasifier quench water blowdown and syngas scrubber blowdown. The centrifuge operated at 500 rpm with a 5 minute residence time without chemical additives.

[0023] Optionally, a coagulant or flocculant can be used to reduce the residence time. Polymeric flocculants are preferred, without additional metal salt coagulants or flocculants. For example, in some later trials a cationic polyacrylamide compound was added to the black water in the centrifuge. Similarly, a coagulant or flocculant, preferably a polymeric flocculant, can be added when treating blackwater in another solid-liquid separation device. A preferred flucculant is a cationic polyacrylamide flocculant such as BetzDearborn CP1153 available from GE Water & Process Technologies. The dosage may be 1 to 10 ppm, or 3-5 ppm, of polymeric flocculant. In tests on black water in a laboratory scale centrifuge as described above, the clarified effluent had 58 NTU turbidity after being treated in the centrifuge at 1000 rpm for 20 minutes without adding a flocculant. With 3 ppm

of CP1153, the clarified effluent had about 9 NTU turbidity after being treated in the centrifuge at 1000 rpm for 3 minutes. With 5 ppm of CP1153, the clarified effluent had about 4 NTU turbidity after being treated in the centrifuge at 1000 rpm for 3 minutes. The total suspended solids (TSS) concentration of the clarified effluent for black water samples centrifuged with 3 and 5 ppm of CP1153 was about 1 mg/L.

[0024] Evaporator performance factors for the model were based on distilling the centrifuge effluent described above in a bench scale distillation unit to produce 95% recovery of distillate. Sodium sulfate was added to the centrifuge effluent to simulate the addition of sodium sulfate to the feedwater that would be appropriate for a calcium sulfate seeded slurry thermal evaporator. pH of the centrifuge effluent was 7.4. pH of the brine in the bottom of the distillation flask after 95% recovery was about 5.

[0025] Based on the ammonium concentration in the evaporator feed water, the anticipated loss of ammonia gas in the distillation process would have caused the pH of the brine after 95% recovery to be reduced to less than 3. This would suggest that expensive corrosion resistant materials would be required in the evaporator, and that scaling might make operation of the evaporator unreliable. However, over an 18-day trial with a seeded slurry evaporator, the pH of the brine remained stable at about 5 and no unusual accumulations of scale were observed.

[0026] It is not certain why the pH of the brine remained at about 5. One possibility is that formic acid in the evaporator feed water produced ammonium formate (NH_4COOH) in the brine and so reduced the amount of volatile ammonia vapor. Another possibility is that sodium initially in the feed water or added to simulate a seeded slurry process combined with formate or other compounds to produce a buffering compound. Formate is created in the gasifier from gasification of coal (and possibly other feedstocks) as the reaction products are quenched through a range of about 250 to 300 degrees C. Accordingly, the inventors predict that the reduced change in pH during distillation (i.e. observed brine pH of 5 rather than a predicted brine pH of 3) is likely to occur at least in any process in which gasifier quench water is part of the black water treated in the evaporator.

[0027] The brine was boiled out further and produced a loose white solid primarily made up of calcium sulfate, which suggests that the brine was suitable for a seeded slurry evaporator process in the evaporator and that waste brine could be crystallized in a zero liquid discharge system.

[0028] In a comparative example, a gasification plant was modeled in which the centrifuge and evaporator in the model above were replaced with an additional vacuum flash tank and a conventional settler. The settler produces an effluent having almost 300 ppm chlorides and a pH of 7. The grey water blowdown rate is 27 m^3/hr. Equilibrium chloride concentration in the low pressure flash drum bottoms was over 250 ppm. The comparative system required about 40% more make up water.

[0029] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

CLAIMS:

We claim:

1. A method of treating water in a gasification plant comprising a step of desalinating syngas scrubber blowdown or quench water blowdown or both in the primary water recycle loop of the gasification plant and recycling the desalinated water to a syngas scrubber or gasifier quench water stream of the gasification plant.

2. The method of claim 1 wherein at least half of the quench water blowdown is desalinated.

3. The method of claim 1 wherein at least half of the syngas scrubber blowdown is desalinated.

4. The method of claim 1 wherein the desalinated water recycled to the syngas scrubber or the gasifier quench water stream has a chloride concentration of less than 10 ppm.

5. The method of claim 1 wherein the desalinated water recycled to the syngas scrubber or the gasifier has a total dissolved solids concentration of 100 ppm or less.

6. The method of claim 1 wherein 80% or more of black water produced in the gasification plant is desalinated.

7. The method of claim 1 wherein the desalination occurs in a thermal evaporator.

8. The method of claim 1 wherein the thermal evaporator is operated with a seeded slurry.

9. The method of claim 1 wherein the thermal evaporator is operated with a calcium sulfate slurry.

10. The method of claim 1 further comprising a soot removal step before the desalination step, wherein the soot removal step comprises adding a polymeric flocculant.

11. The method of claim 1 wherein feedwater to the desalination step is adjusted to promote formation of calcium sulfate crystals.

12. The method of claim 1 wherein feedwater to the desalination step includes gasifier quench water blowdown.

13. The method of claim 1 comprising a step of adding sodium to the desalination step.

14. The method of claim 1 wherein the gasifer is an entrained bed gasifier.

15. The method of claim 1 wherein the gasifier is fed coal.

16. The method of claim 1 wherein the gasifier is fed a coal slurry.

17. The method of claim 1 further comprising forming ammonium formate during the desalinating step.

18. A gasification system having,
a primary water recycle loop in which water is drawn from the gasifier or syngas scrubber or both and returns to the gasifier quench water inlet or syngas scrubber or both; and,
a desalination unit in the primary water recycle loop.

19. The gasification system of claim 18 wherein the desalination unit comprises a thermal evaporator.

20. The gasification system of claim 18 wherein the gasifier is an entrained bed gasifier.

21. The gasification system of claim 20 wherein the gasifier receives a coal, preferably a coal slurry.

22. The gasification system of claim 18 wherein the desalination unit receives gasifier quench water blowdown.

23. The gasification system of claim 18 wherein at least most of the blowdown from the primary water recycle loop is removed through the desalination unit.

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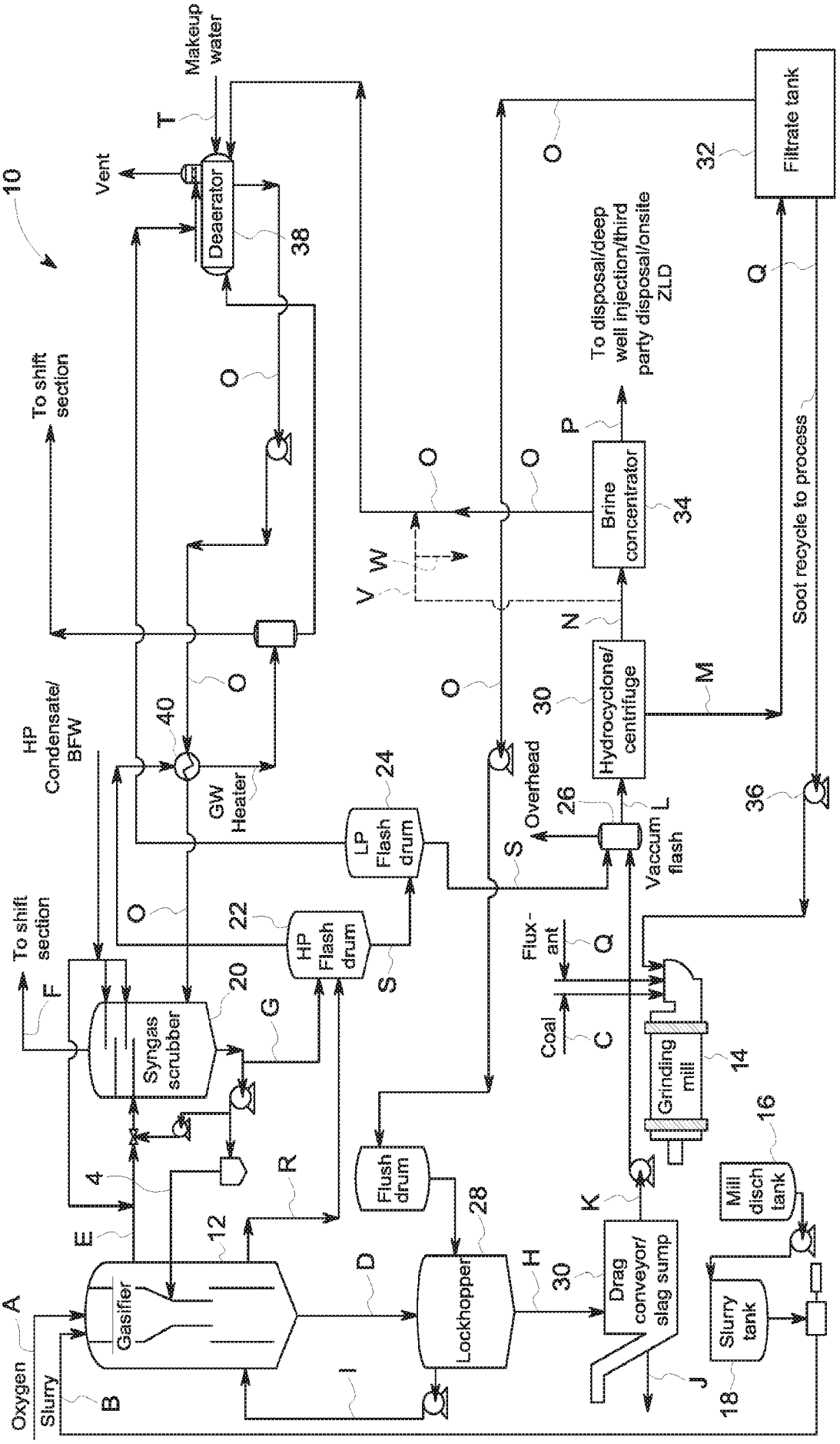

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To shift section
F
Syngas scrubber
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Grinding mill
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Coal
C
Flux-ant
Q
Overhead
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S
Vaccum flash
L
Hydrocyclone/ centrifuge
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M
Brine concentrator
34
P
To disposal/deep well injection/third party disposal/onsite ZLD
V
W
O
Filtrate tank
32
Q
Soot recycle to process
36

FIG. 1

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/064897

A. CLASSIFICATION OF SUBJECT MATTER
INV. C10J3/48 C02F1/52 C02F103/18
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10J C02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/209407 A1 (ARYA ALAY S [IN] ET AL) 1 September 2011 (2011-09-01) paragraph [0016] - paragraph [0027]; figure 1	1-23
A	US 2011/016787 A1 (DINU CONSTANTIN [US] ET AL) 27 January 2011 (2011-01-27) the whole document	1-23
A	US 2009/282735 A1 (FIEN ROBERT B [US] ET AL) 19 November 2009 (2009-11-19) the whole document	1-23

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 March 2016	10/03/2016

Name and mailing address of the ISA/	Authorized officer
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1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2015/064897

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		CN 101967406 A	09-02-2011
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		US 2011016787 A1	27-01-2011
US 2009282735 A1	19-11-2009	NONE	