

1 **METHOD AND APPARATUS FOR SULFUR RECOVERY**

2 CROSS REFERENCE TO PRIOR APPLICATIONS

3 **[0001]** The present application claims priority under the Paris Convention to US
4 Application Number 62/000,845, filed May 20, 2014, the entire content of which is
5 incorporated herein by reference.

6 TECHNICAL FIELD

7 **[0002]** The following relates generally to methods and apparatuses for sulfur recovery.
8 In particular, the following relates to recovery of sulfur from acid gas streams in Claus plants.

9 BACKGROUND

10 **[0003]** Sulfur recovery units (SRUs) are widely used to recover sulfur from acid gas
11 streams. For example, an acid gas stream can be produced through amine gas treating
12 process, wherein sour gas containing hydrogen sulfide (H_2S) is passed through an absorber
13 unit and a regenerator unit to produce a gas stream rich in hydrogen sulfide, which is
14 commonly known as the amine acid gas stream. Depending on the composition of the sour
15 gas, the acid gas stream may also contain other components, such as carbon dioxide (CO_2),
16 water vapour (H_2O), ammonia (NH_3), and other impurities.

17 **[0004]** Generally, sulfur is recovered from acid gas stream in sulfur recovery units using
18 a process known as the Claus process, which is described, for example, in the article titled
19 “Fundamentals of Sulfur Recovery by the Claus Process” by B. G. Goar, published in Gas
20 Conditioning Conference Report (1977).

21 **[0005]** It is also known that the capacity of the sulfur recovery unit can be enhanced
22 through oxygen enrichment, which is a process wherein a supplemental oxygen stream is
23 introduced into the reaction furnace to increase the concentration of oxygen in the furnace.
24 The increased oxygen concentration increases the amount of hydrogen sulfide that is
25 combusted during the Claus process. The capacity of the SRU is typically increased when
26 oxygen enrichment is used, primarily because a portion of the inert gas (e.g. nitrogen) that is
27 normally present in ambient air is replaced with supplemental oxygen, which hydraulically
28 unloads the SRU. This allows an increased amount of acid gas feed to be introduced to the
29 SRU, therefore raising the overall sulfur production rate.

1 **[0006]** However, the degree to which oxygen enrichment can be used in a commercial
2 Claus plant is generally limited by the maximum allowable operating temperature of the
3 refractory material used in the reaction furnace of the SRU. For example, typical refractory
4 material used in commercially available reaction furnaces have continuous maximum
5 operating temperatures of up to around 2850 °F (1565 °C). To reduce the stress on the
6 refractory material, operators of Claus plants may conservatively limit the operating
7 temperature to as low as between 2500 °F and 2600 °F. Since oxygen enrichment generally
8 increases the operating temperature, the amount of oxygen being added into the reaction
9 furnace is closely monitored and controlled to ensure that the operating temperature does
10 not exceed the desired or maximum allowable temperature of the refractory material. As a
11 result, the degree of oxygen enrichment is generally limited and thus the capacity of these
12 SRUs remain relatively low.

13 **[0007]** Some attempts have been made to increase the capacity of the SRUs,
14 particularly in Claus plants where oxygen enrichment is used. For example, U.S. Patent No.
15 6,508,998 to Nasato describes a process for improving the SRU capacity in an oxygen
16 enriched Claus plant by introducing a process recycle stream through an ejector into the
17 furnace, such that the recycle stream acts as a heat sink for controlling the operating
18 temperature in the reaction furnace. However, such process can be challenging to
19 implement in some cases, since it requires handling of the recycle gas stream. Since the
20 recycle gas stream is typically at the sulfur dew point, the sulfur vapor in the recycle stream
21 may condense to liquid and subsequently solidify and deposit inside reaction furnace burner
22 and/or process lines. Condensation or solidification of sulfur is an operating hazard, since it
23 may result in reduced Claus plant capacity, poor burner performance, or catastrophic
24 equipment failures. Moreover, recycle stream may contain undesirable contaminants such
25 as ammonia, ammonia salts, and unburnt hydrocarbons, which can result in the formation of
26 solid salts which can foul the equipment and reduce the capacity or affect the performance
27 of the SRU. The process will also generally require a steam jacket for the ejector and
28 process lines as well as recycle piping and valves to operate properly, which increases the
29 cost of implementation and operation of the plant.

30 **[0008]** U.S. Patent No. 5,294,428 to Watson describes a two-stage combustion process
31 for recovering sulfur from a feed gas stream containing hydrogen sulfide. In Watson's
32 process, two separate combustion regions are used to handle the heat load resulting from
33 the oxygen enriched combustion process. However, Watson's process requires two sets of

1 thermal stage equipment and a relatively large plot space to install all of the required
2 equipment. Accordingly, the process is generally expensive and difficult to implement,
3 especially when retrofitting an existing Claus plant where there may be space limitations.

4 **[0009]** It is an object of the following to address at least one of the above disadvantages.

5 SUMMARY

6 **[0010]** In one aspect, a sulfur recovery system is provided, the system comprising a
7 reaction furnace, a motive fluid stream for providing a motive fluid to an ejector, an acid gas
8 stream for providing an acid gas to the ejector, the ejector connected to the reaction furnace
9 for providing to the reaction furnace a mixture comprising the motive fluid and the acid gas,
10 and a combustion gas supply stream connected to the reaction furnace for providing a
11 combustion gas to the reaction furnace, the combustion gas comprising oxygen.

12 **[0011]** In another aspect, a method for treating an acid gas stream in a sulfur recovery
13 system is provided, the method comprising providing a motive fluid to an ejector, providing
14 the acid gas stream to the ejector to obtain a mixture, the mixture comprising the motive fluid
15 and the acid gas stream, providing the mixture to a reaction furnace, providing a combustion
16 gas to the reaction furnace, the combustion gas comprising oxygen, and reacting the
17 contents of the reaction furnace.

18 BRIEF DESCRIPTION OF THE DRAWINGS

19 **[0012]** The features of the invention will become more apparent in the following detailed
20 description in which reference is made to the appended drawings wherein:

21 **[0013]** FIG. 1 is a schematic diagram of a sulfur recovery system according to one
22 embodiment;

23 **[0014]** FIG. 2 is a flow diagram illustrating a method for recovering sulfur according to
24 one embodiment; and

25 **[0015]** FIG. 3 is a chart showing the relationship between the stream flow rate and the
26 oxygen concentration in one embodiment.

1 DETAILED DESCRIPTION

2 **[0016]** The terms “comprise”, “comprises”, “comprised” or “comprising” may be used in
3 the present specification. As used herein (including the description and/or the claims), these
4 terms are to be interpreted as specifying the presence of the stated features, integers, steps
5 or components, but not as precluding the presence of one or more other feature, integer,
6 step, component or a group thereof as would be apparent to persons having ordinary skill in
7 the relevant art.

8 **[0017]** In one aspect, a sulfur recovery system is provided, the sulfur recovery system
9 comprising a reaction furnace, a motive fluid stream for providing a motive fluid to an ejector,
10 an acid gas stream for providing an acid gas to the ejector, the ejector being connected to
11 the reaction furnace for providing to the reaction furnace a mixture comprising the motive
12 fluid and the acid gas, and a combustion gas supply stream connected to the reaction
13 furnace for providing a combustion gas to the reaction furnace, the combustion gas
14 comprising oxygen. For example, the combustion gas may be air, a mixture of air and
15 supplemental oxygen, or pure oxygen.

16 **[0018]** In one embodiment, the motive fluid stream is supplied to the ejector at a first
17 pressure, and the acid gas stream is supplied to the ejector at a second pressure, the first
18 pressure being greater than the second pressure.

19 **[0019]** In one embodiment, the acid gas comprises amine acid gas. For example, amine
20 acid gas may be produced by processing sour gas with the amine gas treating process,
21 which is well known in the art. In another embodiment, the acid gas comprises sour water
22 stripper acid gas. As will be appreciated, the acid gas will generally comprise at least 5 mole
23 percent hydrogen sulfide and typically up to about 80-95 mole percent hydrogen sulfide. It
24 will be understood that amine acid gas may comprise other gases including, but not limited
25 to, carbon dioxide, water vapour, ammonia, and other impurities. As will be appreciated, the
26 acid gas stream as used herein is generally a clean stream and not a recycled stream (i.e. a
27 stream which has been at least partially treated by the Claus process).

28 **[0020]** In one embodiment, the motive fluid comprises steam. In other embodiments, the
29 motive fluid may comprise pressurized liquid water, water vapor, supersaturated water
30 vapor, hydrogen sulfide, sulfur dioxide, carbon dioxide, or mixtures thereof.

1 [0021] In one embodiment, the system further comprises a sulfur recovery block
2 connected to the reaction furnace for receiving an effluent stream from the reaction furnace,
3 and a back pressure control valve positioned downstream from the sulfur recovery block for
4 controlling the operating pressure of the sulfur recovery block.

5 [0022] In another embodiment, the sulfur recovery system further comprises a sulfur
6 recovery block connected to the reaction furnace for receiving an effluent stream from the
7 reaction furnace, a tail gas treatment block connected to the reaction furnace for receiving a
8 tail gas stream from the sulfur recovery block, and a back pressure control valve positioned
9 downstream from the tail gas treatment unit for controlling the operating pressure of at least
10 one of the tail gas treatment unit block and the sulfur recovery block. The sulfur recovery
11 system may also include another back pressure control valve positioned downstream of the
12 sulfur recovery block, but upstream of the tail gas treatment unit block.

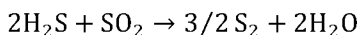
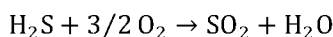
13 [0023] FIG. 1 is a schematic of a sulfur recovery system 100 according to one
14 embodiment. In the sulfur recovery system 100, an acid gas feed stream 30 is used to
15 introduce amine acid gas, and a steam supply line 20 is used to introduce steam. The acid
16 gas feed stream 30 and the steam supply line 20 are connected to a vapor-liquid separator
17 80, which is used to separate out any liquid present in the input streams. Any liquid that is
18 separated from the input streams is pressurized by a compressor 86 and removed via line
19 84, and the separated gas is provided to the burner 120 of the reaction furnace 130 via line
20 82.

21 [0024] An oxygen inlet stream 40 and an air inlet stream 50 is used to introduce oxygen
22 and air, respectively, to the burner 120. In the embodiment of FIG. 1, the air inlet stream 50
23 is shown as having a main line and a trim line 55. Other inlet streams, such as a sour water
24 stripper acid gas (SWSAG) stream 10 and a fuel gas stream 60 may also be connected to
25 the burner 120 for introducing additional gases to the burner. For example, the SWSAG
26 stream 10 may be used to introduce a gas stream comprising H_2S and NH_3 , and the fuel gas
27 stream 60 may be used to introduce fuel for the burner 120.

28 [0025] In the configuration of system 100, an ejector 26 is illustrated as being connected
29 to the steam supply line 20 and the acid gas feed stream 30. The steam being carried by the
30 steam supply line 20 is generally a high pressure steam, which acts as a motive fluid when
31 introduced into the ejector 26. In use, the amine acid gas being carried by the acid gas feed
32 stream 30 is introduced into the ejector 26 as the suction fluid to produce an output stream,

1 which is then fed into the burner 120 via the vapor-liquid separator 80 and line 82. It will be
2 appreciated that since the output stream of the ejector 26 is formed by mixing the high
3 pressure steam with the amine acid gas, the pressure of the output stream will generally be
4 greater than the pressure of the input amine acid gas, but lower than the pressure of the
5 input steam.

6 **[0026]** The mixture of inlet streams are then combusted in the burner 120 and evolved
7 into the reaction furnace 130, where the reactions of the Claus process occur. Specifically, in
8 the reaction furnace 130, approximately one third of hydrogen sulfide is reacted with oxygen
9 to produce sulfur dioxide and water, and the remaining hydrogen sulfide is reacted with the
10 sulfur dioxide to produce sulfur and water. These reactions are represented by the following
11 formulae:



12 **[0027]** The effluent from the reaction furnace 130 is then sent to a sulfur recovery block
13 140, which is generally used to extract sulfur from the reaction furnace effluent. For example,
14 the sulfur recovery block 140 may comprise one or more condensers, heaters, and/or
15 catalytic converter reactors. Such components are well known and reactions which may
16 occur in such components are described, for example, in U.S. Patent No. 6,508,998 to
17 Nasato and U.S. Patent No. 7,597,871 to Ferrell.

18 **[0028]** The stream exiting the sulfur recovery block 140 may then be introduced into a
19 tail gas treatment unit (TGTU) block 160, which is used to reduce the amount of any residual
20 sulfur bearing compounds present in the stream. The stream exiting the TGTU block 160 is
21 sent to an incinerator before being released into the atmosphere. Alternatively, the stream
22 exiting the sulfur recovery block 140 may be directly sent to the incinerator without being
23 passed through the TGTU block 160, if the gas being vented from the incinerator is at an
24 acceptable sulfur content level for meeting the emission standards.

25 **[0029]** The system 100 further includes a number of valves for regulating the flow of
26 gases through various streams and lines. As illustrated in FIG. 1, the flow of pressurized
27 steam through steam supply line 20 and the flow of amine acid gas through the acid gas
28 feed stream 30 are regulated by normally closed (NC) valves 22, 32 and normally open (NO)
29 valve 34. The outlet of the ejector 26 is regulated by the NC valve 24. In the oxygen inlet

1 stream 40, the flow of gas is regulated by valve 42, and in the air inlet stream 50, the flow is
2 regulated by valve 52 in the main line and by valve 57 in the trim line 55.

3 **[0030]** The valves are generally controlled according to one or more parameters
4 measured in the system 100. For example, NC valve 22 for regulating the flow of steam is
5 adjusted according to the amount of flow measured by the flow control 220. As illustrated in
6 FIG. 1, other NC valves 24, 32 and NO valve 34 are controlled by the flow controller 240,
7 which is connected to valve 42 positioned on the oxygen inlet stream 40. Valve 52
8 positioned on the main line of the air inlet stream 50 is controlled by a controller unit 270,
9 and valve 57 positioned on the trim line 55 is controlled by the tail gas analyzer.

10 **[0031]** Various measurement units, controllers and/or indicators are located throughout
11 the system 100 for monitoring and/or controlling different process parameters. For example,
12 flow indicators 210, 230, 260 are located on the SWSAG stream 10, acid gas feed stream
13 30, and the fuel gas stream 60, respectively, for measuring the flow of gas through each of
14 the respective streams. Pressure controller 250, which is in communication with the
15 controller unit 270, is located on the air inlet stream 50 for controlling the pressure of the gas
16 flowing through the air inlet stream 50. The measurements taken from these measurement
17 units, controllers and/or indicators are transmitted to the controller unit 270, and if necessary,
18 the controller unit 270 may generate and transmit signals to control the flow of gas in various
19 inlet/outlet streams. As shown, a hand control unit 280 for manually controlling the control
20 unit 270 may be provided. Additionally, the temperature inside the reaction furnace 130 may
21 be monitored by a temperature indicator 330.

22 **[0032]** In one embodiment, one or more back pressure control valves are located
23 downstream of the sulfur recovery block 140. The one or more back pressure control valves
24 are generally used to control the operating pressure of any sulfur recovery systems located
25 upstream from the one or more valves. For example, in the system 100 illustrated in FIG. 1,
26 a first back pressure control valve 170 is located downstream of the TGTU block 160 and the
27 sulfur recovery block 140 for controlling the operating pressure of the sulfur recovery block
28 140 and/or the TGTU block 160, and a second back pressure control valve 150 is located
29 downstream of the sulfur recovery block 140 but upstream of the TGTU block 160 for
30 controlling the operating pressure of the sulfur recovery block 140. Alternatively, the system
31 100 may comprise only the first pressure control valve 170 and not the second pressure
32 control valve 150 if sufficient control of the operating pressure in both sulfur recovery
33 systems can be attained using only one back pressure control valve.

1 **[0033]** In other embodiments where the system does not include a TGTU block, the tail
2 gas exiting from the sulfur recovery block may be sent directly to the incinerator. In such
3 embodiments, the pressure control valve may be located between the sulfur recovery block
4 and the incinerator to control the operating pressure of the sulfur recovery block.
5 Alternatively, it will be appreciated that the pressure control valve may be located
6 downstream of the incinerator and upstream of the stack.

7 **[0034]** The one or more back pressure control valves are generally adjusted according
8 to various measurements taken from the system 100. In the embodiment illustrated in FIG.
9 1, the first back pressure control valve 170 is controlled by the pressure controller 370 and
10 the second pressure control valve 150 is controlled by the pressure controller 350. The
11 pressure controllers 350, 370 are configured to monitor the pressure of any sulfur recovery
12 systems located upstream of the respective valves, and control the respective valves 150,
13 170 to adjust the operating pressure of these sulfur recovery systems. By restricting the flow
14 of gas exiting the sulfur recovery block 140 and/or the TGTU block 160 using the one or
15 more back pressure control valves, the operating pressure within these blocks are
16 increased, thus enhancing recovery of sulfur from the acid gas stream.

17 **[0035]** The system described above may be advantageous over some other systems
18 known in the art in certain cases. For example, since the ejector 26 does not require a steam
19 jacket to operate, the costs and complexity associated with installing the system are kept
20 relatively low. Moreover, since only one set of thermal stage equipment is required in system
21 100, no manifolding or flow splitting of Claus plant feed stream is needed. This also reduces
22 the costs and complexity of installation, operation and maintenance. Further advantages
23 may be realized especially in cases where the system 100 is retrofitted to an existing Claus
24 plant or system, since installation of the components will not generally require additional plot
25 space for most existing Claus plants or systems.

26 **[0036]** It will be appreciated that in other embodiments, a second ejector may be
27 configured in a similar way as the ejector 26 to enhance the pressure of the SWSAG stream
28 10 before SWSAG is introduced to the burner 120. In yet another embodiment, the SWSAG
29 stream 10 may be combined with the acid gas feed stream 30 before entering the ejector 26.

30 **[0037]** In one aspect, a method for treating an acid gas stream in a sulfur recovery
31 system is provided, the method comprising providing a motive fluid to an ejector, providing
32 the acid gas stream to the ejector to obtain a mixture, the mixture comprising the motive fluid

1 and the acid gas stream, providing the mixture to a reaction furnace, providing a combustion
2 gas to the reaction furnace, the combustion gas comprising oxygen, and reacting the
3 contents of the reaction furnace. For example, the combustion gas may be air, a mixture of
4 air and supplemental oxygen, or pure oxygen.

5 **[0038]** In one embodiment, the motive fluid is provided at a first pressure and the acid
6 gas stream is provided at a second pressure, wherein the first pressure is greater than the
7 second pressure.

8 **[0039]** In one embodiment, the motive fluid comprises steam. For example, in the
9 embodiment of FIG. 1, steam is illustrated as being introduced into the ejector 26 via the
10 steam supply line 20 as the motive fluid for the ejector 26. In other embodiments, the motive
11 fluid may comprise water vapor, supersaturated water vapor, hydrogen sulfide, sulfur
12 dioxide, carbon dioxide, and/or mixtures thereof.

13 **[0040]** FIG. 2 is a flow diagram illustrating the method according to one embodiment.
14 For greater clarity, the method is described in relation to the system 100 shown in FIG. 1. In
15 510, the burner 120 of the reaction furnace 130 is turned on. For example, the burner 120
16 may be started by supplying a fuel gas through the fuel gas stream 60 and igniting the fuel
17 gas. In 520, acid gas, oxygen, and air is supplied to the burner 120 through the acid gas
18 feed stream 30, the oxygen inlet stream 40, and the air inlet stream 50, respectively. As will
19 be appreciated, NC valves 22, 24, 32 are closed and the NO valve 34 is generally open at
20 this stage, to enable the acid gas to flow through the acid gas feed stream 30 into the vapor-
21 liquid separator 80, and to the burner 120 via line 82. The amount of oxygen and air flowing
22 into the burner 120 may be regulated by adjusting the valves 42, 52, 57.

23 **[0041]** Although the fuel gas is typically shut off once the acid gas, oxygen and air is
24 introduced into the burner 120, it will be appreciated that the fuel gas stream 60 may
25 continue to supply fuel to the burner 120, especially in cases where the burner 120 cannot
26 sustain the flame at the desired temperature without the fuel gas. For example, this may
27 occur in cases where the acid gas is rich in carbon dioxide.

28 **[0042]** In 530, the motive fluid is introduced into the ejector 26. In the embodiment of
29 FIG. 1, the motive fluid is steam being carried by the steam supply line 20. In order to
30 introduce the steam, NC valves 22, 24 are at least partially opened such that steam may
31 travel through the ejector 26 into the vapor-liquid separator 80, and to the burner 120 via line

82. In one embodiment, the motive fluid is introduced when the oxygen concentration reaches 30 to 35 volume percent of the air and oxygen stream mixture. Once steam is introduced, NO valve 34 located on the acid gas feed stream 30 is closed to redirect the flow of the acid gas into the ejector 26 in 540. In this way, the pressure of the acid gas being introduced into the burner 120 through line 82 is increased, since the high pressure steam from line 20 is mixed with the acid gas from line 30. Furthermore, introduction of steam lowers the temperature inside the reaction furnace, thus enhancing the capacity as will be explained below.

[0043] Without wishing to be bound by the theory, the inventors believe that the steam acts as a heat sink for moderating the temperature of the combustion products in the reaction furnace. The inventors also believe that the presence of the steam favourably shifts the Claus furnace reactions to lower the oxygen demand, thus further reducing the flame and furnace temperatures. By lowering the operating temperature of the reaction furnace in this way, it is possible to increase the oxygen concentration to higher levels while maintaining the furnace temperature below the desired level. For example, as illustrated in the chart of FIG. 3, additional steam, also referred to as a “make-up steam”, may be introduced to moderate the furnace temperature at higher oxygen levels (e.g. above 30%). In FIG. 3, while the flow rate of the motive steam is kept at a constant level as the oxygen concentration is increased beyond 30%, make-up steam is introduced separately from the motive steam to maintain the furnace temperature at an acceptable level. For example, make-up steam may be introduced directly into the burner 120 through an inlet stream, which is operated independently from the steam supply line 20. Alternatively, the make-up steam may be combined with the motive steam and introduced to the ejector 26 by line 20, and into the reaction furnace 130.

[0044] In one embodiment, a pressurized liquid water stream is injected into the burner 120 by itself. In another embodiment, the pressurized liquid water stream is injected into the burner 120 in combination with steam. For example, the pressurized liquid water stream may be introduced together with the motive steam and the make-up steam, if present.

[0045] Even in cases where the plant operator does not wish to increase the oxygen concentration in the reaction furnace 130, the introduction of steam may still be beneficial, since steam lowers the oxygen demand while maintaining substantially the same level of throughput. By lowering the amount of oxygen that is required, the operating costs associated with purchasing and/or producing pure oxygen is reduced. Moreover, since

1 steam lowers the operating temperature inside the reaction furnace 130, a furnace operated
2 with steam would experience less thermal stress while maintaining substantially the same
3 level of throughput as a furnace operated without steam. Imposing less thermal stress on the
4 burner and the furnace material may potentially increase the lifespan of the furnace and
5 various components therein.

6 **[0046]** In cases where the motive fluid comprises nitrogen or carbon dioxide, the motive
7 fluid may still act as a heat sink to moderate the temperature of the combustion products in
8 the reaction furnace, thus increasing capacity. Specifically with regard to carbon dioxide, it is
9 believed that the introduction of carbon dioxide may shift the thermodynamic equilibrium of
10 the furnace reactions to favour formation of the products. In cases where sulfur dioxide is
11 introduced as the motive fluid, it can also shift the equilibrium of the Claus reactions to
12 favour formation of the products, since sulfur dioxide is one of the reactants. Introducing
13 sulfur dioxide also reduces the amount of oxygen that is required in the reaction, since less
14 hydrogen sulfide will need to be reacted with oxygen to form hydrogen sulfide.

15 **[0047]** For at least one implementation of the sulfur recovery system, Computational
16 Fluid Dynamic (CFD) modelling was used to analyze the dynamics of the Sulphur Recovery
17 Unit (SRU) flame. Specifically, the CFD modelling was performed in order to gain further
18 understanding of the potential capabilities of the high pressure ejector system and the
19 resulting kinetic and thermodynamic effects on the SRU thermal stage flame zone. By
20 analyzing the CFD model, it was found that some regions of the SRU flame may possess
21 substantially higher temperatures compared to other regions of the flame. Accordingly, it can
22 be considered that certain beneficial chemical reactions may be promoted in these higher
23 temperature regions from the use of the ejector pressurized gas stream. Furthermore, it can
24 be considered that the effects provided by such reactions may be enhanced by manipulating
25 the flame pattern and characteristics, such that the pressurized gas stream is injected into
26 the preferred regions of the burner.

27 **[0048]** Returning to FIG. 2, in 550, back pressure valves 150, 170 are used to increase
28 the operating pressure in the sulfur recovery block 140 and/or the TGTU block 160. For
29 example, the operating pressure in the sulfur recovery block 140 may be increased by
30 restricting the flow of gas exiting the sulfur recovery block 140 using the second back
31 pressure valve 150. Similarly, restricting the flow of gas exiting the TGTU block 160 using
32 the first back pressure valve 170 increases the operating pressure of the TGTU block 160. It
33 will be appreciated that in some configurations, the first back pressure valve 170 may be

1 used to moderate the operating pressure of both the sulfur recovery block 140 and the
2 TGTU block 160.

3 **[0049]** As mentioned above, elevating the operating pressure of sulfur recovery block
4 130 and/or TGTU block 160 enhances the recovery of sulfur from acid gas feed stream
5 primarily due to Le Chatelier's principle. For example, since the reactants for the Claus
6 reactions are generally gases, increasing the pressure of the reaction vessels shifts the
7 equilibrium of the reactions such that formation of the products is favored. Increase in the
8 operating pressure also reduces the flow velocities of the reactant gases, thus increasing the
9 residence time of the reactant gases in the reaction vessels. Increased residence time may
10 give rise to higher conversion of the reactants in some cases.

11 **[0050]** Although various embodiments of the apparatus have been described with
12 reference to an ejector, it will be appreciated that other mechanisms for increasing the
13 pressure of the feed source and introducing steam may be used instead. For example, a
14 mechanical blower and/or compressor may be used to increase the pressure of the amine
15 acid gas stream, and steam may be added to the amine acid gas stream before or after the
16 pressure is increased. However, the use of the ejector may be advantageous over other
17 pressure enhancing mechanisms due to the ease of maintenance and relatively high
18 reliability, especially in long-term operations. It is noted that an ejector may also be referred
19 to as an eductor or thermocompressor in the industry.

20 **[0051]** It will be appreciated that although various embodiments have been described
21 with relation to valves, other flow restriction devices or back pressure enhancing strategies,
22 such as dampers, moveable gates, and shutters may be used instead of valves.

23 **[0052]** It will be understood that although various embodiments have been described
24 with reference to oxygen enriched plants and systems, substantially the same method and
25 apparatus may be applied to air-based plants and systems in which no supplemental oxygen
26 is introduced to the reaction furnace.

27 **[0053]** It will also be appreciated that although the apparatus and method have been
28 described herein with reference to sulfur recovery processes, similar apparatuses and
29 methods may be used in conjunction with other processes not involving sulfur recovery.

30 **[0054]** Although the method and apparatus have been described with reference to
31 certain specific embodiments, various modifications thereof will be apparent to those skilled

1 in the art. Any examples provided herein are included solely for the purpose of illustrating
2 the method and apparatus and are not intended to limit the invention in any way. Any
3 drawings provided herein are solely for the purpose of illustrating various aspects of the
4 invention and are not intended to be drawn to scale or to limit the invention in any way. The
5 scope of the claims appended hereto should not be limited by the preferred embodiments
6 set forth in the above description, but should be given the broadest interpretation consistent
7 with the present specification as a whole. The disclosures of all prior art recited herein are
8 incorporated herein by reference in their entirety.

WE CLAIM:

1. A sulfur recovery system comprising:
a reaction furnace;
a motive fluid stream for providing a motive fluid to an ejector;
an acid gas stream for providing an acid gas to the ejector, the ejector connected to the reaction furnace for providing to the reaction furnace a mixture comprising the motive fluid and the acid gas; and
a combustion gas supply stream connected to the reaction furnace for providing a combustion gas to the reaction furnace, the combustion gas comprising oxygen.
2. The sulfur recovery system of claim 1, wherein the acid gas comprises amine acid gas.
3. The sulfur recovery system of claim 1 or 2, wherein the acid gas comprises between 5 and 100 mole percent hydrogen sulfide.
4. The sulfur recovery system according to any one of claims 1 to 3, further comprising an oxygen stream connected to the reaction furnace for providing oxygen to the reaction furnace.
5. The sulfur recovery system according to any one of claims 1 to 4, wherein the motive fluid comprises steam.
6. The sulfur recovery system according to any one of claims 1 to 5, wherein the motive fluid comprises pressurized liquid water, water vapor, hydrogen sulfide, sulfur dioxide, carbon dioxide, or mixtures thereof.
7. The sulfur recovery system according to any one of claims 1 to 6, further comprising a sulfur recovery block connected to the reaction furnace for receiving an effluent stream from the reaction furnace, and a pressure control valve positioned downstream from the sulfur recovery block for controlling the operating pressure of the sulfur recovery block.

8. The sulfur recovery system according to any one of claims 1 to 6, further comprising a sulfur recovery block connected to the reaction furnace for receiving an effluent stream from the reaction furnace, a tail gas treatment unit connected to the reaction furnace for receiving a tail gas stream from the sulfur recovery block, and a pressure control valve positioned downstream from the tail gas treatment unit for controlling the operating pressure of at least one of the tail gas treatment unit and the sulfur recovery block.

9. A method for treating an acid gas stream in a sulfur recovery system, the method comprising:

providing a motive fluid to an ejector;

providing the acid gas stream to the ejector to obtain a mixture, the mixture comprising the motive fluid and the acid gas stream;

providing the mixture to a reaction furnace;

providing a combustion gas to the reaction furnace, the combustion gas comprising oxygen; and

reacting the contents of the reaction furnace.

10. The method of claim 9, wherein the motive fluid is provided at a first pressure and the acid gas stream is provided at a second pressure, the first pressure being greater than the second pressure.

11. The method of claim 9 or 10, wherein the motive fluid comprises steam.

12. The method according to any one of claims 9 to 11, wherein the motive fluid comprises pressurized liquid water, water vapor, hydrogen sulfide, sulfur dioxide, carbon dioxide, or mixtures thereof.

13. The method according to any one of claims 9 to 12, wherein the acid gas stream comprises amine acid gas.

14. The method according to any one of claims 9 to 13, wherein the acid gas stream comprises between 5 and 100 mole percent hydrogen sulfide.

15. The method according to any one of claims 9 to 14, further comprising providing air, a secondary acid gas stream, fuel gas, or combinations thereof to the reaction furnace.
16. The method of claim 15, wherein the mixture, the combustion gas, and at least one of air, the secondary acid gas stream, and fuel gas are provided to a burner of the reaction furnace.
17. The sulfur recovery system of claim 1, wherein the combustion gas is air.
18. The sulfur recovery system of claim 1, wherein the combustion gas comprises air and supplemental oxygen.
19. The method of claim 9, wherein the combustion gas is air.
20. The method of claim 9, wherein the combustion gas comprises air and supplemental oxygen.