

SYSTEMS AND METHODS FOR SUB-DEWPOINT SULFUR RECOVERY**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims priority to U.S. Provisional Application No. 63/579,323 filed August 29, 2023, which is incorporated herein by reference.

FIELD OF THE DISCLOSURE

[0002] The present disclosure generally relates to systems and methods for sub-dewpoint sulfur recovery. More particularly, the systems and methods leverage a separation device and/or an interstage heater to improve the performance of a single (catalytic) step sulfur recovery system without the need for a thermal step or an additional catalyst.

BACKGROUND

[0003] The removal and recovery of sulfur compounds from a high-pressure gas stream is typically a two-step process: an amine or physical solvent sulfur removal step followed by a Claus-type process to convert the sulfur species to elemental sulfur. This normally requires cooling the gas to ambient temperature or lower before treating. In addition, the sulfur removal step will usually remove some of the carbon dioxide and generate a medium pressure carbon dioxide stream and/or the carbon dioxide may be with the hydrogen sulfide as a low-pressure gas stream for feeding to a Claus sulfur recovery unit.

[0004] The Bechtel Pressure Swing Claus (BPSC) is a single-step sulfur removal and recovery technology that operates at full gas pressure and at medium temperatures. The technology can reduce plant capital cost and improve operating efficiency by eliminating amine treatment and, if required, provide a high purity carbon dioxide stream for subsequent use. The process involves: gas conditioning; H₂S and COS reaction over a conventional Claus catalyst at sub-dewpoint

conditions; and regeneration by pressure swing and/or heating. This allows sulfur formation, collection and separation in a single step. Multiple reaction stages can be used to achieve very low treated gas sulfur content.

[0005] The effectiveness of a high-pressure sulfur condenser in a BPSC system depends on the temperature of the cooling medium, which can be directly related to its pressure. The high-pressure sulfur condenser operates with a cooling medium, which has relatively efficient heat transfer, but with a flow of process gas on the other side, which has relatively inefficient heat transfer. A change in flowrate or inlet temperature (based on upstream reactor activity) can alter the efficiency of the high-pressure sulfur condenser and thus, the temperature of the gas entering the secondary (lag) reactor. Moreover, any mist not properly separated from the gas in the outlet plenum of the high-pressure sulfur condenser can prematurely age the catalyst in the secondary (lag) reactor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The detailed description is described below with reference to the accompanying drawing, in which like elements are referenced with like reference numbers, and in which:

[0007] **FIG. 1** is a schematic diagram illustrating one embodiment of a single step sulfur recovery system, which includes a separation device and an interstage heater.

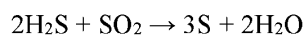
[0008] **FIG. 2** is a schematic diagram illustrating another embodiment of a single step sulfur recovery system, which recycles elemental sulfur produced by the system.

DETAILED DESCRIPTION OF THE ILLUSTRATIVE EMBODIMENTS

[0009] The subject matter of the present disclosure is described with specificity, however, the description itself is not intended to limit the scope of the disclosure. The subject matter thus, might also be embodied in other ways, to include different structures, steps and/or combinations

similar to and/or fewer than those described herein, in conjunction with other present or future technologies. Although the term “step” may be used herein to describe different elements of methods employed, the term should not be interpreted as implying any particular order among or between various steps herein disclosed unless otherwise expressly limited by the description to a particular order. Other features and advantages of the disclosed embodiments will be or will become apparent to one of ordinary skill in the art upon examination of the following figures and detailed description. It is intended that all such additional features and advantages be included within the scope of the disclosed embodiments. Further, the illustrated figures described herein are only exemplary and are not intended to assert or imply any limitation with regard to the environment, architecture, design, or process in which different embodiments may be implemented. To the extent that temperatures and/or pressures are referenced in the following description, those conditions are merely illustrative and are not meant to limit the disclosure. All streams described are carried by physical lines.

[0010] The systems and methods disclosed herein leverage a separation device and/or an interstage heater to improve the performance of a single-step sulfur recovery system without the need for a thermal step or an additional catalyst. The sulfur bearing compounds are removed at a higher pressure than traditional Claus operating pressures prior to additional feed gas processing. The main reaction in the Claus-type process used to convert the sulfur species to elemental sulfur is:



where SO_2 is used as the oxidant for the Claus catalytic reaction. The catalytic recovery of sulfur consists of three sub steps: heating, catalytic reaction and cooling plus condensation.

[0011] In one embodiment, a system for sulfur recovery is disclosed, which comprises: i) a primary feed stream comprising elemental sulfur; ii) a separation device in fluid communication with the primary feed stream for separating the primary feed stream into a first liquid stream comprising elemental sulfur and a vapor stream comprising a sulfur vapor; iii) a first heater fluidly connected to the separation device by the vapor stream for producing a heated vapor stream; and iv) a primary reactor fluidly connected to the first heater by the heated vapor stream, the primary reactor including a catalyst for adsorbing elemental sulfur from the heated vapor stream and producing a treated vapor stream comprising a sulfur vapor.

[0012] In another embodiment, a method for sulfur recovery is disclosed, which comprises: i) separating a primary feed stream into a first liquid stream comprising elemental sulfur and a vapor stream comprising a sulfur vapor; ii) heating the vapor stream to produce a heated vapor stream; iii) adsorbing elemental sulfur from the heated vapor stream onto a catalyst; and iv) producing a treated vapor stream comprising a sulfur vapor.

[0013] In yet another embodiment, a system for sulfur recovery is disclosed, which comprises: i) a primary reactor with a catalyst for adsorbing elemental sulfur from a primary feed stream and producing a treated vapor stream comprising a sulfur vapor; ii) a first condenser fluidly connected to the primary reactor by the treated vapor stream for converting the treated vapor stream to a first liquid stream comprising elemental sulfur and a first cooled vapor stream; and iii) a heater fluidly connected to the first condenser by the first cooled vapor stream for producing a heated vapor stream.

[0014] In yet another embodiment, a method for sulfur recovery is disclosed, which comprises: i) adsorbing elemental sulfur from a primary feed stream onto a catalyst; ii) producing a treated vapor stream comprising a sulfur vapor; iii) converting the treated vapor stream to a first

liquid stream comprising elemental sulfur and a first cooled vapor stream; and iv) producing a heated vapor stream.

[0015] In yet another embodiment, a system for sulfur recovery is disclosed, which comprises: i) a primary reactor with a catalyst for adsorbing elemental sulfur from a primary feed stream and producing a treated vapor stream comprising a sulfur vapor; ii) a first condenser fluidly connected to the primary reactor by the treated vapor stream for converting the treated vapor stream to a first liquid stream comprising elemental sulfur and a first cooled vapor stream; iii) a regeneration reactor in fluid communication with the primary feed stream for regenerating a catalyst comprising adsorbed elemental sulfur and producing a flashed-gas vapor stream comprising elemental sulfur; iv) a second condenser fluidly connected to the regeneration reactor by the flashed-gas vapor stream for converting the flashed-gas vapor stream to a second liquid stream comprising elemental sulfur and a second cooled vapor stream; v) an oxidizer in fluid communication with the first liquid stream and the second liquid stream for converting elemental sulfur in the first liquid stream and the second liquid stream into a secondary feed stream comprising at least one of thiosulfate, sulfur dioxide, sulfur trioxide, sulfuric acid and sulfurous acid; and vi) another secondary feed stream comprising hydrogen sulfide, wherein the secondary feed stream and the another secondary feed stream are fluidly connected to the primary feed stream for converting at least one of thiosulfate, sulfur dioxide, sulfur trioxide, sulfuric acid and sulfurous acid in the secondary feed stream and hydrogen sulfide in the another secondary feed stream to elemental sulfur in the primary feed stream.

[0016] In yet another embodiment, a method for sulfur recovery is disclosed, which comprises: i) adsorbing elemental sulfur from a primary feed stream onto a catalyst; ii) producing a treated vapor stream comprising a sulfur vapor; iii) converting the treated vapor stream to a first

liquid stream comprising elemental sulfur and a first cooled vapor stream; iv) regenerating a catalyst comprising adsorbed elemental sulfur; v) producing a flashed-gas vapor stream comprising elemental sulfur; vi) converting the flashed-gas vapor stream to a second liquid stream and a second cooled vapor stream; vii) converting the elemental sulfur in the first liquid stream and the second liquid stream into a secondary feed stream comprising at least one of thiosulfate, sulfur dioxide, sulfur trioxide, sulfuric acid and sulfurous acid; and viii) converting at least one of thiosulfate, sulfur dioxide, sulfur trioxide, sulfuric acid and sulfurous acid in the secondary feed stream and hydrogen sulfide in another secondary feed stream into elemental sulfur in the primary feed stream.

[0017] Referring now to **FIG. 1**, a schematic diagram of a single step sulfur recovery system **100** is illustrated, which includes a separation device (e.g., knock-out drum) **108** and an interstage heater **125**. A pressurized feed gas (e.g., syngas) stream **102** containing hydrogen sulfide (H_2S) is mixed with a stream **104** containing a high concentration of sulfur dioxide (SO_2). The feed gas stream **102** and the SO_2 stream **104** may be a gas and/or a liquid. At the point where the SO_2 stream **104** is introduced to the feed gas stream **102**, a non-catalytic reaction with H_2S in the feed gas stream **102** takes place. Because the SO_2 stream **104** is at high concentration, it can readily react with the H_2S (low or high concentration) present in the feed gas stream **102** to form a mixed stream **105** containing elemental sulfur. To the extent the newly formed elemental sulfur in the mixed stream **105** includes a liquid phase, a separation device **108** may be used to separate the mixed stream **105** into a first liquid stream **110** containing elemental sulfur and a vapor stream **112** containing sulfur vapor and unreacted components. The separation device **108** may be positioned horizontally, vertically, or at an angle and is able to remove elemental sulfur without any additional catalyst. The separation device **108** decreases catalyst requirements, lengthens the time between

regenerations, and increases catalyst life because a portion of the elemental sulfur is removed before being introduced to the catalyst beds (reactor beds). The presence of liquid sulfur also enables the mixed stream **105** to be washed, which can remove any heavier molecular weight contaminants that are detrimental to product purity and catalyst activity and reduce the expected catalyst life. The first liquid stream **110** containing elemental sulfur may be sent to a separate storage device.

[0018] The vapor stream **112** proceeds to reactor feed heater **106** where the vapor stream is heated to within 240-1000°F (more preferably 300-400°F), which helps optimize the reaction temperature. The heated vapor stream **114** is fed to a primary (lead) high-pressure sub-dewpoint reactor **116** where most of the H₂S, COS and SO₂ are converted to elemental sulfur and adsorbed on a catalyst bed **118** comprising alumina, activated alumina and/or gamma activated alumina. The primary reactor **116** is expected to produce a sweet gas under 500 ppmv total sulfur (typically under 200 ppmv total sulfur), depending upon temperature, pressure, and composition of the feed gas stream **102**. The sweet gas forms a treated vapor stream **120** comprising sulfur vapor and unreacted components within 200°F of the primary reactor inlet temperature, which is sent to a high-pressure sulfur condenser **122** to cool the treated vapor stream **120** to within 100-500°F (preferably within 250-280°F) and remove some of the residual elemental sulfur in the outlet plenum (not shown) of the high-pressure sulfur condenser **122** as a second liquid stream **123** containing elemental sulfur. The cooling of the stream and condensation heat is used to generate heat (e.g., steam) at the shell side (not shown) of the high-pressure sulfur condenser **122**.

[0019] The remaining gas forms a first cooled vapor stream **124** comprising sulfur vapor and unreacted components at 100-500°F (preferably within 250-280°F), which is sent to a reactor interstage heater **125** where the first cooled vapor stream **124** is heated to within 5-100°F above

the reactor interstage heater inlet temperature (more preferably 300-325°F). Heating the first cooled vapor stream **124** in this manner helps control the temperature of the gas entering the secondary (lag) high-pressure sub-dewpoint reactor **128** as another heated vapor stream **126**. Because sulfur recovery efficiency is greatly influenced by temperature, process control is critical in the operation of the system **100**. The reactor interstage heater **125** will also reduce, if not eliminate, any sulfur mist not properly separated from the vapor in the outlet plenum of the high-pressure sulfur condenser **122**, which can prematurely age the catalyst in the secondary reactor **128**. The reactor interstage heater **125** will thus improve reliability and decrease operating costs in the form of reduced catalyst replacement.

[0020] The another heated vapor stream **126** is fed to the secondary reactor **128** where most of the remaining H₂S, COS and SO₂ are converted to elemental sulfur on a catalyst bed **130** comprising alumina, activated alumina and/or gamma activated alumina. The secondary reactor **128** is expected to reduce the sulfur in the product gas to 20 ppmv or less, preferably 4 ppmv or less. The remaining gas forms a product vapor stream **132** comprising sulfur vapor and unreacted components within 50°F of the secondary reactor inlet temperature, which is available for additional processing, such as compression and liquefaction, combustion in a turbine-generator for power production, or separated into basic chemicals for specialty chemicals production.

[0021] After the catalyst bed **118** for the primary reactor **116** is saturated with adsorbed sulfur, the primary reactor **116** is rotated to replace a regeneration high-pressure sub-dewpoint reactor **134** with a clean and essentially sulfur free catalyst bed **135** comprising alumina, activated alumina and/or gamma activated alumina. The regeneration reactor **134** replaces the secondary reactor **128**, which replaces the primary reactor **116**. In their new positions, the regeneration reactor **134** and the secondary reactor **128** perform the function of the reactor each replaced while the

catalyst bed **118** in the primary reactor **116** is regenerated by pressure let down. The pressure letdown produces a flashed gas vapor stream **136** comprising elemental sulfur and adsorbed and non-adsorbed components at about the same temperature as treated vapor stream **120** (preferably 300-400°F), which is sent to a low-pressure sulfur condenser **138** for cooling to about 100-500°F (more preferably 250-280°F), and removal of the elemental sulfur in the outlet plenum (not shown) of the low-pressure sulfur condenser **138** as a third liquid stream **139** containing elemental sulfur. The cooling of the stream and condensation heat is used to generate heat (e.g., steam) at the shell side (not shown) of the low-pressure sulfur condenser **138**.

[0022] The remaining gas forms a second cooled vapor stream **140** comprising elemental sulfur and adsorbed and non-adsorbed components at about 100-500°F (more preferably 250-280°F), which is sent to a regeneration compressor **142** for compression in a sweep gas circuit. After compression of the second cooled vapor stream **140** in the regeneration compressor **142** to a pressure of about 10-200 psig (more preferably 45 psig), the compressed second cooled vapor stream forms a sweep gas **144**, which may be directed through valve **145a** and/or valve **145b**. The sweep gas passing through valve **145a** may be sent (optionally) i) to a heater **150** or ii) to the reactor in regeneration. The sweep gas passing through valve **145b** may be sent (optionally) i) to a recycle compressor **152** for further compression and/or to mix with the feed gas stream **102** or ii) the recycle compressor **152** and/or to exit the system **100**. The recycle compressor **152** forms a pressurized gas (e.g., syngas) stream **148** that may be mixed with the feed gas stream **102** or sent outside the system **100**. The regeneration compressor **142** and the recycle compressor **152** may thus be used individually or in combination to depressurize the reactor in regeneration to a pressure of -5 - 100 psig (more preferably 10-20 psig). After the reactor in regeneration is depressurized, the flow through valve **145b** is essentially terminated. The heater **150** may be used to hasten

regeneration of the catalyst bed for the reactor in regeneration to a temperature of 300-900°F (more preferably 500- 700°F). A heated sweep gas stream **146** travels through the reactor in regeneration, to vaporize adsorbed components from the catalyst bed. The regeneration process is repeated until a sufficient amount of sulfur, preferably a majority, is removed from the catalyst bed such that the reactor in regeneration can be placed back into service. After removal of a sufficient amount of sulfur, the heater **150** may optionally be used as a cooler by changing the heat exchange medium to a cooling medium and the sweep gas **144** can then be used for cooling the catalyst bed to at or near the expected reaction temperature of about 300-400°F. At this time, the reactor in regeneration may sit idle until the current primary reactor needs regeneration, at which time the reactors switch positions as described above.

[0023] Referring now to **FIG. 2**, a schematic diagram of a single step sulfur recovery system **200** is illustrated, which recycles elemental sulfur produced by the system **200**. The system **200** includes the same components as the system **100** in **FIG. 1** which perform the same functions described in reference to **FIG. 1**. The elemental sulfur in the first liquid stream **110**, the second liquid stream **123** and the third liquid stream **139**, however, are recycled to reduce the amount of SO₂ stored on-site. Because oxides of sulfur (e.g., thiosulfate (S₂O₃), sulfur dioxide (SO₂), sulfur trioxide (SO₃), sulfuric acid (H₂SO₄) and/or sulfurous acid (H₂SO₃)) are toxic to people and the environment, creating any of these as needed is superior to on-site storage and represents a cost savings to the facility.

[0024] The first liquid stream **110**, the second liquid stream **123** and the third liquid stream **139** are sent to a storage device **202** for collection. The storage device **202** is used to produce a fourth liquid stream **203** comprising elemental sulfur and a fifth liquid stream **204** also comprising elemental sulfur. The fourth liquid stream **203** is sent to an oxidizer **206** and the fifth liquid stream

204 is sent outside the battery limits as a sulfur by-product. Alternatively, the second liquid stream **123** and the third liquid stream **139** may be merged with the first liquid stream **110** into a single stream, which may be separated into the fourth liquid stream **203** and the fifth liquid stream **204** using one or more valves. An oxidant **207** is added to the fourth liquid stream **203** in the oxidizer **206**, which generates a first fluid stream **208** comprising thiosulfate (S_2O_3), sulfur dioxide (SO_2), sulfur trioxide (SO_3), sulfuric acid (H_2SO_4) and/or sulfurous acid (H_2SO_3). The oxidant **207** can be atmospheric oxygen, purified oxygen, ozone, permanganate, hypochlorite, and/or peroxide, for example. The first fluid stream **208** may then be combined with SO_2 stream **104** to reduce the SO_2 requirements. Alternatively, the oxidant **207** may be H_2SO_4 , H_2SO_3 , and/or SO_3 , for example, which generates a first fluid stream **208** comprising S_2O_3 and/or SO_2 when added to the fourth liquid stream **203** in the oxidizer **206**.

[0025] While the present disclosure has been described in connection with presently preferred embodiments, it will be understood by those skilled in the art that it is not intended to limit the disclosure of those embodiments. It is therefore contemplated that various alternative embodiments and modifications may be made to the disclosed embodiments without departing from the spirit and scope of the disclosure defined by the appended claims and equivalents thereof.

CLAIMS

1. A sulfur recovery system, comprising:
 - a primary feed stream comprising elemental sulfur;
 - a separation device in fluid communication with the primary feed stream for separating the primary feed stream into a first liquid stream comprising elemental sulfur and a vapor stream comprising a sulfur vapor;
 - a first heater fluidly connected to the separation device by the vapor stream for producing a heated vapor stream; and
 - a primary reactor fluidly connected to the first heater by the heated vapor stream, the primary reactor including a catalyst for adsorbing elemental sulfur from the heated vapor stream and producing a treated vapor stream comprising a sulfur vapor.
2. The sulfur recovery system of claim 1, further comprising:
 - a first condenser fluidly connected to the primary reactor by the treated vapor stream for converting the treated vapor stream to a second liquid stream comprising elemental sulfur and a first cooled vapor stream; and
 - a second heater fluidly connected to the first condenser by the first cooled vapor stream for producing another heated vapor stream.
3. The sulfur recovery system of claim 2, further comprising:
 - a secondary reactor fluidly connected to the second heater by the another heated vapor stream, the secondary reactor including a catalyst for adsorbing elemental sulfur from the another heated vapor stream and producing a product vapor stream comprising a sulfur vapor.
4. The sulfur recovery system of claim 3, further comprising:

a regeneration reactor in fluid communication with the primary feed stream for regenerating a catalyst comprising adsorbed elemental sulfur and producing a flashed-gas vapor stream comprising elemental sulfur; and

a second condenser fluidly connected to the regeneration reactor by the flashed-gas vapor stream for converting the flashed-gas vapor stream to a third liquid stream comprising elemental sulfur and a second cooled vapor stream.

5. The sulfur recovery system of claim 4, further comprising an oxidizer in fluid communication with the first liquid stream, the second liquid stream and the third liquid stream for converting elemental sulfur in the first liquid stream, the second liquid stream and the third liquid stream into a secondary feed stream comprising at least one of thiosulfate, sulfur dioxide, sulfur trioxide, sulfuric acid and sulfurous acid.

6. The sulfur recovery system of claim 5, further comprising another secondary feed stream comprising hydrogen sulfide, wherein the secondary feed stream and the another secondary feed stream are fluidly connected to the primary feed stream for converting at least one of thiosulfate, sulfur dioxide, sulfur trioxide, sulfuric acid and sulfurous acid in the secondary feed stream and hydrogen sulfide in the another secondary feed stream to elemental sulfur in the primary feed stream.

7. The sulfur recovery system of claim 6, wherein each catalyst comprises at least one of alumina, activated alumina and gamma activated alumina.

8. The sulfur recovery system of claim 3, wherein the sulfur vapor in the product vapor stream includes less than 20 ppmv sulfur.

9. The sulfur recovery system of claim 1, wherein the heated vapor stream is 240°F to 400°F.

10. The sulfur recovery system of claim 2, wherein the another heated vapor stream is 240°F to 325°F.
11. A sulfur recovery method, comprising:
 - separating a primary feed stream into a first liquid stream comprising elemental sulfur and a vapor stream comprising a sulfur vapor;
 - heating the vapor stream to produce a heated vapor stream;
 - adsorbing elemental sulfur from the heated vapor stream onto a catalyst; and
 - producing a treated vapor stream comprising a sulfur vapor.
12. The sulfur recovery method of claim 11, further comprising:
 - converting the treated vapor stream to a second liquid stream comprising elemental sulfur and a first cooled vapor stream; and
 - heating the first cooled vapor stream to produce another heated vapor stream.
13. The sulfur recovery method of claim 12, further comprising:
 - adsorbing elemental sulfur from the another heated vapor stream onto a catalyst; and
 - producing a product vapor stream comprising a sulfur vapor.
14. The sulfur recovery method of claim 13, further comprising:
 - regenerating a catalyst comprising adsorbed elemental sulfur;
 - producing a flashed-gas vapor stream comprising elemental sulfur; and
 - converting the flashed-gas vapor stream to a third liquid stream and a second cooled vapor stream.
15. The sulfur recovery method of claim 14, further comprising converting the elemental sulfur in the first liquid stream, the second liquid stream and the third liquid stream into

a secondary feed stream comprising at least one of thiosulfate, sulfur dioxide, sulfur trioxide, sulfuric acid and sulfurous acid.

16. The sulfur recovery method of claim 15, further comprising converting at least one of thiosulfate, sulfur dioxide, sulfur trioxide, sulfuric acid and sulfurous acid in the secondary feed stream and hydrogen sulfide in another secondary feed stream into elemental sulfur in the primary feed stream.

17. The sulfur recovery method of claim 16, wherein each catalyst comprises at least one of alumina, activated alumina and gamma activated alumina.

18. The sulfur recovery method of claim 13, wherein the sulfur vapor in the product vapor stream includes less than 20 ppmv sulfur.

19. The sulfur recovery method of claim 11, wherein the heated vapor stream is 240°F to 400°F.

20. The sulfur recovery method of claim 12, wherein the another heated vapor stream is 240°F to 325°F.

21. A sulfur recovery system, comprising:

a primary reactor with a catalyst for adsorbing elemental sulfur from a primary feed stream and producing a treated vapor stream comprising a sulfur vapor;

a first condenser fluidly connected to the primary reactor by the treated vapor stream for converting the treated vapor stream to a first liquid stream comprising elemental sulfur and a first cooled vapor stream; and

a heater fluidly connected to the first condenser by the first cooled vapor stream for producing a heated vapor stream.

22. The sulfur recovery system of claim 21, further comprising:

a secondary reactor fluidly connected to the heater by the heated vapor stream, the secondary reactor including a catalyst for adsorbing elemental sulfur from the heated vapor stream and producing a product vapor stream comprising a sulfur vapor.

23. The sulfur recovery system of claim 22, further comprising:

a regeneration reactor in fluid communication with the primary feed stream for regenerating a catalyst comprising adsorbed elemental sulfur and producing a flashed-gas vapor stream comprising elemental sulfur; and

a second condenser fluidly connected to the regeneration reactor by the flashed-gas vapor stream for converting the flashed-gas vapor stream to a second liquid stream comprising elemental sulfur and a second cooled vapor stream.

24. The sulfur recovery system of claim 23, further comprising an oxidizer in fluid communication with the first liquid stream and the second liquid stream for converting elemental sulfur in the first liquid stream and the second liquid stream into a secondary feed stream comprising at least one of thiosulfate, sulfur dioxide, sulfur trioxide, sulfuric acid and sulfurous acid.

25. The sulfur recovery system of claim 24, further comprising another secondary feed stream comprising hydrogen sulfide, wherein the secondary feed stream and the another secondary feed stream are fluidly connected to the primary feed stream for converting at least one of thiosulfate, sulfur dioxide, sulfur trioxide, sulfuric acid and sulfurous acid in the secondary feed stream and hydrogen sulfide in the another secondary feed stream to elemental sulfur in the primary feed stream.

26. A sulfur recovery method, comprising:

adsorbing elemental sulfur from a primary feed stream onto a catalyst;

- producing a treated vapor stream comprising a sulfur vapor;
converting the treated vapor stream to a first liquid stream comprising elemental sulfur and
a first cooled vapor stream; and
producing a heated vapor stream.
27. The sulfur recovery method of claim 26, further comprising:
adsorbing elemental sulfur from the heated vapor stream onto a catalyst; and
producing a product vapor stream comprising a sulfur vapor.
28. The sulfur recovery method of claim 27, further comprising:
regenerating a catalyst comprising adsorbed elemental sulfur;
producing a flashed-gas vapor stream comprising elemental sulfur; and
converting the flashed-gas vapor stream to a second liquid stream and a second cooled
vapor stream.
29. The sulfur recovery method of claim 28, further comprising converting the elemental sulfur
in the first liquid stream and the second liquid stream into a secondary feed stream comprising at
least one of thiosulfate, sulfur dioxide, sulfur trioxide, sulfuric acid and sulfurous acid.
30. The sulfur recovery method of claim 29, further comprising converting at least one of
thiosulfate, sulfur dioxide, sulfur trioxide, sulfuric acid and sulfurous acid in the secondary feed
stream and hydrogen sulfide in another secondary feed stream into elemental sulfur in the primary
feed stream.
31. A sulfur recovery system, comprising:
a primary reactor with a catalyst for adsorbing elemental sulfur from a primary feed stream
and producing a treated vapor stream comprising a sulfur vapor;

a first condenser fluidly connected to the primary reactor by the treated vapor stream for converting the treated vapor stream to a first liquid stream comprising elemental sulfur and a first cooled vapor stream;

a regeneration reactor in fluid communication with the primary feed stream for regenerating a catalyst comprising adsorbed elemental sulfur and producing a flashed-gas vapor stream comprising elemental sulfur;

a second condenser fluidly connected to the regeneration reactor by the flashed-gas vapor stream for converting the flashed-gas vapor stream to a second liquid stream comprising elemental sulfur and a second cooled vapor stream;

an oxidizer in fluid communication with the first liquid stream and the second liquid stream for converting elemental sulfur in the first liquid stream and the second liquid stream into a secondary feed stream comprising at least one of thiosulfate, sulfur dioxide, sulfur trioxide, sulfuric acid and sulfurous acid; and

another secondary feed stream comprising hydrogen sulfide, wherein the secondary feed stream and the another secondary feed stream are fluidly connected to the primary feed stream for converting at least one of thiosulfate, sulfur dioxide, sulfur trioxide, sulfuric acid and sulfurous acid in the secondary feed stream and hydrogen sulfide in the another secondary feed stream to elemental sulfur in the primary feed stream.

32. The sulfur recovery system of claim 31, wherein the oxidizer includes an oxidant comprising at least one of atmospheric oxygen, purified oxygen, ozone, permanganate, hypochlorite, and peroxide.

33. The sulfur recovery system of claim 31, wherein the oxidizer includes an oxidant comprising at least one of sulfuric acid, sulfurous acid, and sulfur trioxide.

34. A sulfur recovery method, comprising:
- adsorbing elemental sulfur from a primary feed stream onto a catalyst;
 - producing a treated vapor stream comprising a sulfur vapor;
 - converting the treated vapor stream to a first liquid stream comprising elemental sulfur and a first cooled vapor stream;
 - regenerating a catalyst comprising adsorbed elemental sulfur;
 - producing a flashed-gas vapor stream comprising elemental sulfur;
 - converting the flashed-gas vapor stream to a second liquid stream and a second cooled vapor stream;
 - converting the elemental sulfur in the first liquid stream and the second liquid stream into a secondary feed stream comprising at least one of thiosulfate, sulfur dioxide, sulfur trioxide, sulfuric acid and sulfurous acid; and
 - converting at least one of thiosulfate, sulfur dioxide, sulfur trioxide, sulfuric acid and sulfurous acid in the secondary feed stream and hydrogen sulfide in another secondary feed stream into elemental sulfur in the primary feed stream.
35. The sulfur recovery method of claim 34, wherein an oxidant comprising at least one of atmospheric oxygen, purified oxygen, ozone, permanganate, hypochlorite, and peroxide is used for converting the elemental sulfur in the first liquid stream and the second liquid stream into the secondary feed stream.
36. The sulfur recovery method of claim 34, wherein an oxidant comprising at least one of sulfuric acid, sulfurous acid, and sulfur trioxide is used for converting the elemental sulfur in the first liquid stream and the second liquid stream into the secondary feed stream.