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(54) **REDUCING SLURRY EMULSION AND  
FOAMING IN OXIDATION-REDUCTION  
SULFUR REMOVAL PROCESSES**

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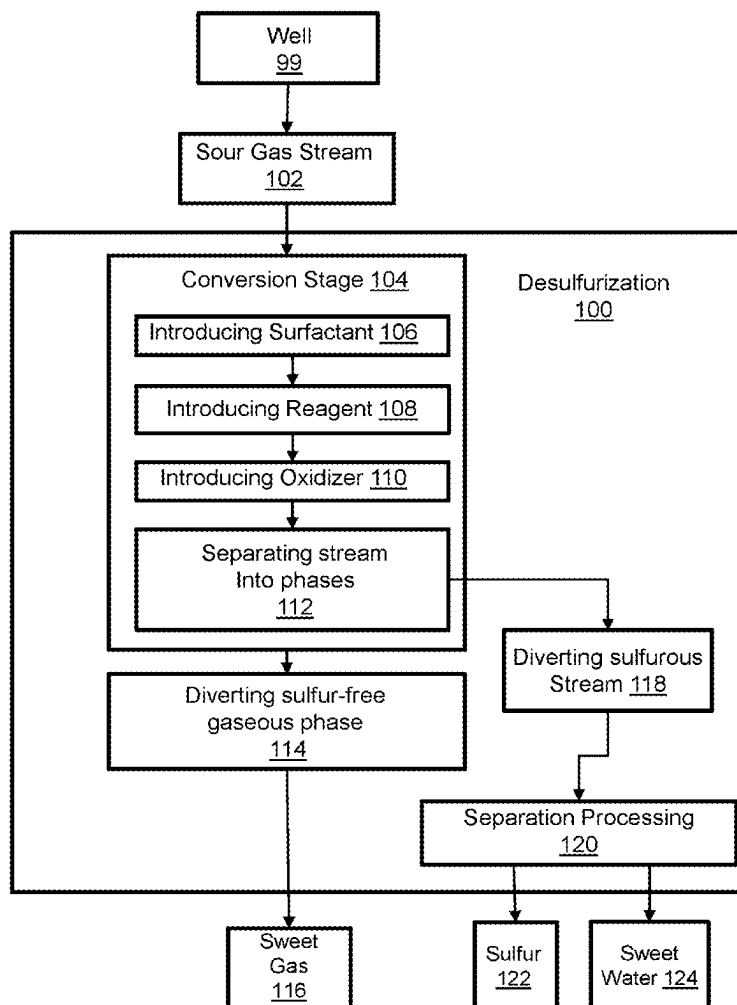
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**Related U.S. Application Data**

(63) Continuation of application No. 17/529,342, filed on Nov. 18, 2021, now Pat. No. 12,291,664, which is a continuation of application No. 16/425,254, filed on May 29, 2019, now abandoned.

(57) **ABSTRACT**

A method may introduce a surfactant to the sour gas stream, the surfactant including an alkoxylated block copolymer and a glycol ether. A method may introducing, to the sour gas stream, a reducing reagent configured to convert the sulfur species in the sour gas stream into at least one of solid sulfur or solid sulfur species.



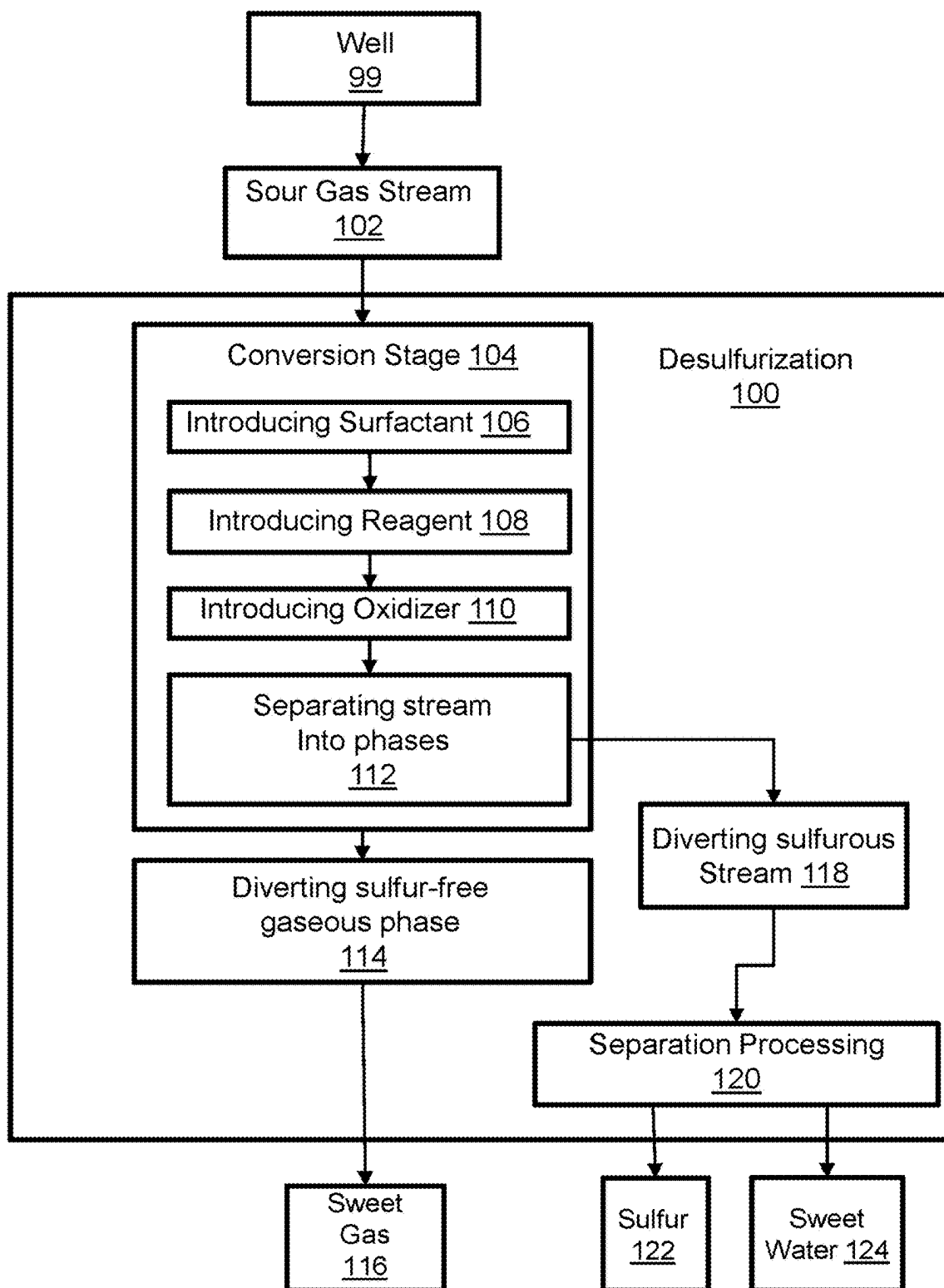


Figure 1

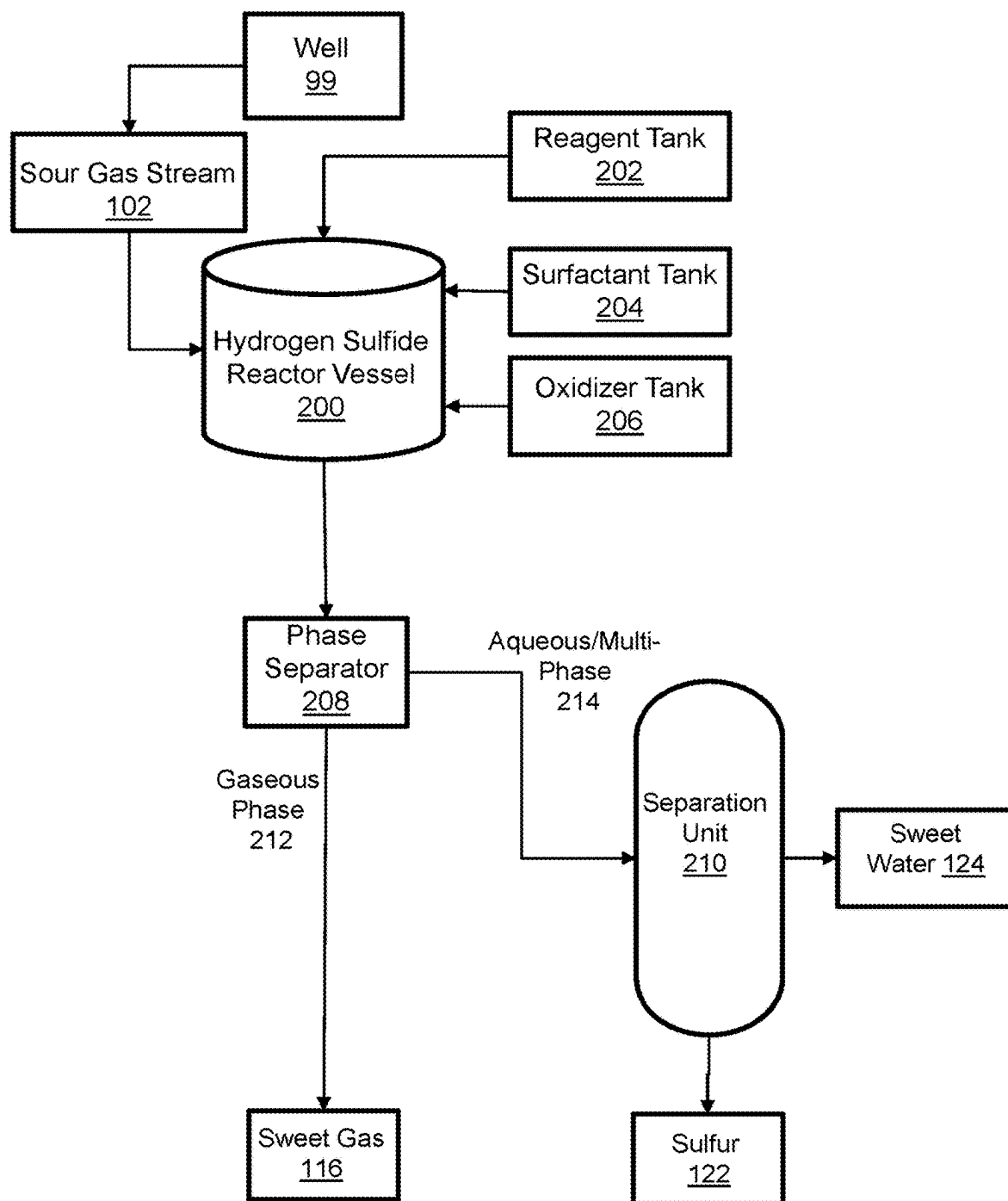


Figure 2

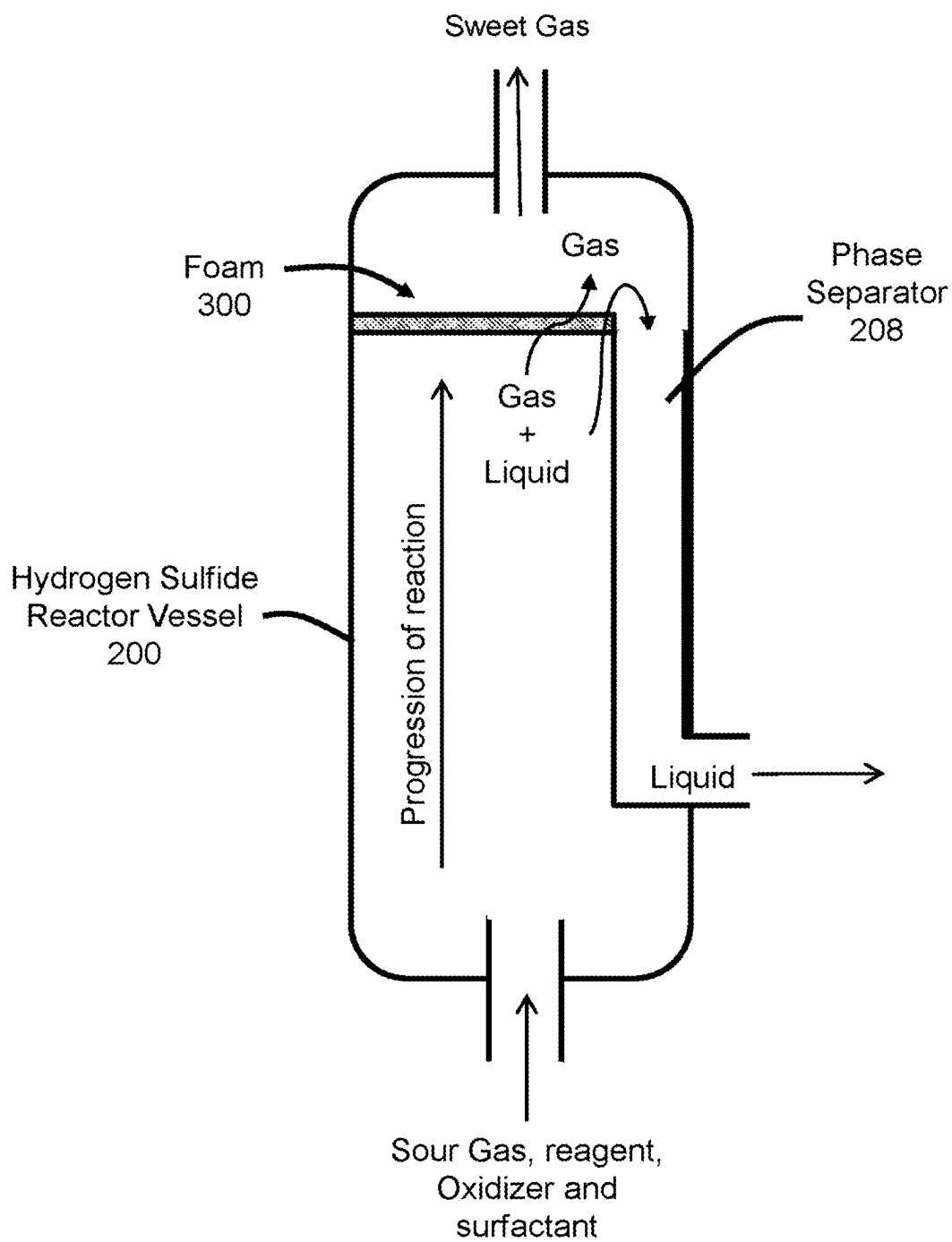


Figure 3

## REDUCING SLURRY EMULSION AND FOAMING IN OXIDATION-REDUCTION SULFUR REMOVAL PROCESSES

### CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This is a continuation application claiming priority to U.S. application Ser. No. 17/529,342 filed Nov. 18, 2021, which claims priority to U.S. application Ser. No. 16/425,254 filed May 29, 2019, which claims priority to U.S. Provisional Application No. 62/678,647 filed May 31, 2018. The disclosures of the prior applications are hereby incorporated herein by reference in their entirety.

### TECHNICAL FIELD

[0002] Aspects of the present disclosure are generally related to treatment of sour gas and wastewater streams, and more particularly to surfactants for reduction of slurry emulsion and foaming in oxidation-reduction systems for removing sulfur-based contaminants from sour gas and wastewater streams.

### BACKGROUND OF THE DISCLOSURE

[0003] Raw natural gas from oil and gas wells typically contains contaminants such as hydrogen sulfide ( $H_2S$ ). Natural gas is usually considered sour if there are more than 5.7 milligrams of hydrogen sulfide per cubic meter of natural gas, which is equivalent to approximately 4 ppm by volume under standard temperature and pressure. Because hydrogen sulfide is highly toxic and sour gas requires relatively costly infrastructure to transport it is desirable to remove the hydrogen sulfide from the sour gas stream at or near the well head. However, commercially viable small-scale field processing systems for desulfurization of raw natural gas have proved to be difficult to implement.

### SUMMARY OF THE DISCLOSURE

[0004] A surfactant composition for processing sour gas and wastewater streams using oxidation-reduction desulfurization comprises a block copolymer and glycol ether. The block copolymer disrupts the emulsion and allows the now-coated sulfur particles to escape the existing emulsion. The glycol ether acts as a mutual solvent, which also augments the emulsion breaking capabilities of the diblock copolymer by providing additional surface tension reduction to the system, as well as emulsion inhibition at the aqueous-gaseous interface.

[0005] In some aspects, the techniques described herein relate to a method for converting a sulfur species present in a sour gas stream into at least one of solid sulfur or a solid sulfur species, including: introducing a surfactant to the sour gas stream, the surfactant including an alkoxyated block copolymer and a glycol ether; and introducing, to the sour gas stream, a reducing reagent configured to convert the sulfur species in the sour gas stream into at least one of solid sulfur or solid sulfur species.

[0006] In some aspects, the techniques described herein relate to a method, further including: introducing an oxidizer into the sour gas stream.

[0007] In some aspects, the techniques described herein relate to a method, wherein introducing the surfactant includes introducing an aqueous surfactant composition to

the sour gas stream, the aqueous surfactant composition including the alkoxyated block copolymer and the glycol ether.

[0008] In some aspects, the techniques described herein relate to a method, wherein introducing the surfactant further includes introducing the surfactant to the sour gas stream, the surfactant including the alkoxyated block copolymer, the glycol ether and an alcohol ethoxylate.

[0009] In some aspects, the techniques described herein relate to a method, wherein introducing the surfactant further includes introducing an aqueous surfactant composition to the sour gas stream, the aqueous surfactant composition including 0.5% to 15% by weight of the alkoxyated block copolymer and greater than 0% and up to 50% by weight of the glycol ether.

[0010] In some aspects, the techniques described herein relate to a method, wherein introducing the surfactant further includes introducing an aqueous surfactant composition to the sour gas stream, the aqueous surfactant composition including 0.5% to 15% by weight of the alkoxyated block copolymer and greater than 0% and up to 50% by weight of the glycol ether, wherein the alkoxyated block copolymer includes a structure:  $R1-[R2]_n-R3$ , wherein R1 is an alkyl group arranged in a chain, R2 is a block copolymer, n is a number, and R3 is an end cap.

[0011] In some aspects, the techniques described herein relate to a method, wherein introducing the aqueous surfactant composition includes introducing the alkoxyated block copolymer including the end cap, the end cap including at least one of: a hydroxyl group or a short-chained alcohol of less than five carbon atoms.

[0012] In some aspects, the techniques described herein relate to a method, wherein introducing the surfactant further includes introducing an aqueous surfactant composition to the sour gas stream, the aqueous surfactant composition including 0.5% to 15% by weight of the alkoxyated block copolymer and greater than 0% up to 50% by weight of the glycol ether, wherein the glycol ether includes a structure:  $R5-(O-CH_2)_x-OH$ , wherein R5 is a short-chained alkyl group and x is a number between 2 and 4.

[0013] In some aspects, the techniques described herein relate to a method, wherein introducing the surfactant further includes introducing an aqueous surfactant composition including 0.5% to 15% by weight of the alkoxyated block copolymer and greater than 0% up to 50% by weight of the glycol ether, wherein the glycol ether includes a structure  $R6-R7$  wherein R6 is an alkyl or aryl group, and R7 is a short-chained glycol group.

[0014] In some aspects, the techniques described herein relate to a method, wherein introducing the surfactant further includes introducing an aqueous surfactant composition to the sour gas stream, the aqueous surfactant composition including 0.5% to 15% by weight of the alkoxyated block copolymer and greater than 0% up to 50% by weight of the glycol ether, wherein at least one block of the alkoxyated block copolymer includes polyethylene glycol, with a number of blocks between three and ten units.

[0015] In some aspects, the techniques described herein relate to a method, wherein introducing the aqueous surfactant composition further includes introducing the at least one block of the alkoxyated block copolymer, wherein at least one block of the alkoxyated block copolymer is a more hydrophobic unit than the polyethylene glycol, and the at

least one block includes at least one of: polypropylene glycol, polylactone, polycaprolactone, polybutadiene, or any combination thereof.

**[0016]** In some aspects, the techniques described herein relate to a method, wherein introducing the surfactant includes introducing an aqueous surfactant composition to the sour gas stream, the aqueous surfactant composition including 0.5% to 15% by weight of the alkoxyated block copolymer and greater than 0% up to 50% by weight of the glycol ether, wherein the alkoxyated block copolymer includes a hydrophobic-lipophilic balance between 0 and 10.

**[0017]** In some aspects, the techniques described herein relate to a method, wherein introducing the surfactant includes introducing an aqueous surfactant composition including 0.5% to 15% by weight of the alkoxyated block copolymer and greater than 0% up to 50% by weight of the glycol ether, wherein the glycol ether includes one of: ethylene glycol ( $\text{—O—CH}_2\text{—CH}_2\text{—OH}$ ), propylene glycol ( $\text{—O—CH}_2\text{—CH}_2\text{—CH}_2\text{—OH}$ ) or diethylene glycol ( $\text{—OCH}_2\text{—CH}_2\text{—O—CH}_2\text{—CH}_2\text{—OH}$ ).

**[0018]** In some aspects, the techniques described herein relate to a method, wherein introducing the surfactant includes introducing an aqueous surfactant composition including 0.5% to 15% by weight of the alkoxyated block copolymer, greater than 0% and up to 50% by weight of the glycol ether and 0.5% to 15% by weight of an alcohol ethoxylate.

**[0019]** In some aspects, the techniques described herein relate to a method, wherein introducing the aqueous surfactant composition including 0.5% to 15% by weight of an alkoxyated block copolymer and greater than 0% and up to 50% by weight of the glycol ether further includes introducing the glycol ether, wherein the alkyl or the aryl group on R6 includes one of: methyl, ethyl, propyl, isopropyl, butyl, n-butyl, tert-butyl, phenyl, or benzyl groups.

**[0020]** In some aspects, the techniques described herein relate to a method, wherein introducing the aqueous surfactant composition including 0.5% to 15% by weight of the alkoxyated block copolymer and greater than 0% and up to 50% by weight of the glycol ether further includes introducing the glycol ether, wherein the short-chained glycol group includes ethylene glycol ( $\text{—O—CH}_2\text{—CH}_2\text{—OH}$ ), propylene glycol ( $\text{—O—CH}_2\text{—CH}_2\text{—CH}_2\text{—OH}$ ), or diethylene glycol ( $\text{—OCH}_2\text{—CH}_2\text{—O—CH}_2\text{—CH}_2\text{—OH}$ ).

**[0021]** In accordance with some implementations an aqueous surfactant composition comprises: 0.5% to 15% by weight of an alkoxyated block copolymer; and 0.5% to 15% by weight of an alcohol ethoxylate. Some implementations comprise greater than 0% and up to 50% by weight of a glycol ether. Some implementations comprise greater than 0% and up to 50% by weight of an alkyl alcohol. In some implementations the alkoxyated block copolymer comprises a structure:  $\text{R1—[R2]}_n\text{—R3}$ , wherein R1 is a long-chain alkyl group, R2 is a block copolymer, and R3 is an end cap, and wherein n is a number of different blocks in the block copolymer. In some implementations the alcohol ethoxylate comprises a long-chain alkyl group, wherein the alkyl group comprises at least seven carbon atoms. In some implementations at least one block of the alkoxyated block copolymer comprises polyethylene glycol, with a number of blocks between three and ten units. Some implementations, wherein at least one block of the alkoxyated block copolymer is a more hydrophobic unit than the polyethylene glycol, com-

prise at least one of: polypropylene glycol, polylactone, polycaprolactone, and/or polybutadiene, with the number of blocks between twenty and forty units. In some implementations the end cap comprises at least one of: a hydroxyl group and a short-chained alcohol of less than five carbon atoms. In some implementations the alkoxyated block copolymer comprises a Hydrophobic-Lipophilic Balance between 0 and 10. In some implementations the alcohol ethoxylate comprises a structure:  $\text{R4—O—(CH}_2\text{)}_x\text{—OH}$ , where R4 is a long chain alkyl group, and x is a number between 1 and 5. In some implementations the alkyl group comprises at least seven carbon atoms. In some implementations the alcohol ethoxylate comprises a Hydrophobic-Lipophilic Balance between 5 and 15. In some implementations the Draves Wetting Time of the alcohol ethoxylate is less than half than that of the alkoxyated block copolymer. In some implementations the concentration of the block copolymer is between 2- and 10-times by weight the concentration of the alcohol ethoxylate. In some implementations the glycol ether comprises a structure:  $\text{R5—(O—CH}_2\text{)}_x\text{—OH}$ , where R5 is a short-chained alkyl group and x is a number between 2 and 4. In some implementations the short-chained alkyl group comprises less than six carbon atoms. In some implementations the alkyl alcohol comprises an alkyl chain between 2 and 8 carbon units selected from the group including: ethanol, propanol, isopropanol, n-butanol, isobutanol, n-pentanol, isopentanol, hexanol, heptanol and/or octanol isomers. In some implementations the glycol ether comprises a structure R6-R7 wherein R6 is an alkyl or aryl group, and R7 is a short-chained glycol group. In some implementations the R6 group comprises one of: methyl, ethyl, propyl, isopropyl, butyl, n-butyl, tert-butyl, phenyl, and benzyl groups. In some implementations the R7 group comprises one of: ethylene glycol ( $\text{—O—CH}_2\text{—CH}_2\text{—OH}$ ), propylene glycol ( $\text{—O—CH}_2\text{—CH}_2\text{—CH}_2\text{—OH}$ ), and diethylene glycol ( $\text{—OCH}_2\text{—CH}_2\text{—O—CH}_2\text{—CH}_2\text{—OH}$ ).

**[0022]** All examples, aspects, and features mentioned in this document can be combined in any technically possible way. Moreover, alternative chemical forms including, but not limited to, salts, polymorphs, and solvates are within the scope of the present disclosure.

#### BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

**[0023]** The foregoing summary, as well as the detailed description of the preferred embodiments of the present invention, will be better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, there is shown in the drawings, which are diagrammatic, embodiments that are presently preferred. It should be understood, however, that the present invention is not limited to the precise arrangements and instrumentalities shown. In the drawings:

**[0024]** FIG. 1 illustrates an oxidation-reduction desulfurization process using a surfactant that simultaneously improves reaction kinetics and mitigates operational difficulties associated with the oxidation-reduction process;

**[0025]** FIG. 2 illustrates an apparatus for implementing the oxidation-reduction desulfurization process of FIG. 1; and

**[0026]** FIG. 3 illustrates how the surfactant facilitates operation of the phase separator.

# DETAILED DESCRIPTION OF THE DISCLOSURE

**[0027]** Small scale field processing systems for oxidation-reduction desulfurization of raw natural gas have eluded full commercialization due to the complexities of the multiphase nature of the process. The presence of multiple phases (oil, water, solid, and gaseous) promotes the creation of foams and emulsions that can cause operational difficulties such as pump cavitation, clogging, and sensor degradation. The multiphase composition of the raw natural gas stream is further complicated by a wide range in pH and temperature often seen in such operations, which has previously restricted the use of any single surfactant and/or demulsifier to abrogate the challenges seen in such complex systems. Anionic surfactants are non-ideal because of their extreme foaming tendencies. Defoamers have not provided a solution to the problem because they interfere with the oxidation-reduction chemistry and restrict the agricultural applications of the produced sulfur.

**[0028]** FIG. 1 illustrates an oxidation-reduction desulfurization process **100** for removal or recovery of sulfur-based contaminants from a sour gas stream **102** by using a surfactant that simultaneously improves reaction kinetics and mitigates operational difficulties associated with the desulfurization process. Although the desulfurization process is described and illustrated in the context of removing hydrogen sulfide from a sour gas stream **102** from a well **99**, wastewater that contains sulfur-based contaminants from a wide variety of sources other than oil and gas wells could be treated. For example, and without limitation, the process might be used to treat leachate from landfills and discharge wastewater from meat production facilities. Consequently, the invention should not be viewed as limited to treatment of sour gas streams from oil and gas wells. The order in which steps are performed may be rearranged, and some steps may be implemented partially or wholly concurrently.

**[0029]** The desulfurization process **100** includes a conversion stage **104** in which sulfur species that are present in the sour gas stream **102** are converted into elemental sulfur, sulfur species, or both. The conversion stage **104** includes introducing a surfactant in step **106**, introducing a reduction reagent in step **108**, and introducing oxidizer in step **110**. The reagent may include one or more of ferric salts, ferrous salts, ferric chelants, ferrous chelants, and Fe-MGDA (ferric/ferrous methylglycinediacetate), e.g. Alanine, n,n-bis, (carboxymethyl) iron complex (CAS 547763-83-7). The oxidizer may include one or more of chlorine, hypochlorous acid, hypochlorite, chlorine dioxide, chlorite, perchlorate, inorganic peroxides, permanganates, sodium, oxygen, and ozone. In the conversion stage **104** the hydrogen sulfide in the sour gas stream is oxidized into elemental sulfur, sulfur species, or both by exposure to the combination of reduction reagent and oxidizer. The surfactant inhibits emulsion formation, promotes settling of sulfur, reduces or prevents foaming, and facilitates removal of solids. The surfactant may simultaneously improve reaction kinetics and mitigate operational difficulties associated with the oxidation-reduction desulfurization process. Step **112** is separating the converted stream into phases. The gaseous phase is diverted in step **114**, resulting in recovery of sweet gas **116** from the sour gas stream **102**. The remaining aqueous or multi-phase stream is diverted in step **118** and subjected to further separation processing in step **120**. The result of step **120** may

include, but is not limited to, sulfur **122** (elemental sulfur, sulfur species, or both) and sweet water **124**.

**[0030]** The surfactant may be a blend of two chemical compositions that act in concert. The first chemical composition is a non-ionic alkyl ethoxylate. The non-ionic alkyl ethoxylate acts as a fast wetting agent. The second chemical composition is a block copolymer, e.g. a diblock copolymer. The block copolymer is characterized by a longer wetting time than the non-ionic alkyl ethoxylate. In the first minute within addition the non-ionic alkyl ethoxylate creates a thin film around the sulfur particles. The block copolymer disrupts the emulsion and allows the now-coated sulfur particles to escape the existing emulsion.

**[0031]** An aspect that promotes efficacy of the surfactant is the difference in reaction rates between the non-ionic alkyl ethoxylate and the block copolymer. If both compositions had the same reaction rates and operated at the same time scale, the wetting agent would be competing with the diblock copolymer on the sulfur particle surface, thereby requiring a greater amount of the wetting agent. Additionally, the diblock copolymer on the sulfur particle surface would slow down settling due to steric hindrance effects, thereby making the formulation less efficient.

**[0032]** Another aspect that promotes efficacy of the surfactant is the ratio of concentrations of the non-ionic alkyl ethoxylate and the block copolymer. Surplus alkyl ethoxylate will inhibit the emulsion-breaking capabilities of the block copolymer, and surplus block copolymer will sterically hinder the alkyl ethoxylate from reaching the sulfur particle surface. The ratio of block copolymer to alkyl ethoxylate in some implementations is between 2- and 10-times in concentration by weight.

**[0033]** The surfactant may include additional components. A first component is an alkyl alcohol that has a carbon length chain between 3 and 8, possibly including, but not limited to: propanol, isopropanol, n-pentanol, n-butanol, isobutanol, sec-butanol, tert-butanol, and/or isomers of pentanol, hexanol, heptanol, or octanol. The first component augments the emulsion-breaking capabilities of the diblock copolymer by providing additional surface tension reduction to the system, as well as emulsion inhibition at the aqueous-gaseous interface. A second component is glycol ether, possibly including, but not limited to: ethylene glycol monobutyl ether, ethylene glycol benzyl ether, and diethylene glycol monobutyl ether. The glycol ether acts as a mutual solvent, which also augments the emulsion breaking capabilities of the diblock copolymer by providing additional surface tension reduction to the system, as well as emulsion inhibition at the aqueous-gaseous interface.

**[0034]** In some implementations the surfactant includes of 1% to 4% by weight non-ionic alkyl ethoxylate, for example, an alkyl-ethoxylate with a Hydrophilic-Lipophilic Balance (HLB) of 2-4; 8% to 10% by weight diblock copolymer, for example a PEG-PEO diblock copolymer with HLB of 8-10; 30% to 50% by weight alcohol, and the balance glycol ether. In some implementations the surfactant includes 1% to 4% by weight non-ionic alkyl alkoxyate, for example, an ethoxy alkoxyate with a Hydrophilic-Lipophilic Balance (HLB) of 2-4; 8% to 10% by weight diblock copolymer; and the balance water. Some implementations comprise greater than 0% and up to 50% by weight of a glycol ether. Some implementations comprise greater than 0% and up to 50% by weight of an alkyl alcohol. In some implementations the alkoxyated block copolymer com-

prises a structure:  $R1-[R2]_n-R3$ , wherein  $R1$  is a long-chain alkyl group,  $R2$  a block copolymer, and  $R3$  an end cap, and wherein  $n$  is a number of different blocks in the block copolymer. In some implementations the alcohol ethoxylate comprises a long-chain alkyl group, wherein the alkyl group comprises at least seven carbon atoms. In some implementations at least one block of the alkoxyated block copolymer comprises polyethylene glycol, with a number of blocks between three and ten units. Some implementations, wherein at least one block of the alkoxyated block copolymer is a more hydrophobic unit than the polyethylene glycol, comprise at least one of: polypropylene glycol, polylactone, polycaprolactone, and/or polybutadiene, with the number of blocks between twenty and forty units. In some implementations the end cap comprises at least one of: a hydroxyl group and a short-chained alcohol of less than five carbon atoms. In some implementations the alkoxyated block copolymer comprises a Hydrophobic-Lipophilic Balance between 0 and 10. In some implementations the alcohol ethoxylate comprises a structure:  $R4-O-(CH_2)_x-OH$ , where  $R4$  is a long chain alkyl group, and  $x$  is a number between 1 and 5. In some implementations the alkyl group comprises at least seven carbon atoms. In some implementations the alcohol ethoxylate comprises a Hydrophobic-Lipophilic Balance between 5 and 15. In some implementations the Draves Wetting Time of the alcohol ethoxylate is less than half than that of the alkoxyated block copolymer. In some implementations the concentration of the block copolymer is between 2- and 10-times by weight the concentration of the alcohol ethoxylate. In some implementations the glycol ether comprises a structure:  $R5-(O-CH_2)_x-OH$ , where  $R5$  is a short-chained alkyl group and  $x$  is a number between 2 and 4. In some implementations the short-chained alkyl group comprises less than six carbon atoms. In some implementations the alkyl alcohol comprises an alkyl chain between 2 and 8 carbon units selected from the group including: ethanol, propanol, isopropanol, n-butanol, isobutanol, n-pentanol, isopentanol, hexanol, heptanol and/or octanol isomers. In some implementations the glycol ether comprises a structure  $R6-R7$  wherein  $R6$  is an alkyl or aryl group, and  $R7$  is a short-chained glycol group. In some implementations the  $R6$  group comprises one of: methyl, ethyl, propyl, isopropyl, butyl, n-butyl, tert-butyl, phenyl, and benzyl groups. In some implementations the  $R7$  group comprises one of: ethylene glycol ( $-O-CH_2-CH_2-OH$ ), propylene glycol ( $-O-CH_2-CH_2-CH_2-OH$ ), and diethylene glycol ( $-OCH_2-CH_2-O-CH_2-CH_2-OH$ ).

[0035] FIG. 2 illustrates an apparatus for implementing the oxidation-reduction desulfurization process of FIG. 1. The apparatus includes a hydrogen sulfide reactor vessel 200, a reagent tank 202, a surfactant tank 204, an oxidizer tank 206, a phase separator 208, and a separation unit 210. The sour gas stream 102 from well 99 is inputted to the hydrogen sulfide reactor vessel 200. The reactor vessel is a pressure vessel matched to the pressure of the sour gas stream. Reagent, surfactant, and oxidizer are introduced to the reactor vessel 200 from their respective tanks 202, 204, 206. The hydrogen sulfide in the sour gas stream is oxidized into elemental sulfur, sulfur species, or both by exposure to the reagent and oxidizer. The surfactant inhibits emulsion formation, promotes settling of sulfur, reduces or prevents foaming, and facilitates removal of solids. The phase separator 208 is used to separate the gaseous phase 212 from the

remaining aqueous/multi-phase 214. The gaseous phase 212 is sweet gas 116. The aqueous/multi-phase is provided to the separation unit to separate sulfur 122 (elemental and/or sulfur species) and sweet water 124.

[0036] FIG. 3 illustrates how the surfactant facilitates operation of the phase separator 208. In the illustrated example the phase separator 208 includes a vertically oriented conduit in the reactor vessel 200. As sour gas, reagent, oxidizer, and surfactant are introduced at the bottom of the reactor vessel the reaction progresses upward in the column of gas and liquid. A layer of foam 300 forms at the top surface of the liquid and gas column. Separated sweet gas is removed at the top of the reactor vessel. The remaining liquid flows into the phase separator. Excessive amounts of foam would potentially cause gas to flow into the phase separator with the liquid, resulting in recovery of less sweet gas. Further, excessive amounts of foam could cause sour liquid to exit the reactor vessel with the sweet gas.

[0037] Several features, aspects, embodiments, and implementations have been described. Nevertheless, it will be understood that a wide variety of modifications and combinations may be made without departing from the scope of the inventive concepts described herein. Accordingly, those modifications and combinations are within the scope of the following claims.

What is claimed is:

1. A method for converting a sulfur species present in a sour gas stream into at least one of solid sulfur or a solid sulfur species, comprising:

introducing a surfactant to the sour gas stream, the surfactant including an alkoxyated block copolymer and a glycol ether; and

introducing, to the sour gas stream, a reducing reagent configured to convert the sulfur species in the sour gas stream into at least one of solid sulfur or solid sulfur species.

2. The method of claim 1, further comprising: introducing an oxidizer into the sour gas stream.

3. The method of claim 1, wherein introducing the surfactant includes introducing an aqueous surfactant composition to the sour gas stream, the aqueous surfactant composition including the alkoxyated block copolymer and the glycol ether.

4. The method of claim 1, wherein introducing the surfactant further comprises introducing the surfactant to the sour gas stream, the surfactant including the alkoxyated block copolymer, the glycol ether and an alcohol ethoxylate.

5. The method of claim 1, wherein introducing the surfactant further comprises introducing an aqueous surfactant composition to the sour gas stream, the aqueous surfactant composition including 0.5% to 15% by weight of the alkoxyated block copolymer and greater than 0% and up to 50% by weight of the glycol ether.

6. The method of claim 1, wherein introducing the surfactant further comprises introducing an aqueous surfactant composition to the sour gas stream, the aqueous surfactant composition including 0.5% to 15% by weight of the alkoxyated block copolymer and greater than 0% and up to 50% by weight of the glycol ether, wherein the alkoxyated block copolymer comprises a structure:  $R1-[R2]_n-R3$ , wherein  $R1$  is an alkyl group arranged in a chain,  $R2$  is a block copolymer,  $n$  is a number, and  $R3$  is an end cap.

7. The method of claim 6, wherein introducing the aqueous surfactant composition comprises introducing the



alkoxylated block copolymer including the end cap, the end cap comprising at least one of: a hydroxyl group or a short-chained alcohol of less than five carbon atoms.

8. The method of claim 1, wherein introducing the surfactant further comprises introducing an aqueous surfactant composition to the sour gas stream, the aqueous surfactant composition including 0.5% to 15% by weight of the alkoxylated block copolymer and greater than 0% up to 50% by weight of the glycol ether, wherein the glycol ether includes a structure:  $R5-(O-CH_2)_x-OH$ , wherein R5 is a short-chained alkyl group and x is a number between 2 and 4.

9. The method of claim 1, wherein introducing the surfactant further comprises introducing an aqueous surfactant composition comprising 0.5% to 15% by weight of the alkoxylated block copolymer and greater than 0% up to 50% by weight of the glycol ether, wherein the glycol ether comprises a structure R6-R7 wherein R6 is an alkyl or aryl group, and R7 is a short-chained glycol group.

10. The method of claim 1, wherein introducing the surfactant further comprises introducing an aqueous surfactant composition to the sour gas stream, the aqueous surfactant composition including 0.5% to 15% by weight of the alkoxylated block copolymer and greater than 0% up to 50% by weight of the glycol ether, wherein at least one block of the alkoxylated block copolymer comprises polyethylene glycol, with a number of blocks between three and ten units.

11. The method of claim 10, wherein introducing the aqueous surfactant composition further comprises introducing the at least one block of the alkoxylated block copolymer,

wherein at least one block of the alkoxylated block copolymer is a more hydrophobic unit than the polyethylene glycol, and the at least one block comprises at least one of: polypropylene glycol, polylactone, polycaprolactone, polybutadiene, or any combination thereof.

12. The method of claim 1, wherein introducing the surfactant comprises introducing an aqueous surfactant

composition to the sour gas stream, the aqueous surfactant composition including 0.5% to 15% by weight of the alkoxylated block copolymer and greater than 0% up to 50% by weight of the glycol ether, wherein the alkoxylated block copolymer comprises a hydrophobic-lipophilic balance between 0 and 10.

13. The method of claim 1, wherein introducing the surfactant comprises introducing an aqueous surfactant composition comprising 0.5% to 15% by weight of the alkoxylated block copolymer and greater than 0% up to 50% by weight of the glycol ether, wherein the glycol ether comprises one of: ethylene glycol ( $-O-CH_2-CH_2-OH$ ), propylene glycol ( $-O-CH_2-CH_2-CH_2-OH$ ) or diethylene glycol ( $-OCH_2-CH_2-O-CH_2-CH_2-OH$ ).

14. The method of claim 4, wherein introducing the surfactant comprises introducing an aqueous surfactant composition comprising 0.5% to 15% by weight of the alkoxylated block copolymer, greater than 0% and up to 50% by weight of the glycol ether and 0.5% to 15% by weight of an alcohol ethoxylate.

15. The method of claim 9, wherein introducing the aqueous surfactant composition comprising 0.5% to 15% by weight of an alkoxylated block copolymer and greater than 0% and up to 50% by weight of the glycol ether further comprises introducing the glycol ether, wherein the alkyl or the aryl group on R6 comprises one of: methyl, ethyl, propyl, isopropyl, butyl, n-butyl, tert-butyl, phenyl, or benzyl groups.

16. The method of claim 9, wherein introducing the aqueous surfactant composition comprising 0.5% to 15% by weight of the alkoxylated block copolymer and greater than 0% and up to 50% by weight of the glycol ether further comprises introducing the glycol ether, wherein the short-chained glycol group comprises ethylene glycol ( $-O-CH_2-CH_2-OH$ ), propylene glycol ( $-O-CH_2-CH_2-CH_2-OH$ ), or diethylene glycol ( $-OCH_2-CH_2-O-CH_2-CH_2-OH$ ).

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