

CORROSION INHIBITOR FOR ALKANOLAMINE UNITS

FIELD OF THE INVENTION

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The present invention relates to methods of inhibiting corrosion in aqueous alkanolamine solutions and compositions for inhibiting corrosion in aqueous alkanolamine solutions. More particularly, the present invention relates to methods of inhibiting corrosion of metals in contact with aqueous alkanolamine solutions in acid gas removal amine units using urea and thiourea compositions.

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BACKGROUND OF THE INVENTION

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The conditioning of naturally occurring liquid and gas streams by absorbing acid gases such as CO₂ and H₂S in an absorbent solution is a well known commercial practice. Acid gas removal is commonly practiced in the oil refining, natural gas recovery, ammonia plant and wood pulp industries. For example, when crude oil and natural gas are removed from a formation they frequently contain CO₂ or H₂S (acid gases). Acid gases are removed from the hydrocarbon in an acid gas removal amine system (an amine unit). Amine units are typically constructed of carbon steel and operate at temperatures of from about

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110° to about 300° F, at pressures of from about 10 to about 500 psig and with less than about 10 ppm of oxygen present as an undesirable contaminant in the aqueous alkanolamine solution. An amine unit utilizes an alkanolamine such as monoethanolamine (MEA), diethanolamine
5 (DEA), methyldiethanolamine (MDEA), diisopropylamine (DIPA), and diglycolamine (DGA) in an aqueous solution. The hydrocarbon containing acid gases are contacted with the aqueous amine solution in a tray or packed absorber where the amine reacts with the acid gases thereby removing them from the hydrocarbon and forming an aqueous
10 amine solution containing the absorbed acid gases (rich stream). The amine-acid gas reaction is later reversed in a plate or packed stripper resulting in an acid gas stream and a reusable aqueous amine solution (lean stream).

15 Amine units present a variety of corrosion control problems. Unreacted carbon dioxide dissolved in the aqueous alkanolamine solution forms acid species which are corrosive to metals. Oxygen can enter an amine unit through storage tanks, sumps, surge vessels, and the like and attack metals causing corrosion. Oxygen also can oxidize the
20 alkanolamine. Oxidation and degradation products of alkanolamines can cause metal corrosion. Efforts to control corrosion in amine units usually focus on the use of metallurgy, minimization of acid gas flashing, filtration, stress relieving, process controls and corrosion inhibitors such as metal passivating agents. However, environmental and safety
25 concerns have limited the practicality of using some materials such as nickel, cobalt, calcium, copper, chromium, zinc, tin, aluminum, magnesium and cyano compounds and the like as corrosion inhibiting agents. Since corrosion, if left untreated, can cause shut-down of an amine unit, corrosion control is a very important consideration. In

addition, most corrosion control efforts have focused on treating the rich stream of the amine unit. However, the lean sections of amine units also experience corrosion.

5 Therefore, a need exists for compositions which when added to an aqueous alkanolamine solution in an acid gas removal amine unit inhibits corrosion of metals in contact with the aqueous alkanolamine solutions and which are effective for inhibiting corrosion in both the rich and lean portions of the amine unit.

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Accordingly, it is an object of the present invention to provide compounds for inhibiting corrosion of metals in contact with aqueous alkanolamine solutions.

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It is also an object of this invention to provide compounds which are effective for inhibiting metal corrosion in both the rich and lean portions of amine units containing aqueous alkanolamine solutions.

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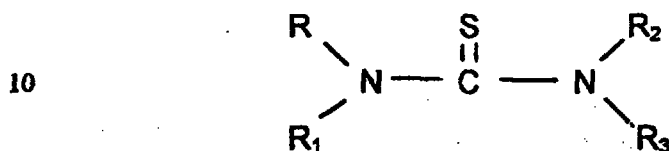
It is an additional object of the present invention to provide aqueous acid gas removal solutions for use in amine units which are inhibited against acid gas promoted corrosion of metals.

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It is yet another object of this invention to provide a method for inhibiting corrosion of metals in contact with aqueous alkanolamine solutions in amine acid gas removal units.

PRIOR ART

U.S. Patent 3,133,028 to Kenhere discloses that corrosion of metals in contact with water can be inhibited by the use of water-soluble
5 hexavalent chromium compounds in conjunction with water-soluble thiocyanates, and/or water soluble thiourea compounds of the type represented by the formula:



where R, R₁, R₂ and R₃ are selected from the group consisting of hydrogen, alkali metal, and alkyl radicals containing from 1 to 4 carbon
15 atoms. Zinc compounds are also disclosed as corrosion inhibiting compounds when used in conjunction with water-soluble hexavalent chromium.

U.S. Patent 4,100,100 to Clouse et al. discloses the corrosion of
20 iron and steel by an aqueous sour gas conditioning solution to remove CO₂ from a gas stream is inhibited by a combination of a quaternary pyridinium salt and an organic thioamide or water-soluble thiocyanate and a water-soluble cobalt salt. The patent discloses that the cobalt compound, the thio compound or the pyridinium salt alone will provide no
25 inhibition or only partial inhibition.

U.S. Patent 4,102,804 to Clouse et al. discloses the corrosion of iron and steel in an aqueous sour gas conditioning system is inhibited by a combination of a quaternary pyridinium salt and an organic thioamide, a

water-soluble sulfide or a water-soluble thiocyanate. The patent also discloses that either the thio compound or the pyridinium salt alone will provide no inhibition or only partial inhibition.

5 U.S. Patent 4,446,119 to DuPont et al. discloses a corrosion inhibited composition containing a gas conditioning solution such as an alkanolamine with water or with organic solvents and with soluble thiocyanate compounds, soluble trivalent bismuth compounds with or without soluble divalent nickel or cobalt compounds.

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U.S. Patent 4,431,563 to Krawczyk et al. discloses that corrosion of ferrous metals in gas conditioning apparatus is inhibited by using a gas conditioning solution such as aqueous alkanolamines which contain thionitrogen compounds such as metal thiocyanates or thioamides. The
15 patent discloses that metals such as cobalt, nickel, calcium, copper, chromium, zinc, tin, aluminum and magnesium will dissolve from the equipment after a few days of recycling the gas conditioning solution or these metals may be introduced into the gas conditioning solution as additives. The metals in the gas conditioning solution act as a synergist
20 with the thionitrogen compounds to inhibit metal corrosion in the gas conditioning apparatus.

U.S. Patent 4,541,946 to Jones et al. discloses a corrosion inhibitor composition useful for preventing corrosion by solvents used in
25 treating sour gas streams comprising a quaternary pyridinium salt, a surface-active and/or a thio compound and a water soluble nickel compound. The thio compound can be an organic thioamide or preferably a water-soluble thiocyanate. The patent also discloses that the nickel

compound, the thio compound, the surface-active compound or the pyridinium salt, when used alone, provide little or no corrosion inhibition.

U.S. Patent 4,595,723 to Henson et al. discloses a thiourea -
5 amine-formaldehyde based polymer used in combination with a nickel (II) ion for inhibiting corrosion of ferrous metals and its alloys in gas conditioning service using aqueous monoethanolamine to scrub carbon dioxide.

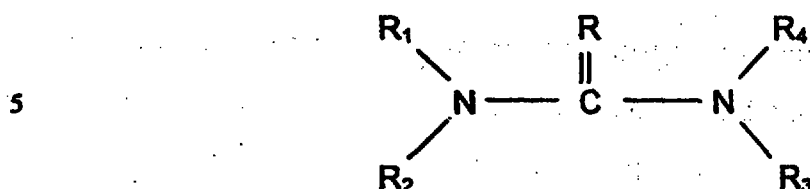
10 U.S. Patent 4,596,849 to Henson et al. discloses a thiourea - amine-formaldehyde based polymer used in combination with a copper (II) ion for inhibiting corrosion of ferrous metals and its alloys in gas conditioning service using aqueous monoethanolamine to scrub carbon dioxide containing oxygen.

15 U.S. Patent 5,531,937 to Minevski et al. discloses non-sulfur based compositions comprising water soluble n-alkyl morpholine, saturated dicarboxylic acid and optionally alkanolamine and optionally
20 surfactants for inhibition of ferrous metal corrosion in oxygen-free solutions.

SUMMARY OF THE INVENTION

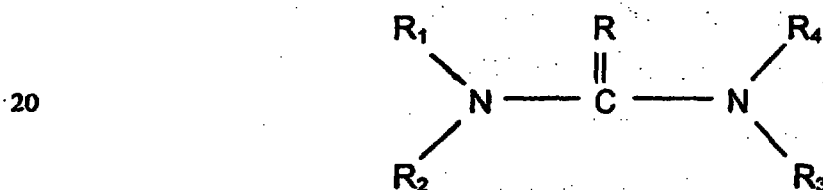
To achieve the foregoing objects, the present invention provides
25 compositions for inhibiting corrosion of metals in contact with aqueous alkanolamine solutions. The compositions are compounds effective for

inhibiting metal corrosion having the formula:



where R is S or O, and R₁, R₂, R₃ and R₄ are independently H, C₁ to C₈ alkyl, C₁ to C₈ alkenyl, C₆ to C₁₀ aryl, C₇ to C₁₂ alkaryl, C₇ to C₁₂ aralkyl, C₃ to C₁₀ cycloalkyl, C₁ to C₈ thiophene, or amino groups.

The invention also provides aqueous acid gas removal solutions inhibited against acid gas promoted corrosion of metals. The solutions are comprised of an alkanolamine, at least one compound effective for inhibiting corrosion having the formula:

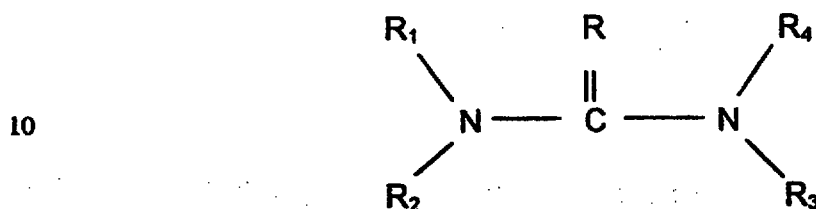


where R is S or O, and R₁, R₂, R₃ and R₄ are independently H, C₁ to C₈ alkyl, C₁ to C₈ alkenyl, C₆ to C₁₀ aryl, C₇ to C₁₂ alkaryl, C₇ to C₁₂ aralkyl, C₃ to C₁₀ cycloalkyl, C₁ to C₈ thiophene, or amino groups and water.

The invention further provides a method for inhibiting corrosion of metals in contact with aqueous alkanolamine solutions. The method comprises adding an amount of the invention compound, to an aqueous alkanolamine solution, sufficient to establish a concentration of the compound in the aqueous solution which is effective for the purpose of inhibiting metal corrosion in an amine acid gas removal unit.

DETAILED DESCRIPTION OF THE INVENTION

In accordance with the present invention, a method of and a composition for inhibiting corrosion of metals in aqueous alkanolamine solutions is provided. The present inventors have discovered that one or more compounds, effective as metal corrosion inhibitors and represented by the formula:



where R is S or O, and R₁, R₂, R₃ and R₄ are independently H, C₁ to C₈ alkyl, C₁ to C₈ alkenyl, C₆ to C₁₀ aryl, C₇ to C₁₂ alkaryl, C₇ to C₁₂ aralkyl, C₃ to C₁₀ cycloalkyl, C₁ to C₈ thiophene, or amino groups, when added to an aqueous alkanolamine solution, inhibits corrosion of metals in contact with the alkanolamine solution in acid gas removal amine units. The invention compounds are effective for inhibiting metal corrosion in both the rich and lean portions of acid gas removal equipment.

The inventors believe that tetramethylurea; 1,3-dicyclohexylurea; m-tolylurea; benzylurea; phenylurea; 1,1,3,3-tetramethylthiourea; 1,3-dicyclohexylthiourea; m-tolylthiourea; benzylthiourea; phenylthiourea; 1,3-diphenylthiourea; 1,3-n-dibutylthiourea; 1-phenyl-3-ethylthiourea; 1,3-diaminothiourea; 1,3-diethylthiourea; 1,3-diallylthiourea; 1,1-dibenzylthiourea; 1,1-diethylthiourea; and 1,1,3-triethylthiourea would be effective for the practice of this invention.

The preferred invention compounds for the practice of this invention are thiourea; thiosinamine; 1,1-diethylurea; 1-3-diethylurea; 2-thiophene carboxamide; aminothiourea and 1,3-diphenyl-2-thiourea.

5 The corrosion inhibiting compounds of this invention can be added neat to the alkanolamine solution in an amine unit or can be added diluted with water, and/or a water soluble alkanol, cyclic acid or amide, and/or with an alkanolamine solution.

10 Preferred solvents are isopropanol, phthalic acid and N-methyl- α -pyrrolidone (NMP).

The compounds of this invention are also effective for inhibiting corrosion in aqueous alkanolamine solutions substantially free of
15 materials such as passivating agents including nickel, cobalt, calcium, copper, chromium, zinc, tin, aluminum, magnesium and cyano compounds.

As used herein, "substantially free of" means that less than about
20 1 ppm of a material is present in the aqueous alkanolamine solution as an undesirable contaminant.

The amount of corrosion inhibiting compound which will be added to an amine unit to inhibit corrosion will vary depending on the operating
25 conditions of each amine unit. However, it is expected that from about 5 parts to about 1000 parts of the invention corrosion inhibiting compound per million parts alkanolamine solution (ppm) will be effective to inhibit corrosion of metals in contact with an aqueous alkanolamine solution within an amine unit. The preferred treatment level is from about 25 to

about 750 ppm and the most preferred treatment level is from about 25 ppm to about 500 ppm of corrosion inhibiting compound in the alkanolamine unit.

5 On a weight percent basis, the corrosion inhibited alkanolamine solution in the amine unit is comprised of about 15 to 75 weight percent alkanolamine, about 25 to 85 weight percent water and less than about 1 weight percent corrosion inhibiting compound with the proviso that the sum of the weight percentages equals 100 weight percent.

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In order to show the efficacy of using the invention corrosion inhibiting compounds to inhibit corrosion of metals in contact with aqueous alkanolamine solutions, various tests were performed. The results are presented herein for purposes of illustration and not limitation.

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EXAMPLE I

A standard three electrode system was used to evaluate the corrosion inhibiting effect of various amounts of the invention corrosion inhibitor on metal in contact with an aqueous alkanolamine solution.

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Test conditions simulated conditions in the lean portions of an amine unit by using an alkanolamine which had been purged with argon. Rich portions of an amine unit were simulated by using an alkanolamine purged with CO₂ or a mixture of alkanolamine and Na₂S purged with CO₂. Various alkanolamine acid gas removal fluids containing acidic materials were used in the tests.

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Mild steel 1018 electrodes in the form of a disk were used as the metal simulating the metal in amine unit equipment. The temperature ranged from about 150°F to 260°F. Gases were either purged continuously through the solution in the electrochemical glass cell or 20-80 psi of CO₂ pressure was applied in an autoclave.

Table I below shows the formulations tested. The results are shown in Tables II and III.

TABLE I

Weight percentages of components in each formulation A-E.

	A	B	C	D	E
Water	91	62.5	75	50	0
Thiourea	9	0	0	0	0
Thiosinamine	0	12.5	0	0	0
Isopropanol	0	25	0	47.5	0
1,1-Diethylurea	0	0	25	0	0
2-Thiophene Carboxamide	0	0	0	1.25	0
Phthalic acid	0	0	0	1.25	0
Thiocarbanilide	0	0	0	0	10
NMP	0	0	0	0	90

Test results after 16 hours are shown in Tables II and III.

Table II
 % Protection at temperature 190°F in *MDEA fluid in the
 presence of different inhibitor formulations

Treatment Concentration (ppmA)	Sample	Lean System Ar	Rich System CO ₂	Rich System CO ₂ /H ₂ S
300	B	/	61	50
90	A	33	75	/
250	A	53	74	/
300	A	40	65	/
250	A	80	87	/
500	A	53	81	58

where ppmA means parts per million actives, / indicates that testing was not done under the indicated condition and where *MDEA was 50 weight percent methyldiethanolamine in water containing 1950 ppm formic acid, 940 ppm acetic acid, 370 ppm oxalic acid, 185 ppm lactic acid, 40 ppm propionic acid and 20 ppm sodium chloride.

Table III
 % Protection at temperature 190°F in *MEA fluid in the
 presence of different inhibitor formulations

Treatment Concentration (ppmA)	Sample	Lean System Ar	Rich System CO ₂	Rich System CO ₂ /H ₂ S
277	B	0	26	60
500	B	/	59	48
250	C	19	37	20
300	A	47	42	/
56	D	30	75	/
250	E	0	20	50

where ppmA means parts per million actives, / indicates that testing was not done under the indicated condition and where *MEA was 18 weight percent monoethanolamine in water containing 140 ppm sulfuric acid, 150 ppm oxalic acid, 140 ppm acetic acid, 240 ppm formic acid and 30 ppm sodium chloride.

Tables II-III demonstrate that the invention compounds, when added to an aqueous alkanolamine solution, inhibit acid gas induced corrosion of metals in contact with the aqueous alkanolamine solution.

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Thus, the present invention provides compounds for inhibiting corrosion of metals in contact with aqueous alkanolamine solutions and also provides aqueous acid gas removal solutions inhibited against acid gas promoted corrosion of metals.

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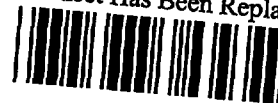
The invention further provides a method for inhibiting corrosion of metals in contact with aqueous alkanolamine solutions in amine acid gas removal units. The method comprises adding an amount of the invention compounds, to an aqueous alkanolamine solution, sufficient to establish a concentration of the compounds in the aqueous alkanolamine solution which is effective for the purpose of inhibiting metal corrosion in both the rich and lean portions of an amine acid gas removal unit.

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While this invention has been described with respect to particular embodiments thereof, it is apparent that numerous other forms and modifications of the invention will be obvious to those skilled in the art. The appended claims and this invention generally should be construed to cover all such obvious forms and modifications which are within the true spirit and scope of the present invention.

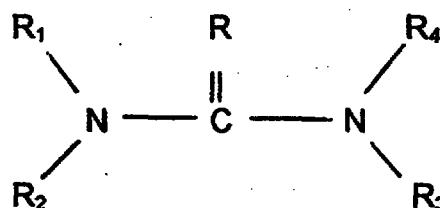
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What is claimed is:

1. A method for inhibiting corrosion of metals in contact with an aqueous alkanolamine solution comprising adding to the aqueous alkanolamine solution an effective corrosion inhibiting amount of a compound, effective as a corrosion inhibitor and having the formula:



where R is S or O, and R₁, R₂, R₃ and R₄ are independently H, C₁ to C₈ alkyl, C₁ to C₈ alkenyl, C₆ to C₁₀ aryl, C₇ to C₁₂ alkaryl, C₇ to C₁₂ aralkyl, C₃ to C₁₀ cycloalkyl, C₁ to C₈ thiophene, or amino groups in said aqueous alkanolamine solution, wherein said aqueous alkanolamine solution is substantially free of metal and cyano compound passivating agents.

2. The method of claim 1 wherein said compound is selected from the group consisting of thiourea; thiosinamine; 1, 1-diethylurea; 1,3-diethylurea; 2-thiophene carboxamide; aminothiurea; 1,3-diphenyl-2-thiourea; tetramethylurea; 1,3-dicyclohexylurea; m-tolylurea; benzylurea; phenylurea; 1,1,3,3-tetramethylthiourea; 1,3-dicyclohexylthiourea; m-tolylthiourea; benzylthiourea; phenylthiourea; 1,3-diphenylthiourea; 1,3-n-dibutylthiourea; 1-phenyl-3-ethylthiourea; 1,3-diaminothiourea; 1,3-diethylthiourea; 1,3-diallylthiourea; 1,1-dibenzylthiourea; 1,1-diethylthiourea; and 1,1,3-triethylthiourea.



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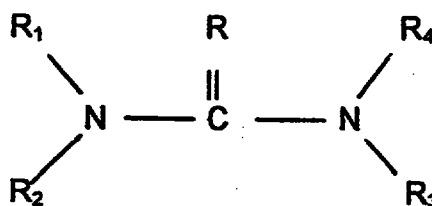
3. The method of claim 1 wherein said compound is thiourea; thiosinamine; 1,1-diethylurea; 1-3-diethylurea; 2-thiophene carboxamide; aminothiourea; or 1,3-diphenyl-2-thiourea.

4. The method of claim 1 wherein said aqueous alkanolamine solution contains dissolved acid gases.

5. The method of claim 1 wherein said effective corrosion inhibiting amount is from about 5 ppm to about 1000 ppm of alkanedithiol in said aqueous alkanolamine solution.

6. A method for inhibiting corrosion of metals in contact with an aqueous alkanolamine solution, in the lean portions of acid gas removal equipment, comprising adding to said aqueous alkanolamine solution a corrosion inhibiting amount of a compound effective as a corrosion inhibitor and having the formula:

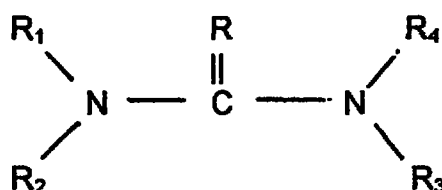
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where R is S or O, and R₁, R₂, R₃ and R₄ are independently H, C₁ to C₈ alkyl, C₁ to C₈ alkenyl, C₆ to C₁₀ aryl, C₇ to C₁₂ alkaryl, C₇ to C₁₂ aralkyl, C₃ to C₁₀ cycloalkyl, C₁ to C₈ thiophene, or amino groups and wherein said alkanolamine solution is substantially free of metal and cyano compound passivating agents.

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7. The method of claim 6 wherein said compound is selected from the group consisting of thiourea; thiosinamine; 1, 1-diethylurea; 1,3-diethylurea; 2-thiophene carboxamide; aminothiurea; 1,3-diphenyl-2-thiourea; tetramethylurea; 1,3-dicyclohexylurea; m-tolylurea; benzylurea; phenylurea; 1,1,3,3-tetramethylthiourea; 1,3-dicyclohexylthiourea; m-tolylthiourea; benzylthiourea; phenylthiourea; 1,3-diphenylthiourea; 1,3-n-dibutylthiourea; 1-phenyl-3-ethylthiourea; 1,3-diaminothiourea; 1,3-diethylthiourea; 1,3-diallylthiourea; 1,1-dibenzylthiourea; 1,1-diethylthiourea; and 1,1,3-triethylthiourea.
8. The method of claim 6 wherein said compound is thiourea; thiosinamine; 1,1-diethylurea; 1,3-diethylurea; 2-thiophene carboxamide; aminothiurea; or 1,3-diphenyl-2-thiourea.
9. The method of claim 6 wherein said effective corrosion inhibiting amount is from about 5 ppm to about 1000 ppm of alkanedithiol in said aqueous alkanolamine solution.
10. An aqueous acid gas removal solution inhibited against acid gas promoted corrosion of metals consisting essentially of:
- a) an alkanolamine;
 - b) a compound effective as a corrosion inhibitor having the formula:



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where R is S or O, and R₁, R₂, R₃ and R₄ are independently H, C₁ to C₈ alkyl, C₁ to C₈ alkenyl, C₆ to C₁₀ aryl, C₇ to C₁₂ alkaryl, C₇ to C₁₂ aralkyl, C₃ to C₁₀ cycloalkyl, C₁ to C₈ thiophene, or amino groups; and

c) water;

wherein said alkanolamine solution is substantially free of metal and cyano compound passivating agents.

11. The aqueous acid gas removal solution inhibited against acid gas promoted corrosion of metals of claim 10 wherein said compound is selected from the group consisting of thiourea; thiosinamine; 1, 1-diethylurea; 1,3-diethylurea; 2-thiophene carboxamide; aminothiurea; 5 1,3-diphenyl-2-thiourea; tetramethylurea; 1,3-dicyclohexylurea; m-tolylurea; benzylurea; phenylurea; 1,1,3,3-tetramethylthiourea; 1,3-dicyclohexylthiourea; m-tolylthiourea; benzylthiourea; phenylthiourea; 1,3-diphenylthiourea; 1,3-n-dibutylthiourea; 1-phenyl-3-ethylthiourea; 1,3-diaminothiourea; 1,3-diethylthiourea; 1,3-diallylthiourea; 1,1-10 dibenzylthiourea; 1,1-diethylthiourea; and 1,1,3-triethylthiourea.

12. The aqueous acid gas removal solution inhibited against acid gas promoted corrosion of metals of claim 10 wherein said compound is thiourea; thiosinamine; 1,1-diethylurea; 1-3-diethylurea; 2-thiophene carboxamide; aminothiurea; or 1,3-diphenyl-2-thiourea.

13. The aqueous acid gas removal solution inhibited against acid gas promoted corrosion of metals of claim 10 wherein said aqueous alkanolamine solution contains dissolved acid gases.

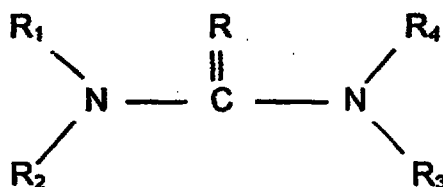
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14. The aqueous acid gas removal solution inhibited against acid gas promoted corrosion of metals of claim 10 wherein said solution comprises about 15 to 75 weight percent alkanolamine, less than about 1 weight percent a compound effective as a corrosion inhibitor having the formula:

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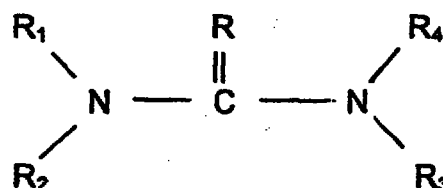
where R is S or O, and R₁, R₂, R₃ and R₄ are independently H, C₁ to C₈ alkyl, C₁ to C₈ alkenyl, C₆ to C₁₀ aryl, C₇ to C₁₂ alkaryl, C₇ to C₁₂ aralkyl, C₃ to C₁₀ cycloalkyl, C₁ to C₈ thiophene, or amino groups and from about 25 to 85 weight percent water with the proviso that the combined weight percentages equal 100 weight percent.

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15. A corrosion inhibitor for inhibiting corrosion of metals in contact with an aqueous alkanolamine solution substantially free of cyano and metal passivating agents, in acid gas removal equipment, said corrosion inhibitor comprising a compound having the formula:

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where R is S or O, and R₁, R₂, R₃ and R₄ are independently H, C₁ to C₈ alkyl, C₁ to C₈ alkenyl, C₆ to C₁₀ aryl, C₇ to C₁₂ alkaryl, C₇ to C₁₂ aralkyl, C₃ to C₁₀ cycloalkyl, C₁ to C₈ thiophene, or amino groups.



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16. The corrosion inhibitor of claim 15 wherein said compound is selected from the group consisting of thiourea; thiosinamine; 1, 1-diethylurea; 1,3-diethylurea; 2-thiophene carboxamide; aminothiourea; 1,3-diphenyl-2-thiourea; tetramethylurea; 1,3-dicyclohexylurea; m-
5 tolylurea; benzylurea; phenylurea; 1,1,3,3-tetramethylthiourea; 1,3-dicyclohexylthiourea; m-tolylthiourea; benzylthiourea; phenylthiourea; 1,3-diphenylthiourea; 1,3-n-dibutylthiourea; 1-phenyl-3-ethylthiourea; 1,3-diaminothiourea; 1,3-diethylthiourea; 1,3-diallylthiourea; 1,1-dibenzylthiourea; 1,1-diethylthiourea; and 1,1,3-triethylthiourea.

17. The corrosion inhibitor of claim 16 wherein said compound is thiourea, thiosinamine, 1,1-diethylurea, 1,3-diethylurea, 2-thiophene carboxamide, aminothiourea or 1,3-diphenyl-2-thiourea.



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