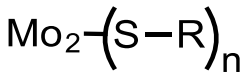
What is claimed is:

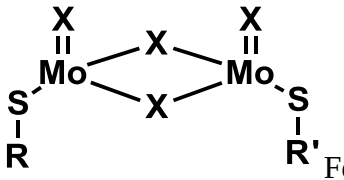
1. A method of inhibiting deposition of a foulant in process equipment for processing a hydrocarbon fluid in contact with the process equipment, comprising:

introducing into ~~a~~ the process equipment or ~~a~~ the hydrocarbon fluid in contact with the process equipment a fouling inhibitor composition comprising a sulfur-containing molybdenum complex having ~~the~~ a general formula selected from Formula I, II, III, IV, V, or VI~~I or II~~:



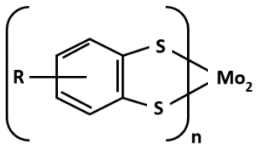
Formula I

~~Wherein~~ wherein R of Formula I represents an oxygen, nitrogen or carbon-containing group~~compounds such as alcohols, alkyl, alkenyl, amides, amines, or aryl groups~~; and n is 4-10~~.~~;



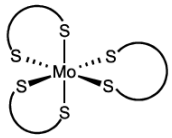
Formula II

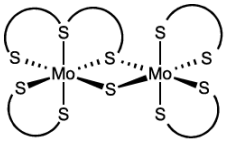
wherein R and R' each represents a group selected from an alkyl group comprising one or more hydroxyl groups, an alkyl group, an alkenyl group, or an aryl group~~an oxygen, nitrogen or carbon-containing compounds such as alcohols, alkyl, alkenyl, amides, amines, or aryl groups~~; and each X represents oxygen or sulfur and can be the same or different but where at least one X ~~in the formula~~ is sulfur~~.~~;

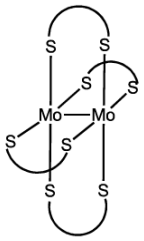


Formula III

wherein R of Formula III represents an oxygen, nitrogen or carbon-containing group; and n is 2-6; or







Formula IV Formula V Formula VI

wherein the arcs in Formulae IV, V, and VI represent alkyl chains (linear, branched and cyclic) with or without saturation and optionally comprising a heteroatom; thiolate, sulfide, thiocarbamate, thiocarbonate, thioacid, aromatic ring with or without substituents, organic polysulfide, or inorganic polysulfide.

2. The method of claim 1, wherein the introducing is by injecting, spraying, or dripping the fouling inhibitor compositionsulfur-containing molybdenum complex.

3. The method as in any preceding claimone of claims 1-2, wherein the introducing is carried out after or during a decoking or cleaning or during a warm up process.

4. The method as in any one of claims 1-3preceding claim, wherein the introducing is carried out during a hydrocarbon processing.

5. The method as in any one of claims 1-4preceding claim, wherein the introducing is carried out intermittently.

6. The method as in any one of claims 1-4preceding claim, wherein the introducing is carried out continuously.

7. The method as in any one of claims 1-6, wherein the process equipment comprises coils, heat exchangers, transfer line exchangers quench coolers, furnaces, separation columns or fractionators.

87. The method as in any one of claims 1-7preceding claim, wherein the process equipment comprises iron or iron alloys.

~~98~~. The method as in ~~any one of claims 1-8~~claim 7, wherein the iron alloy~~s~~ comprise~~s~~ carbon steel, stainless steel, or a nickel-chromium-iron alloy~~s~~.

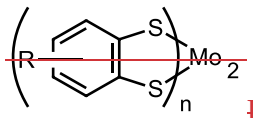
~~109~~. The method as in any ~~one of claims 1-9~~preceding claim, wherein the foulant comprises one or more of coke, sludge, a corrosion product~~s~~, a polymer~~s~~, and catalyst fines.

~~11. The method as in one of claims 1-10, wherein the fluid comprises at least a liquid hydrocarbon material.~~

~~12~~10. The method as in ~~one of claims 1-11~~any preceding claim, wherein the sulfur-containing molybdenum complex is added to the hydrocarbon fluid from 1 ppm to 3000 ppm of the fluid volume.

~~13~~11. The method as in ~~one of claims 1-12~~any preceding claim, wherein the ~~sulfur-containing molybdenum complex~~hydrocarbon fluid further comprises one or more, asphaltene inhibitors, paraffin inhibitors, scale inhibitors, emulsifiers, water clarifiers, dispersants, emulsion breakers, or any combination thereof.

~~14~~12. The method as in ~~one of claims 1-13~~any preceding claim, wherein the sulfur-containing molybdenum complex has the general formula III~~:~~

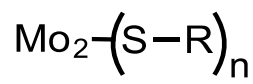


~~Formula III~~

~~Wherein R represents an oxygen, nitrogen or carbon-containing compounds such as alcohols, alkyl, alkenyl, amides, amines, or aryl groups; n is 2-6~~.

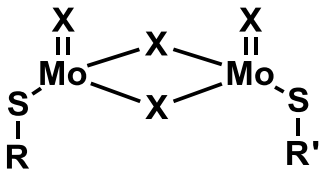
13. A method of passivating process equipment, comprising the step of:

contacting a metal surface of the process equipment with a composition comprising a sulfur-containing molybdenum complex selected from Formula I, II, III, IV, V, or VI:



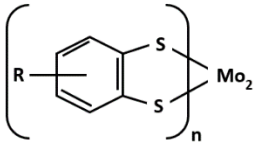
Formula I

wherein R of Formula I represents an oxygen, nitrogen or carbon-containing group; U and n is 4-10;



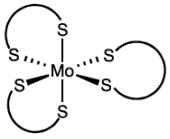
Formula II

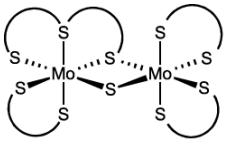
wherein R and R' of Formula II each a group selected from an alkyl group comprising one or more hydroxyl groups, an alkyl group, an alkenyl group, an amide group, an amine group, and an aryl group; and each X represents oxygen or sulfur and can be the same or different but where at least one X in Formula II is sulfur;

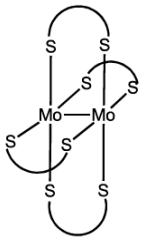


Formula III

wherein R of Formula III represents an oxygen, nitrogen or carbon-containing group; and n is 2-6; or







Formula IV Formula V Formula VI

wherein the arcs in Formulae IV, V, and VI represent alkyl chains (linear, branched and cyclic) with or without saturation and optionally comprising a heteroatom; thiolate, sulfide, thiocarbamate, thiocarbonate, thioacid, aromatic ring with or without substituents, organic polysulfide, or inorganic polysulfide.

14. The method of claim 1, wherein R or R' of Formula II comprises 2 to 30 carbon atoms and one or more hydroxy groups.

15. The method of claim 1, wherein R or R’ of Formula II comprises an alkyl group.

16. The method of claim 1, wherein R or R’ of Formula II comprises an alkenyl group.

17. The method of claim 1, wherein R or R’ of Formula II comprises an aryl group.

18. The method of claim 1, wherein R or R’ comprises an aromatic ring with a substituent.

19. The method of claim 15, wherein the alkyl group of Formula II comprises 2 to 30 carbon atoms.

20. The method of claim 15, wherein the alkyl group of Formula II comprises 5 to 10 carbon atoms.

21. The method of claim 1, wherein the hydrocarbon fluid source comprises crude oil.

22. The method of claim 1, wherein the introducing step comprises introducing the fouling inhibitor composition into the hydrocarbon fluid source, wherein the composition comprises the phosphorus-free, sulfur-containing molybdenum complex and one or more other additives.

23. The method of claim 22, wherein the one or more other additives comprise an asphaltene inhibitor.

24. The method of claim 22, wherein the one or more other additives comprise a paraffin inhibitor.

25. The method of claim 22, wherein the one or more other additives comprise a dispersant.

~~15. The method as in one of claims 1-14, wherein the R or R’ comprise each an alkyl group (linear, branched, or cyclic) with or without saturation or heteroatoms or both; thiolates, sulfides, thiocarbamates, thiocarbonates, thioacids, aromatic rings with or without substituents, organic polysulfides, inorganic polysulfides, polymers thereof and combinations thereof.~~

16. The method as in one of claims 1-15, wherein the R or R'comprise each dithiolates, disulfide, dithiolates, dithiocarbamates, dithiocarbonates, dithioacids, inorganic polysulfides, organic polysulfides, polymers thereof and mixtures thereof.

17. The method as in one of claims 15-16, wherein the organic polysulfide has the general formula IV:

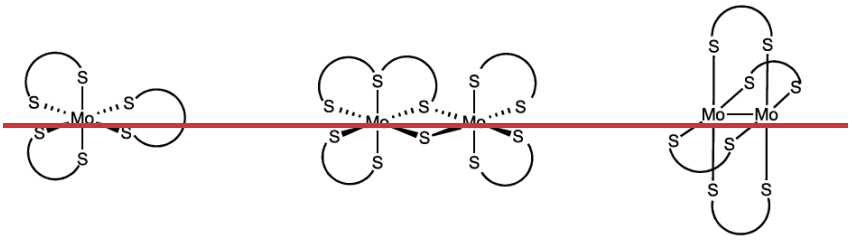
$R^2—S_*—R^3$ Formula IV

Wherein R^2 and R^3 each represents an oxygen, nitrogen or carbon-containing ligands such as alcohols, alkyl, alkenyl, amides, amines, or aryl groups; and R and R' can be the same or different.

18. The method of claim 17, wherein the R^2 and R^3 comprise each an alkyl group (linear, branched, or cyclic) with or without saturation or heteroatoms or both; thiolates, sulfides, thiocarbamates, thiocarbonates, thioacids, aromatic rings with or without substituents, organic polysulfides, inorganic polysulfides, polymers thereof and combinations thereof.

19. The method as in one of claims 17-18, wherein the R^2 and R^3 comprise each an alkyl group (linear, branched, or cyclic) with or without saturation or heteroatoms or both; thiolates, sulfides, thiocarbamates, thiocarbonates, thioacids, aromatic rings with or without substituents, organic polysulfides, inorganic polysulfides, polymers thereof and combinations thereof.

20. The method as in one of claims 1-19, wherein the sulfur-containing molybdenum complex comprises the following:



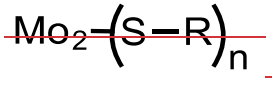
Wherein the arcs represent alkyl chains (linear, branched and cyclic) with or without saturation or heteroatoms or both; thiolates, sulfides, thiocarbamates, thiocarbonates, thioacids, aromatic rings with or without substituents, organic polysulfides, or inorganic polysulfides.

21. The method as in one of claims 1-20 wherein the sulfur-containing molybdenum complex provides at least 70% inhibition of foulant deposition.

22. The method as in one of claims 1-21, wherein the sulfur-containing molybdenum complex provides at least 70% inhibition of foulant deposition in a SS304 mesh test.

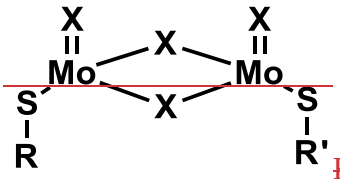
23. The method as in one of claims 1-22, wherein the introducing the sulfur-containing molybdenum complex inhibits foulant deposition of a process equipment compared to a process equipment under the same conditions without the introduction of the sulfur-containing molybdenum complex.

24. A composition comprising sulfur-containing molybdenum complex to inhibit deposition of a foulant in contact with process equipment, the sulfur-containing molybdenum complex



Formula I

Wherein R represents an oxygen, nitrogen or carbon-containing compounds such as alcohols, alkyl, alkenyl, amides, amines, or aryl groups; n is 4-10.

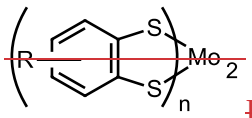


Formula II

R and R' each represents an oxygen, nitrogen or carbon-containing compounds such as alcohols, alkyl, alkenyl, amides, amines, or aryl groups; and X represents oxygen or sulfur and can be the same or different but where at least one X in the formula is sulfur.

25. The composition of claim 24, wherein the composition further comprises one or more, asphaltene inhibitors, paraffin inhibitors, scale inhibitors, emulsifiers, water clarifiers, dispersants, emulsion breakers, or any combination thereof.

26. The composition as in one of claims 24-25, wherein the sulfur-containing molybdenum complex has the general formula III:



Formula III

Wherein R represents an oxygen, nitrogen or carbon-containing compounds such as alcohols, alkyl, alkenyl, amides, amines, or aryl groups; n is 2-6.

27. The composition as in one of claims 24-26, wherein the R, R' comprise each an alkyl group (linear, branched, or cyclic) with or without saturation or heteroatoms or both; thiolates, sulfides, thiocarbamates, thiocarbonates, thioacids, aromatic rings with or without substituents, organic polysulfides, inorganic polysulfides, polymers thereof and combinations thereof.

28. The composition as in one of claims 20-27, wherein the R, R' comprise each disulfides, dithiolates, dithiocarbamates, dithiocarbonates, dithioacids, inorganic polysulfides, organic polysulfides, polymers thereof and mixtures thereof.

29. The composition of claim 28, wherein the organic polysulfide has the general formula IV:

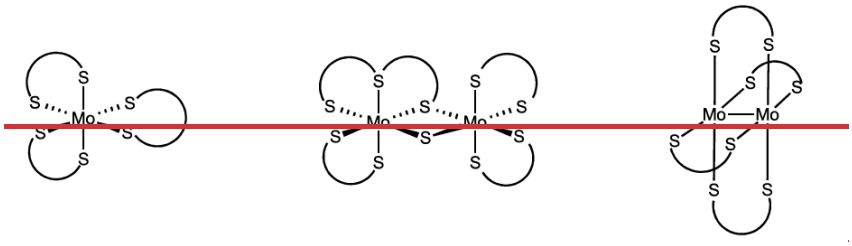
$R^2-S_x-R^3$ Formula IV

Wherein R^2 and R^3 each represents an oxygen, nitrogen or carbon-containing ligands such as alcohols, alkyl, alkenyl, amides, amines, or aryl groups; and R^2 and R^3 can be the same or different.

30. The composition of claim 29, wherein the R^2 and R^3 comprise each an alkyl group (linear, branched, or cyclic) with or without saturation or heteroatoms or both; thiolates, sulfides, thiocarbamates, thiocarbonates, thioacids, aromatic rings with or without substituents, organic polysulfides, inorganic polysulfides, polymers thereof and combinations thereof.

31. The composition as in one of claims 29-30, wherein the R^2 and R^3 comprise each an alkyl group (linear, branched, or cyclic) with or without saturation or heteroatoms or both; thiolates, sulfides, thiocarbamates, thiocarbonates, thioacids, aromatic rings with or without substituents, organic polysulfides, inorganic polysulfides, polymers thereof and combinations thereof.

32. The composition as in one of claims 24-31, wherein the sulfur-containing molybdenum complex comprises the following:



Wherein the arcs represent alkyl chains (linear, branched and cyclic) with or without saturation or heteroatoms or both; thiolates, sulfides, thiocarbamates, thiocarbonates, thioacids, aromatic rings with or without substituents, organic polysulfides, or inorganic polysulfides.

33. The composition as in one of claims 24-32, wherein the sulfur-containing molybdenum complex is about 1 ppm to 3000 ppm of the composition.

34. A composition comprising:

a fluid; and

the at least one sulfur-containing molybdenum complex as in one of claims 24-33.

35. The composition as in one of claims 24-34, wherein the fluid is in contact in with coils, heat exchangers, transfer line exchangers quench coolers, furnaces, separation columns or fractionators.

36. The composition as in one of claims 24-35, wherein the fluid comprises at least a liquid hydrocarbon fraction.

37. The composition as in one of claims 24-36, wherein the hydrocarbon fraction is a distillate.

38. The composition as in one of claims 24-37, wherein the fluid temperature is 200°C to 1500°C.

39. A treated process equipment comprising:

a process equipment comprising a metal surface; and

the fluid source comprising the sulfur-containing molybdenum complex as in one of claims 24-38, wherein at least a portion of the metal surface is contacted by the fluid source.

40. The treated process equipment of claim 39, wherein the process equipment comprises iron or iron alloys.

41. The treated process equipment of claim 40, wherein the iron alloys comprise carbon steel, stainless steel, nickel-chromium-iron alloys, or other alloys.

42. The treated process equipment as in one of claims 39-41, wherein the metal containment comprises coils, heat exchangers, transfer line exchangers quench coolers, furnaces, separation columns or fractionators.

43. The treated process equipment as in one of claims 39-42, wherein the fluid comprises, at least liquid hydrocarbon fraction.

44. Use of the sulfur-containing molybdenum complex as in one of claims 1-43 to inhibit foulant deposition.