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"COMPOSITION AND METHOD FOR INHIBITING SCALE"

This invention relates to the treatment of aqueous systems and, more particularly, to the inhibition and removal of solid deposits in industrial heating and cooling systems.

5 The water used in industrial aqueous systems such as steam generating boilers, hot water heaters, heat exchangers, cooling towers, desalination systems, cleaning systems, pipe lines, gas scrubber systems, and associated equipment contains various impurities. The impurities
10 typically include alkaline earth cations such as calcium, barium, and magnesium and several anions such as bicarbonate, carbonate, sulfate, oxalate, phosphate, silicate, and fluoride. These anions and cations combine and form precipitates due to the pH, pressure, or
15 temperature in the system or the presence of additional ions with which they form insoluble products. The most common impurities in industrial water supplies are the water hardening ions such as the calcium, magnesium and carbonate ions. In addition to precipitating as
20 carbonates, calcium and magnesium as well as any iron or copper present can also react with phosphate, sulfate, and silicate ions and form the respective complex insoluble salts. These solid reaction products accumulate on surfaces of the system and form scale. The water may also
25 contain various solids such as mud, clay, iron oxides, silt, sand, and other mineral matter and microbiological debris that accumulate as sludge deposits in the system. Iron oxides may be present in the feedwater and may be produced by corrosion of metal surfaces in contact with
30 the water. The sludge may become incorporated in the scale deposits and the precipitates tend to cement the sludge particles and form a strongly adherent scale.

Sludge and scale deposits greatly reduce heat transfer efficiency by settling at low flow points in the system and limiting the circulation of the water and insulating it from the heat surfaces. In addition to interfering
5 with heat transfer and fluid flow, corrosion of metal surfaces underneath the deposits is facilitated since corrosion control agents are unable to contact the surfaces effectively. The deposits also harbor bacteria. Removal of the deposits can cause expensive delays and
10 shutdown of the system. Water at the relatively high temperatures in steam generating boilers and hard waters are especially susceptible to scale formation. Extremely severe scale deposits can cause localized overheating and rupture in boilers.

15 Since external treatments of the feedwater to industrial systems such as softening, coagulation, and filtration do not adequately remove solids and solid-forming substances, various internal chemical treatments have been used to prevent and remove scale and
20 sludge in aqueous systems. The chemical treatment generally involves the combined use of a precipitating agent and a solid conditioner to maintain the solids in the boiler water in a suspended state for effective removal. The precipitating chemicals commonly employed
25 for calcium salts are soda ash and sodium phosphates. Magnesium is precipitated by the alkalinity of boiler water as magnesium hydroxide.

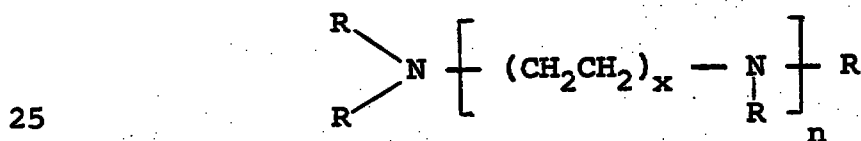
A variety of polycarboxylate and other water soluble, polar polymers such as acrylate polymers have been used as
30 solids conditioners in industrial water systems. The presence of small quantities of these polymers improves the fluidity of the precipitated sludge and results in the

formation of amorphous, frangible and serrated precipitates instead of hard, dense, crystals that form scale on surfaces. The finely dispersed solid particles remain suspended and are carried out of the system by the flow of water or by blowdown.

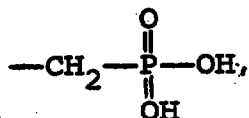
The precipitation of scale forming compounds can be prevented by inactivating their cations with chelating or sequestering agents so that the solubility of their reaction products is not exceeded. Various nitrogen containing compounds such as ethylenediamine tetraacetic acid and nitrilotriacetic acid have been used as chelants in water treatment.

Phosphonates are used extensively in water treatment as precipitation inhibitors and are effective in threshold amounts that are markedly lower than the stoichiometric amount required for chelating or sequestering the scale forming cation.

The composition for inhibiting formation of scale in an aqueous system of the present invention comprises a) a copolymer of maleic acid or anhydride and styrene sulfonic acid or a water soluble salt thereof; b) an organic phosphonate of the general formula:

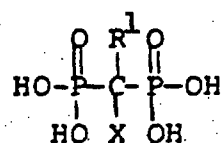


wherein R is

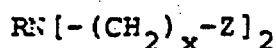


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n is 0 to 6, and x is 1 to 6, or of the general formula:



wherein X is -OH or -NH₂ and R¹ is an alkyl group of from 1 to 5 carbon atoms, or a water soluble salt thereof; and
5 c) an aminocarboxylate chelating compound of the general formula:



- wherein x is 1 or 2, R represents $-(\text{CH}_2)_x-\text{Z}$ or $-\text{CH}_2\text{CH}_2\text{N}[-(\text{CH}_2)_x-\text{Z}]_2$ and each Z individually
10 represents a -COOH group, or a water soluble salt thereof. The method of inhibiting the formation of scale in an aqueous system of the present invention comprises adding to the system a scale inhibiting amount of the composition.
- 15 The present invention provides unexpectedly superior inhibition of deposition and formation of scale, particularly those containing calcium and magnesium phosphates and silicates and iron oxide, on the metallic structures of industrial water systems. The composition
20 and method are effective when used in water at high temperatures and pressures in steam generating boilers and the copolymer remains soluble in water of high hardness and alkalinity. The invention exhibits the threshold effect of the inhibition of formation of metallic salt
25 crystals and the prevention of their adherence to heat transfer surfaces at low treatment levels.

The chelating compounds used in the present invention are water soluble aminocarboxylates. The preferred aminocarboxylate chelating compounds are ethylenediamine

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tetracetic acid and nitrilotriacetic acid. In other words, in these preferred compounds, x is 1 and all the three Z radicals are the same. Nitrilotriacetic acid is an especially preferred chelating compound.

5 The present invention employs water soluble amino alkylene phosphonic acids, hydroxy or amino alkylidene phosphonic acids, or water soluble salts thereof. The preferred compounds are aminotri(methylene phosphonic acid), hydroxyethylidene-1,1-diphosphonic acid and water
10 soluble salts thereof. Hydroxyethylidene-1,1-diphosphonic acid is especially preferred. Other suitable phosphonic acids having these formulas include ethylenediamine tetra(methylene phosphonic acid), diethylenetriamine penta(methylene phosphonic acid), triethylenetetraamine hexa
15 (methylene phosphonic acid), hexamethylenediamine tetra(methylene phosphonic acid), aminoethylidene diphosphonic acid, aminopropylidene diphosphonic acid, hydroxypropylidene diphosphonic acid, hydroxybutylidene diphosphonic acid, and hydroxyhexylidene diphosphonic acid.

20 The composition of the present invention further comprises a water soluble copolymer of maleic acid or anhydride and styrene sulfonic acid or water soluble salts thereof. The polymer may be prepared by copolymerizing maleic acid or anhydride with styrene sulfonic acid or an
25 alkali metal salt thereof. Conventional addition polymerization methods in the presence of light or free radical initiators may be employed. Another method of producing the copolymers is to copolymerize the maleic and styrene monomers and sulfonate the copolymer in accordance
30 with conventional methods such as with a sulfur trioxide-organic phosphorus compound as described in U.S. Patent 3,072,618. The degree of sulfonation can vary but substantially complete sulfonation is preferred.

The relative proportions of styrene sulfonate and maleic anhydride depend upon the degree of scale inhibition needed. The copolymer generally contains from about 10 to about 90 mole percent of the sulfonate.

5 Preferably, the mole ratio of styrene sulfonate moieties to maleic acid or anhydride derived moieties is from about 1:1 to about 4:1 and especially is from about 1:1 to about 3:1.

The average molecular weight of the copolymer is not
10 critical so long as the polymer is water soluble.

Generally, the molecular weight is preferably from about 1,000 to about 25,000 and especially is from about 6,000 to about 10,000.

The aminocarboxylates, phosphonates and copolymers are
15 generally used in the form of an alkali metal salt and usually as the sodium salt. Other suitable water soluble salts include potassium, ammonium, zinc, and lower amine salts. The free acids may also be used and all of the acidic hydrogens need not be replaced nor need the cation
20 be the same for those replaced. Thus, the cation may be any one of or a mixture of NH_4 , H, Na, K, etc. The copolymer is converted into the water soluble salts by conventional methods.

While it is possible to add each of the components
25 separately to an aqueous system, it is generally more convenient to add them together in the form of a composition. The composition of the present invention generally comprises from about 0.1 to about 100, preferably about 2 to about 6, parts by weight of the
30 copolymer; from about 0.1 to about 100, preferably about 0.5 to about 5, parts by weight of the phosphonate, and from about 0.1 to about 100, preferably about 0.5 to about 5, parts by weight of the aminocarboxylate. The polymer and phosphonate are used in weight ratios generally of

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from about 10:1 to about 1:10, preferably of from about 4:1 to about 1:4, and especially of about 1:1. In general, the aminocarboxylate and the copolymer are used in the weight ratios of from about 50:1 to about 1:10, 5 preferably of from about 30:1 to about 10:1, and especially of about 18:1. The ratio of aminocarboxylate to phosphonate is generally from about 50:1 to about 5:1, preferably from about 20:1 to about 5:1, and especially of from about 10:1 to about 8:1.

10 The compositions may be added as dry powders and permitted to dissolve during use but normally are used in the form of aqueous solutions. The solutions generally contain from about 0.1 to about 70 weight percent of the composition and preferably contain from about 1 to about 15 40 weight percent. The solutions can be made by adding the ingredients to water in any order.

The amount of the composition added to the water is a substoichiometric amount that is effective to inhibit scale and sludge and depends on the nature of the aqueous 20 system to be treated. The phosphonate and aminocarboxylate dosage depends to some extent on the amounts of hardness causing and scale forming compounds present in the system. The copolymer dosage depends to some extent on the concentration of suspended solids and 25 existing levels of solids buildup in the system. The composition generally is added to the aqueous system in an amount of from about 0.01 to about 500 parts per million (ppm) and preferably of from about 0.1 to about 50 parts per million of system water.

30 The compositions of this invention may include or be added to water containing other ingredients customarily employed in water treatment such as alkalies, lignin derivatives, other polymers, tannins, other phosphonates, biocides, and corrosion inhibitors. The composition may

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be introduced at any location where it will be quickly and efficiently mixed with the water of the system. The treatment chemicals are customarily added to the makeup or feed water lines through which water enters the system.

- 5 Typically, an injector calibrated to deliver a predetermined amount periodically or continuously to the makeup water is employed.

The present invention is especially useful in the treatment of alkaline boiler water such as the feed or
10 makeup water in a steam generating boiler. Such boiler systems are generally operated at a temperature of from about 298 to about 637°F. (148 to 336°C) and a pressure of from about 50 to about 2,000 psig. (3.5 to 1410 kg/cm² gauge).

- The composition and method for its use of this
15 invention are illustrated by the following examples in which all parts are by weight unless otherwise indicated.

EXAMPLES 1 and 2

Aqueous solutions of a composition containing one part of hydroxyethylidene diphosphonic acid, one part of
20 nitrilotriacetic acid, and three or six parts of a copolymer of sodium styrene sulfonate and maleic anhydride were prepared. The treatment solutions also contain sodium phosphate, sodium sulfate, sodium sulfite, sodium hydroxide, and sodium chloride in amounts sufficient to
25 provide the boiler water composition shown below in Table I. Solutions containing the same amounts of the treatment chemicals and the same parts of each component of the composition were also prepared.

- The sludge conditioning and scale inhibiting
30 properties of these solutions were evaluated in a small laboratory boiler which had three removable tubes as described in the Proceedings of the Fifteenth Annual Water Conference, Engineers Society of Western Pennsylvania, pp.

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87-102 (1954). The feedwater for the laboratory boiler was prepared by diluting Lake Zurich, Illinois tap water with distilled water to 40 ppm total hardness as CaCO_3 and adding calcium chloride to provide a 6 to 1 elemental calcium to magnesium ratio. The feedwater and chemical treatment solutions were fed to the boiler in a ratio of 3 volumes of feedwater to 1 volume of solution giving a feedwater total hardness of 30 ppm of CaCO_3 . The scaling tests for all the treatment solutions were conducted by adjusting boiler blowdown to 10 percent of the boiler feedwater giving approximately 10 concentrations of the boiler water salines and adjusting the composition of the treatment solution to give a boiler water after the 10 concentrations having the composition shown in Table I.

TABLE I

	Sodium Hydroxide as NaOH	258 ppm
	Sodium Carbonate as Na_2CO_3	120 ppm
	Sodium Chloride as NaCl	681 ppm
20	Sodium Sulfite as Na_2SO_3	50 ppm
	Sodium Sulfate as Na_2SO_4	819 ppm
	Silica as SiO_2	less than 1 ppm
	Iron as Fe	less than 1 ppm
	Phosphate as PO_4	10-20 ppm

25 The scaling tests were run for 45 hours each at a boiler pressure of 400 psig (28 kg/cm^2). Upon the completion of a test, the boiler tubes were individually removed from the boiler and the scale or deposit present on 6 inches (15cm) of the central length of each tube was removed by scraping, collected in a tared vial, and weighed. The results of the tests are shown in Table II.

TABLE II

	<u>Run No.</u>	<u>Additive</u>	<u>Additive Dosage in the Feed (ppm)</u>	<u>Scale Reduction (%)</u>
5	1	Styrene sulfonate and maleic anhydride copolymer (I)	0.5	66.1
10	2	Hydroxyethylidene diphosphonic acid (II)	0.5	20.0
	4	Nitrilotriacetic acid (III)	1.0	6.0
15	5	I + II + III (3:1:1 active)	0.5	95.5
	6	I + II + III (6:1:1 active)	0.5	96.0

The comparative results on scale formation shown in Table II demonstrate that the composition and method of the present invention provide scale inhibition that is very considerably superior to that of the components added separately.

EXAMPLE 3

The same laboratory boiler was used to study the efficiency of the composition of this invention and each of its components as additives in preventing the formation of new scale or removal of existing scale in an already scaled boiler. The boiler was first operated to form scale on the tubes and the boiler water surfaces. The amount of calcium phosphate (hydroxyapatite) scale was established by conducting several runs.

After the prescaling, the boiler was shut down to remove one tube specimen and determine the initial amount of scale on the tubes. The operation was continued for another 45 hours using feedwater containing 30 ppm (as CaCO_3) total hardness and the treatment additive. Other boiler water chemicals such as those described in Examples 1 and 2 were also used. The boiler water pressure was 400 psig and the boiler water concentration was ten times.

The scale deposited on the testing tubes was 5.98 10 grams (average) during the first stage (prescaling) and an additional 8.99 grams during the second stage where no additive treatment (blank) was added. The results of the tests are shown in Table III.

TABLE III

Run No.	Additive	Additive Dosage in the Feed (ppm)	Scaling Rate (g/ft ²)(g/m ²)	Scale Reduction (%)
15				
20	1 Blank (No Additive)	-	8.99 90.54	-
	2 Styrene Sulfonic Acid and maleic anhydride (I)	2	(0.07) (0.71)	100.8
25	3 Hydroxyethylidene diphosphonic acid (II)	3	1.52 15.31	83.1
	4 Nitrilotriacetic acid (III)	3	3.64 36.66	59.5
30	5 I + II + III (3:1:1 active)	2	(0.65) (6.55)	107.2

The results demonstrate the unexpectedly superior effectiveness of the composition and method of this invention in removing existing scale .



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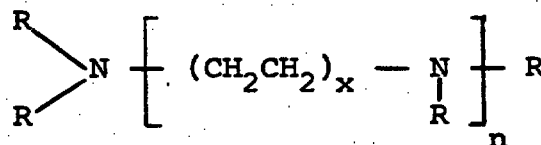
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CLAIMS

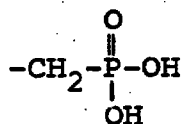
1. A composition suitable for inhibiting formation of scale in an aqueous system comprising

a) a copolymer of maleic acid or anhydride and styrene sulfonic acid or a water soluble salt thereof;

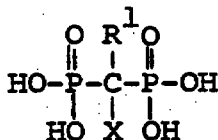
b) an organic phosphonate of the general formula:



10 wherein R is

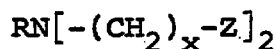


n is 0 to 6, and x is 1 to 6, or of the general formula:



15 wherein X is -OH or -NH₂ and R¹ is an alkyl-group of from 1 to 5 carbon atoms, or a water soluble salt thereof; and

c) an aminocarboxylate chelating compound of the general formula:



20 wherein x is 1 or 2, R represents - (CH₂)_x-Z or -CH₂CH₂N[-(CH₂)_x-Z] and each Z individually represents a -COOH group, or a water soluble salt thereof.

2. A composition according to claim 1 comprising from 0.1 to 100 parts by weight of the copolymer, from 0.1 to 100 parts by weight of the phosphonate, and from 0.1 to 100 parts by weight of the aminocarboxylate.

3. A composition according to claim 1 or 2 in which the phosphonate is a hydroxy alkylidene phosphonic acid or a water soluble salt thereof.



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4. A composition according to claim 1 or 2 in which the phosphonate is hydroxyethylidene-1, 1-diphosphonic acid or a water soluble salt thereof.

5. A composition according to any one of claims 1 to 4 in which the copolymer has a mole ratio of styrene sulfonate moieties to maleic acid or maleic anhydride moieties of from 1:1 to 4:1 and a molecular weight of from 1,000 to 25,000.

6. A composition according to any one of claims 1 to 5 in which the aminocarboxylate is nitrilotriacetic acid or a water soluble salt thereof.

7. A composition according to any one of the preceding claims comprising an aqueous solution of a composition comprising

a) from 2 to 6 parts by weight of a copolymer of maleic anhydride and styrene sulfonic acid, said copolymer having a molecular weight of from 1,000 to 25,000 and a styrene sulfonate to maleic anhydride mole ratio of from 1:1 to 4:1, or a water soluble salt thereof;

b) from 0.5 to 5 parts by weight of hydroxyethylidene-1,1-diphosphonic acid or a water soluble salt thereof; and

c) from 0.5 to 5 parts by weight of nitrilotriacetic acid or a water soluble salt thereof.

8. A composition according to claim 7 in which the copolymer has a molecular weight from 6,000 to 10,000 and a styrene sulfonate to maleic anhydride mole ratio of from 1:1 to 3:1.

9. A composition according to claim 1 substantially as described in any one of Examples 1 to 3.

10. A method for inhibiting formation of scale in an aqueous system comprising adding to the system a scale inhibiting amount of

a) a copolymer of maleic acid or anhydride and styrene sulfonic acid or a water soluble salt thereof;



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b) an organic phosphonate of the general formula defined in claim 1 or a water soluble salt thereof; and

c) an amino carboxylate chelating compound
5 of the general formula as defined in claim 1, or a water soluble salt thereof.

11. A method according to claim 10 in which the copolymer, organic phosphonate and amino carboxylate are added in the form of a composition as claimed in any one
10 of claims 1 to 9.

12. A method according to claim 10 in which the composition is added to the aqueous system in an amount of from 0.01 to 500 parts per million of system water.

13. A method according to claim 11 or 12 in
15 which the composition comprises from 0.1 to 100 parts by weight of the copolymer, from 0.1 to 100 parts by weight of the phosphonate, and from 0.1 to 100 parts by weight of the aminocarboxylate.

14. A method according to any one of claims 10
20 to 13 in which the phosphonate is a hydroxy alkylidene phosphonic acid or a water soluble salt thereof.

15. A method according to claim 14 in which the phosphonate is hydroxyethylidene-1,1-diphosphonic acid or a water soluble salt thereof.

25 16. A method according to any one of claims 10 to 15 in which the copolymer has a mole ratio of styrene sulfonate to maleic acid or maleic anhydride of from 1:1 to 4:1 and a molecular weight of from 1,000 to 25,000.

17. A method according to any one of claims 10
30 to 16 in which the aminocarboxylate is nitrilotriacetic acid or a water soluble salt thereof.

18. A method according to claim 10 comprising adding to the boiler water an aqueous solution of a composition comprising



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- 5 a) from 2 to 6 parts by weight of a copolymer of maleic anhydride and styrene sulfonic acid, said copolymer having a molecular weight of from 1,000 to 25,000 and a styrene sulfonate to maleic anhydride mole ratio of from 1:1 to 4:1 or a water soluble salt thereof;
- b) from 0.5 to 5 parts by weight of hydroxyethylidene-1,1-diphosphonic acid or a water soluble salt thereof; and
- 10 c) from 0.5 to 5 parts by weight of nitrilotriacetic acid or a water soluble salt thereof; said composition being added in an amount of from 0.1 to 50 parts per million of water in the boiler.
- 15 19. A method according to claim 18 in which the copolymer has a molecular weight from 6,000 to 10,000 and a styrene sulfonate to maleic anhydride mole ratio of from 1:1 to 3:1.
20. A method according to claim 10 substantially as hereinbefore described.
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