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## COMPOSITION AND METHOD FOR INHIBITING CORROSION

### Cross-Reference to Related Application

**[0001]** This application claims the benefit of U.S. Provisional Application Serial No. 62/322,616 filed on April 14, 2016 and U.S. Provisional Application Serial No. 62/363,574 filed on July 18, 2016.

### Background of the Invention

#### 1. Field of the Invention

**[0002]** This invention relates to a treatment composition and method for inhibiting corrosion or white rust on metal components in water systems. This invention is particularly useful in the corrosive environments found in low LSI (Langelier Saturation Index) water systems, such as open recirculating systems, closed loop cooling or heating systems, and boilers.

#### 2. Description of Related Art

**[0003]** Various water treatment compositions are used to reduce corrosion, mineral scale, and white rust formation on metal components in contact with an aqueous solution in water systems such as open recirculating systems, closed loop cooling or heating systems, cooling towers and boilers, and help protect the metal components of these systems. The metals typically used in these water systems include ferrous metals, including galvanized steel, aluminum and its alloys, copper and its alloys, lead, and solder. Many known corrosion inhibitors contain regulated toxic metals, such as zinc, chromate, and molybdate, which are harmful to the environment and increase the costs. Zinc is typically used as corrosion inhibitor in water systems with highly corrosive water (low LSI). However its usage is undesirable due to toxicity issues and its use faces regulations in some locations. Tin has also been used as a non-toxic alternative to zinc, but it is more expensive.

**[0004]** The performance of many known corrosion inhibitors is also negatively impacted by the use of biocides, which are frequently used in water systems to control the growth of microorganisms. The use of polyaspartic acid and a single phosphonic acid are disclosed in U.S. Patent No. 5,523,023 as effective in inhibiting corrosion, even in the presence of a biocide when the phosphonic acid is 2-phosphonobutane-1,2,4-tricarboxylic acid (PBTC). The preferred phosphonic acid in the '023 patent is PBTC, but other phosphonic acids, including 1-hydroxyethane 1,1-disphosphonic acid and hydroxyphosphonoacetic acid (HPA) are also mentioned as suitable. The corrosion rate results shown in the '023 patent based on the use of polyaspartic acid and PBTC are better than other corrosion inhibitors, but there is still a need for even greater corrosion inhibition, particularly in the presence of biocides.

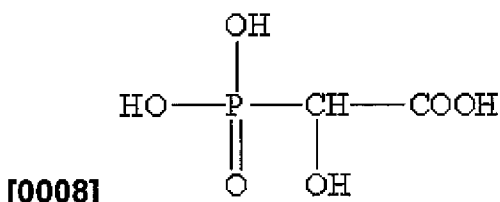
**[0005]** Currently utilized solutions for white rust prevention include passivating the metal surfaces with zinc carbonate and control of water chemistry to reduce potential for white rust formation. Known treatments include the use of inorganic phosphates, thiocarbamates, organo-phosphorous compounds and tannins. For example, U.S. Patent Nos. 5,407,597 and 6,468,470 disclose compositions comprising organophosphorus compounds (including PBTC), an alkali metal salt of molybdenum, titanium, tungsten, or vanadium, and either a carbamate compound or a tannin compound. U.S. Patent No. 6,183,649 discloses a white-rust treatment composition comprising PBTC, sodium polyacrylate, sodium tolytriazole, an alkali metal molybdate, and an alkali metal bromide for treating circulating water systems. The '649 patent also discloses the addition of a 1.5% aqueous solution of decyl thioethyletheramine (DTEA) at a rate of 25lb/1,000 gallons of water/week to the circulating water system prior to adding the white rust treatment composition at a rate of 600 ppm per cycle for ten cycles of recirculation after addition of the DTEA.

**[0006]** There is a need for an effective corrosion inhibitor and an effective white rust inhibitor composition and method that are more environmentally friendly and capable of adequately performing in conjunction with biocides. There is also a need for a single treatment composition and method that will

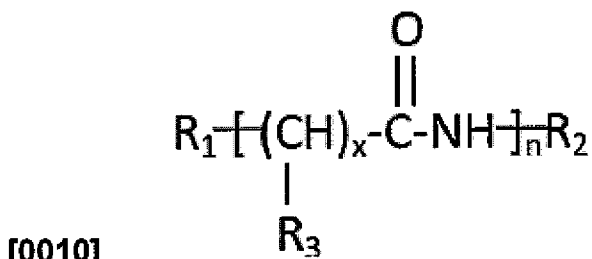
address both corrosion and white rust without the need for separate treatments, which may negatively interact with each other.

## SUMMARY OF THE INVENTION

**[0007]** According to one preferred embodiment of the invention, an improved corrosion inhibitor and white rust inhibitor composition comprises an amino-acid based polymer (AAP), hydroxyphosphonoacetic acid (HPA) or its water soluble salt, and another phosphonic acid or its water soluble salt. Hydroxyphosphonoacetic acid has the following general structure:



**[0009]** Most preferably, the amino-acid based polymer is polyaspartic acid or its water soluble salt, but other compounds such as polyglycine acid, polyglutamic acid and their salts may also be used. Most preferably, the amino acid based polymer has the following formula:



**[0011]** where R1 = H, R2=OH, and R3=COOH and x=1 for polyaspartic acid. Most preferably, the other phosphonic acid is a phosphonocarboxylic acid or any organic phosphonate may also be used. Most preferably, the phosphonocarboxylic acid is 1-hydroxyethane-1,1-diphosphonic acid (HEDP) or 2-phosphonobutene-1,2,4-tricarboxylic acid (PBTC) or phosphonosuccinic acid. Preferably the weight ratio of AAP to HPA in the inhibitor composition is 90:10 to 10:90 and the ratio of combined AAP and HPA to other phosphonic acid is in the range of 90:10 to 60:40. More preferably, the weight ratio range of AAP to HPA in the inhibitor composition is 80:20 to 80:20 and the ratio of combined AAP and HPA to other phosphonic acid is 80:20 to 70:30.

**[0012]** Most preferably, a composition according to a preferred embodiment of the invention is all organic and does not contain regulated metals such as zinc, chromate, and molybdate and its performance is not affected by addition of biocides. Most preferably, a composition according to a preferred embodiment of the invention does not contain tin.

**[0013]** It was previously known to use both HPA and AAP, such as polyaspartic acid, separately as corrosion inhibitors. It was also disclosed in the '023 patent that AAP could be used together with phosphonocarboxylic acid to inhibit corrosion, but it was not previously known to use AAP and HPA together along with another phosphonic acid, preferably a phosphonocarboxylic acid, or an organic phosphonate to inhibit corrosion.

**[0014]** When added to the water in the water system being treated, a preferred composition according to the invention yields at least 3 ppm active AAP, at least 3 ppm active HPA, and at least 2 ppm of the other phosphonic acid. More preferably, when added to the water in the water system being treated, a preferred composition yields 3 ppm-50 ppm AAP, 3 ppm-50 ppm HPA, and 2 ppm-20 ppm of the other phosphonic acid and most preferably between 5ppm-30ppm AAP, 3ppm-20ppm HPA, and 2 ppm-10 ppm of the other phosphonic acid. Additionally, the combined total of the three components of a preferred composition yields at least 8 ppm active corrosion inhibitors when added to the water being treated. These ingredients have the unexpected synergistic effect of improved corrosion inhibition without requiring the use of toxic metals and without being adversely impacted by biocides.

**[0015]** In addition to unexpected and synergistic effect of the inhibitor composition on ferrous metal corrosion inhibition in low LSI water, the same composition also has a positive effect on preventing formation of white rust on galvanized steel. Galvanized steel consists of a thin coating of zinc fused to a steel substrate. White rust is a rapid, localized corrosion attack on zinc that usually appears as a voluminous white deposit. This rapid corrosion can completely remove zinc in a localized area with the resultant reduction in equipment life. Neither hydroxyphosphonoacetic acid nor amino-acid based

polymers, such as polyaspartic acid, alone or in combination, has been previously utilized in commercial products for white rust prevention. Without being bound by theory, it is believed that the compositions according to the invention may be forming a protective layer on the surface of galvanized steel and reduce white rust formation. For treating white rust according to the invention, it is preferred to use hydroxyphosphonoacetic acid, an amino-acid based polymer, and another phosphonic acid in the amounts indicated above for inhibiting corrosion (both weight ratios and concentrations when added to the water in the water system being treated), but it has also been found that the use of an amino-acid based polymer without hydroxyphosphonoacetic or the other phosphonic acid is beneficial at inhibiting white rust. According to another preferred embodiment, a composition for treating white rust comprises an amino-acid based polymer and hydroxyphosphonoacetic acid, without another phosphonic acid. According to yet another preferred embodiment, a composition for treating white rust comprises an amino-acid based polymer, without any hydroxyphosphonoacetic acid.

**[0016]** According to other preferred embodiments, compositions for inhibiting corrosion or white rust also comprise one or more of the following ingredients: a neutralizing amine, chlorine stabilizer, such as monoethanol amine (MEA); a scale inhibitor and dispersion agent, such as polycarboxylate polymer and/or carboxylate/sulfonate functional copolymers (typical examples: polyacrylic acid (PAA), polymethacrylic acid (PMAA), polymaleic acid (PMA), and copolymers of acrylic acid sulfonated monomers, such as AA/AMPS); other scale and corrosion inhibitors, chelant agents;azole corrosion inhibitors, such as benzotriazole, alkylbenzotriazole (tolyltriazole); and/or a fluorescent dye tracer, such as 1,3,6,8-Pyrenetetrasulfonic acid tetrasodium salt (PTSA). The overall composition preferably comprises around 2%-15% (by weight) of an amino-acid based polymer (such as polyaspartic acid), around 2% to 10% (by weight) of hydroxyphosphonoacetic acid, and around 2% to 10% (by weight) of another phosphonic acid.

**[0017]** According to one preferred method of preventing corrosion of metal components and/or white rust on galvanized steel components in a water system, a treatment composition according to the preferred embodiments of invention as described above is added to the water system. For a composition combining one or more of the AAP, HPA, and another phosphonic acid as described above, a preferred method comprises feeding the composition into the water at an effective feed rate of 20ppm - 600 ppm, or more preferably 100 – 300ppm, of treatment composition, depending on the treated water chemistry and the amount of optional components in the treatment composition. Preferably, a sufficient amount of treatment composition is added to the water system to provide effective active amounts of one or more of the three treatment components (depending on whether corrosion or white rust is being treated or both) of at least 3 ppm AAP, at least 3 ppm HPA, and at least 2 ppm of another phosphonic acid, each as concentrations when added to the volume of water in the water system being treated. More preferably, the treatment composition is added in a sufficient amount to provide effective active amounts one or more of the components of between 3 ppm – 50 ppm AAP, between 3pm – 50 ppm HPA, and between 2 ppm - 20 ppm of another phosphonic acid when added to the water in the water system. Most preferably, these effective active amounts are 5ppm – 30 ppm AAP, 3 ppm – 20 ppm HPA, and 2 ppm - 10 ppm other phosphonic acid when added to the water in the water system.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0018]** The composition and method of the invention are further described and explained in relation to the following figures wherein:

FIG. 1 contains photographs showing corrosion levels on steel coupons after spinner tests at flow rates of 3ft/sec and 5ft/sec;

FIG. 2 contains photographs showing corrosion levels on steel coupons after spinner tests run in presence of biocide at flow rates of 3ft/sec and 5 ft/sec;

FIG. 3 contains photographs showing corrosion levels on steel coupons after spinner tests at a flow rate of 3ft/sec; and

FIG. 4 contains photographs showing white rust levels on galvanized coupons after spinner tests.

### DESCRIPTION OF PREFERRED EMBODIMENTS

**[0019]** Several lab tests were run to test the effectiveness of various compositions according to the invention. Compositions according to the invention were evaluated using spinner tests to simulate flowing water over metal components in a water system. Each spinner test set-up comprises a stainless steel container of water with four metal coupons (mild steel coupons (C1010) and copper coupons (CDA 11) were used) suspended in the water in each container from holders hanging from a rotating shaft. The shaft rotates the coupons in the water in the stainless steel container at 147 rotations/min, representing a flow rate of 3-5 ft/s, depending on coupon distance from center of the rotating shaft. The initial volume of water used in each spinner test was characteristic of corrosive, low hardness water typically found in water systems. The water used had the characteristics shown in Table 1 below.

**[0020]** Table 1. Low hardness, corrosive water used in Spinner test experiments

| Characteristic   | Value    | Unit                         |
|------------------|----------|------------------------------|
| pH               | 8 to 8.5 |                              |
| Conductivity     | 220      | cP                           |
| Ca Hardness      | 30       | ppm, (as CaCO <sub>3</sub> ) |
| Mg Hardness      | 10       | ppm, (as CaCO <sub>3</sub> ) |
| Chlorides, Total | 25       | ppm Cl                       |
| M Alkalinity     | 30       | ppm, (as CaCO <sub>3</sub> ) |
| Sulfate, Total   | 28       | ppm, as SO <sub>4</sub>      |

**[0021]** During each spinner test the water is aerated and maintained at constant temperature of 120F and constant volume (any evaporation is compensated with automatic addition of deionized water when water level drops below sensor level). Standard test duration is 48 hours.

**[0022]** Using the spinner test set-up, compositions according to preferred embodiments of the invention (Example Nos. 1-3 including AAP, HPA, and another phosphonic acid - HEDP) without any added zinc or tin (as shown in

Table 2) were compared to compositions using only zinc (Comp. Ex. 4), only tin (Comp. Ex. 5), only AAP (Comp. Ex. 6), only HPA (Comp. Ex. 7), HPA combined with tin (Comp. Ex. 8), and AAP combined with tin (Comp. Ex. 9) (all as shown in Table 3) as the primary inhibitor(s). The ppm concentrations of the various treatments are concentrations when added to the volume of water in the spinner test container. The compositions with zinc or tin were for comparison to those without. Zinc is typically used as corrosion inhibitor in water systems with highly corrosive water (low LSI). However its usage is undesirable due to toxicity issues and its use face regulations in some locations. Tin has been promoted and patented as a non-toxic alternative to zinc, but it is more expensive. In addition to the primary corrosion inhibitor components listed in Tables 2 and 3, all of the tests were carried out in the presence 4 ppm active AA/AMPS copolymer and 4 ppm active TTA. These ingredients were added to the water in each spinner test set-up to provide those concentration levels. The corrosion and pitting level for mild steel coupons after spinner tests in presence of different inhibitors are presented in Figure 1.

[0023] Table 2. Corrosion inhibitor compositions according to the invention

| Inhibitor   | Unit        | Example 1 | Example 2 | Example 3 |
|---|-------------|-----------|-----------|-----------|
| AAP (amino acid based polymer – specifically Baypure DS 100/40, which is a sodium salt of polyaspartic acid; water solution containing about 40% of salt) | ppm active* | 7.5       | 5.2       | 5.2       |
| HPA (hydroxyphosphonoacetic acid)   | ppm active  | 2.5       | 5.0       | 5.0       |
| HEDP  | ppm active  | 3         | 3         | 3         |
| MEA   | ppm         | 0.25      | 1.0       |           |
| Zn (zinc)   | ppm active  | N/A       | N/A       | N/A       |
| Sn (tin)  | ppm active  | N/A       | N/a       | N/A       |

\*ppm active refers to the amount of active raw material, in contrast to ppm which refers to the weight of raw material in mg/L. For example, HPA is commercially available as a 50% water solution, so adding 10 ppm raw material will provide 5 ppm active HPA.

**[0024]** Table 3. Corrosion inhibitor compositions – Comparative

## Examples

| Inhibitor | Unit       | Comp.<br>Ex 4 | Comp.<br>Ex 5 | Comp.<br>Ex 6 | Comp.<br>Ex 7 | Comp.<br>Ex 8 | Comp.<br>Ex 9 |
|-----------|------------|---------------|---------------|---------------|---------------|---------------|---------------|
| AAP       | ppm active |               |               | 15            |               |               | 7.5           |
| HPA       | ppm active |               |               |               | 5             | 5             |               |
| HEDP      | ppm active | 3             | 3             | 3             | 3             | 3             | 3             |
| MEA       | ppm        |               |               |               |               |               |               |
| Zn        | ppm active | 1             |               |               |               |               |               |
| Sn        | ppm active |               | 1             |               |               | 1             | 0.5           |

**[0025]** Spinner tests were run with each composition at a flow rate equivalent to around 3ft/second and at a flow rate equivalent to around 5ft/second. A control test, without any treatment was also carried out for comparison. FIG. 1 shows photographs of a representative mild steel coupon after each spinner test with the control and with Example Composition Nos. 1-9. The amount of corrosion and pitting on the coupons is shown in the photographs. As can be seen, the control coupons show extensive corrosion (dark areas on photographs). The coupons used with compositions according to preferred embodiments of the invention (Ex. Nos. 2-3) show little, if any, corrosion or pitting (very few dark areas on photographs). The coupons used with Ex. No. 1, which contains all three components according to a preferred embodiment of the invention for corrosion inhibition, but only contains 2.5 ppm HPA (less than the more preferred amount of at least 3 ppm), shows improved results over the control and the comparative examples (Comp. Nos. 4-9), but shows slightly more corrosion than Ex. Nos. 2-3, where 5 ppm of HPA was used. The coupons used with the comparative compositions (Comp. Nos. 4-9) are significantly better than the control, but do show evidence of corrosion and pitting that is greater than with Ex. Nos. 1-3. Based on the results, it appears that the combination of AAP, HPA, and another phosphonic acid (in these examples, HEDP) interact synergistically

to provide improved corrosion control, without requiring the use of zinc, tin or other regulated metals.

**[0026]** Some prior art water treatment corrosion inhibition compositions do not provide effective protection when oxidizing biocides are used in the same system to prevent biological growth. The most widely used oxidizing biocides are chlorine and stabilized bromine. Additional spinner corrosion tests were carried out using Example compositions Nos. 2 and 3 compared to comparative Example compositions Nos. 4 (zinc only) and 7 (HPA only) in the presence of a stabilized bromine biocide composition (commercially available as Chem-Aqua 42171). Example compositions 4 and 7 were selected because they showed the best results in the spinner tests of the comparative examples. Both Comp. Ex. Nos. 4 and 7 perform fairly well in low LSI water, but as discussed below, significantly worse when biocide is added. Also, Comp. Ex. No. 4 is based on zinc, which is undesirable to use due to toxicity concerns. As with the prior tests, these tests were carried out in presence 4 ppm active AA/AMPS copolymer and 4 ppm active TTA. A slug dose of 40ppm of biocide was added at the beginning of each spinner test (after the corrosion inhibition composition was added and the test started) to yield about 1ppm FHR (free halogen residue).

**[0027]** FIG. 2 shows photographs of a representative mild steel coupon after each spinner test with the Example Compositions in the presence of biocide. As can be seen, the coupons used with compositions according to preferred embodiments of the invention (Ex. Nos. 2-3) show little, if any, corrosion or pitting, indicating that the functionality of preferred compositions according to the invention is not negatively affected by a biocide. The coupons used with the comparative compositions (Comp. Ex. Nos. 4 and 7) show substantially more corrosion than with Ex. Nos. 2-3. It is noted that Comp. No. 7 was the use of HPA and HEDP, without any AAP, which showed good results without biocide, but significantly more corrosion occurred when a biocide was added. The comparative composition having AAP and HEDP, without any HPA, (Comp. Ex. No. 6) did so poorly without biocide (Fig. 1 above) that it was not tested with biocide because the results would be expected to be even worse than

in FIG. 1. Based on the results, it appears that the combination of AAP, HPA, and another phosphonic acid together interact synergistically to provide improved corrosion control even in the presence of a biocide and show improved results over the use of HPA alone.

**[0028]** Corrosion rates for the mild steel coupons were also measured and calculated from weight loss of the coupons. The results of both the spinner tests without added biocide and with added biocide are summarized in Table 4. Information on corrosion mode, particularly the presence of pitting (which is important in many applications and some corrosion inhibitors, including HPA used alone, are known to be poor protectors against pitting), is also included in Table 4. Most preferably, corrosion inhibitor compositions according to the embodiments of the invention achieve corrosion rates of 3 MPY or less for corrosion, even in the presence of a biocide.

**[0029]** Table 4. Corrosion Rates from spinner test experiments

| Mild Steel Coupon Corrosion Rate, MPY [mil/yr] |                    |         |                |                              |         |                |
|--|--------------------|---------|----------------|------------------------------|---------|----------------|
| Test   | Low Hardness Water |         |                | Low Hardness Water + Biocide |         |                |
|  | 3ft/sec            | 5ft/sec | Pitting Scale  | 3ft/sec                      | 5ft/sec | Pitting        |
| Control  | 370                | 243     | N/A            |                              |         |                |
| Example 1                                      | 2.7                | 2.5     | None           |                              |         |                |
| Example 2                                      | 2.9                | 2.4     | None           | 2.2                          | 2.0     | None           |
| Example 3                                      | 2.5                | 2.5     | None           | 2.7                          | 2.4     | None           |
| Comp. Ex 4                                     | 2.7                | 2.7     | Limited        | 8.0                          | 11      | Sever pitting  |
| Comp. Ex 5                                     | 4.0                | 4.6     | Pitting        |                              |         |                |
| Comp. Ex 6                                     | 13.6               | 8.2     | Severe pitting |                              |         |                |
| Comp. Ex 7                                     | 2.6                | 3.2     | Limited        | 6.4                          | 5.7     | Severe pitting |
| Comp. Ex 8                                     | 3.9                | 5.2     | Pitting        |                              |         |                |
| Comp. Ex 9                                     | 3.8                | 3.2     | Sever pitting  |                              |         |                |

**Pitting scale description:**

None = no pitting observed

Limited = few (1-5) pits per coupon, usually very shallow

Pitting = significant number of pits on coupons (5-50)

Sever pitting = a large number of pits (&gt; 50), usually dipper and larger

**[0030]** Compositions according to preferred embodiments of the invention contain organic phosphate from the HPA and from the other phosphonic acid used in these examples (HEDP). In the presence of a biocide, the organic phosphate is often reverted to orthophosphate, which is not as good in

preventing corrosion and also may cause issues with forming calcium phosphate scale. When the combination of AAP, HPA, and HEDP (or another phosphonic acid) is used as a corrosion inhibitor according to a preferred embodiment of the invention, virtually no reversion of organic phosphate to orthophosphate was detected. Samples from composition Example Nos. 2 and 3 and comparative Example No. 7 were tested for the presence of orthophosphates upon mixing of the composition and again after 48 hours. The results are listed below in Table 5. Example Nos. 2 and 3, which use AAP, HPA, and HEDP (and contain AA/AMPS and TTA as noted above), showed very little orthophosphate increase over the 48 hour period, but comparative Example No. 7 which contains HPA and HEDP (and contains AA/AMPS and TTA as noted above), but no AAP, showed a substantial increase.

**[0031]** Table 5. Orthophosphate levels in low hardness test water in presence of biocide during the spinner corrosion test

| Test        | Orthophosphate (ppm PO <sub>4</sub> ) |                    |
|-------------|---------------------------------------|--------------------|
|             | Initial                               | 48hr (End of Test) |
| Example 2   | 0.4                                   | 0.5                |
| Example 3   | 0.2                                   | 0.4                |
| Comp. Ex -7 | 0.3                                   | 1.6                |

**[0032]** According to another preferred embodiment, a water treatment composition as listed in Table 6 (which is the same as Ex. 2 tested above) is effective at inhibiting corrosion in a water system over a broad range of LSI values and in the presence of a biocide.

**[0033]** Table 6.

| Component  | Available as           | Wt %  | Active %* in Composition |
|--|------------------------|-------|--------------------------|
| Sodium polyaspartate (AAP)                                 | Baypure DS100          | 13.0  | 5.2% as AAP              |
| Hydroxy phosphonoacetic Acid (HPA)                         | Belcor 575             | 10.0  | 5.0% as HPA              |
| 1-Hydroxyethylidene 1,1-diphosphonic acid (HEDP)           | Dequest 2010           | 5.25  | 3.0% as PO4              |
| Monoethanolamine (MEA)                                     | Monoethanolamine       | 1.0   | 0.99%                    |
| Copolymer of acrylic acid and sulfonated monomer (AA/AMPS) | NC-233                 | 8.78  | 3.9% as AA/AMPS          |
| Tolyltriazole (TTA)  | Wintrol T50NA          | 9.40  | 4.0% as TTA              |
| 1,3,6,8-Pyrenetetrasulfonic acid tetrasodium salt (PTSA)   | Spectra Trace SH-L 10% | 1.00  | 1% as PTSA               |
|  | NaOH or KOH            | 15.00 | N/A                      |
| Deionized water  | Deionized water        | 36.57 | N/A                      |

\*Active % refers to active weight percent. Wt% is raw material weight percent. Most of the raw materials are aqueous solutions and contain only a certain amount of solids that is the actual chemical component. The amount of active (Active %) is calculated based on raw material weight percent and the amount of the chemical in the solution per the information provided by the supplier. For example, Baypure DS100 is a 40% solution of AAP in water, so if we use 13% of Baypure we have:  $0.13 \times 0.40 \times 100\% = 5.2\%$  of AAP (actual chemical) in the formula

**[0034]** NaOH and/or KOH is preferably also added to the composition according to an embodiment of the invention. These ingredients are typically added to water treatment formulations in order to neutralize acid and to bring the pH of the final composition to the desired level. Most of the compositions will have pH > 8, some will have pH > 12. In compositions where TTA is used (as with a preferred embodiment of a composition according to the invention) it is desirable to have higher pH (> 11) for the composition in order to ensure solubility of TTA, which has very poor solubility at lower pH.

**[0035]** Additional spinner tests in low LSI water were carried out in order to test the effectiveness of various concentrations of treatment compositions for inhibiting corrosion according to preferred embodiments of the invention. The same spinner test parameters and low LSI water (Table 1) described above were used for these tests. The concentrations of the ingredients when added to the spinner test water and the results of these tests are shown below in Table 7. Figure 3 shows photographs of the test coupons (tested at a flow rate of 3 ft/sec) for each composition after the test was completed.

**[0036]** Table 7 – Additional Spinner Test Compositions & Results

| Inhibitor  | Unit         | Comp. Ex. 10                      | Ex. 11                           | Ex. 12                            | Comp. Ex. 13                     | Ex. 14                           | Comp. Ex. 15                     | Ex. 16                             | Comp. Ex. 17 |
|--|--------------|-----------------------------------|----------------------------------|-----------------------------------|----------------------------------|----------------------------------|----------------------------------|------------------------------------|--------------|
| AAP  | ppm active   | 2.6                               | 5.2                              | 7.8                               | 5.0                              | 10                               | 10                               | 5.0                                | 5.0          |
| HPA  | ppm active   | 2.5                               | 5.0                              | 7.5                               | 2.5                              | 5                                | 2.5                              | 5.0                                | 5.0          |
| AAP:HPA Ratio  |              | 51:49                             | 51:49                            | 51:49                             | 67:33                            | 67:33                            | 80:20                            | 51:49                              | 51:49        |
| HEDP   | ppm active   | 1.6<br>(1.5 ppm PO <sub>4</sub> ) | 3.26<br>(3 ppm PO <sub>4</sub> ) | 4.7<br>(4.4 ppm PO <sub>4</sub> ) | 3.26<br>(3 ppm PO <sub>4</sub> ) | 3.26<br>(3 ppm PO <sub>4</sub> ) | 3.26<br>(3 ppm PO <sub>4</sub> ) |                                    |              |
| PBTC   | ppm active   |                                   |                                  |                                   |                                  |                                  |                                  | 2.6<br>(0.95 ppm PO <sub>4</sub> ) |              |
| MEA  | ppm          |                                   |                                  |                                   | 0.5                              | 1                                | 0.5                              |                                    |              |
| TTA  | ppm TTA      | 4                                 | 4                                | 4                                 | 4                                | 4                                | 4                                | 4                                  | 4            |
| AA/AMPS Copolymer  | ppm active   | 4                                 | 4                                | 4                                 | 4                                | 4                                | 4                                | 4                                  | 4            |
| Corrosion Results from Spinner Test (low LSI water), mild steel (C1010) coupons at 3ft/sec flow rate |              |                                   |                                  |                                   |                                  |                                  |                                  |                                    |              |
| Corrosion Rate*  | MPY (mil/yr) | 5.2                               | 2.3                              | 1.5                               | 3.1                              | 2.2                              | 3.5                              | 2.1                                | 3.3          |
| Pitting  |              | Pitting                           | none                             | none                              | none                             | none                             | none                             | none                               | None         |

\* Average for 2 coupons from the same spinner test pot at 3 ft/sec

**[0037]** Comparative Examples 10, 13, and 15 use AAP, HPA, and HEDP but in amounts less than the preferred concentrations. These examples show increased corrosion (and Comp. Ex. 10 showed moderate pitting) at low levels of the inhibitors. Example Nos. 11-12, 14, and 16 according to preferred embodiments of the invention show good performance (low corrosion rate and no

pitting) for different optional components and varying concentrations and ratios of AAP to HPA. The examples also show that the change from HEDP to PBTC (Ex. 16) and reduction of secondary chelates does not affect the corrosion inhibition performance of compositions according to preferred embodiments of the invention. Example No. 17 used AAP and HPA, without a second phosphonic acid, similar to the composition described in the '023 patent. It shows improved results in controlling corrosion in low LSI water, but the results are not as good as in the examples according to preferred embodiments of the invention.

**[0038]** Additional spinner tests were conducted to compare compositions using AAP and PBTC as disclosed in the '023 patent with compositions according to preferred embodiments of the invention. The test set-up was the same as described above using low LSI water, mild steel (C1010) coupons, and a flow rate of 3 ft/sec. The results are shown in Table 8 below.

**[0039]** Table 8 – Comparing Compositons Using One Phosphonic Acid to Compositions Using Two Phosphonic Acids

| Inhibitor         | Unit         | Comp. Example 18<br>80:20<br>PBTC/AAP | Comp. Example 19<br>40:60<br>PBTC/AAP | Example 20 | Example 21 | Example 12<br>(same as in<br>Table 7) |
|-------------------|--------------|---------------------------------------|---------------------------------------|------------|------------|---------------------------------------|
| PBTC              | ppm active   | 16                                    | 8                                     | 4.8        | 8          |                                       |
| HEDP              | ppm active   |                                       |                                       |            |            | 4.7                                   |
| AAP               | ppm active   | 4                                     | 12                                    | 7.8        | 4          | 7.8                                   |
| HPA               | ppm active   |                                       |                                       | 7.5        | 8          | 7.5                                   |
| TTA               | ppm TTA      | 4                                     | 4                                     | 4          | 4          | 4                                     |
| AA/AMPS Copolymer | ppm active   | 4                                     | 4                                     | 4          | 4          | 4                                     |
| Corrosion Rate*   | MPY (mil/yr) | 3.1                                   | 3.1                                   | 1.9        | 1.7        | 1.5                                   |
| Pitting           |              | none                                  | none                                  | none       | none       | None                                  |

\*Average for 2 coupons from the same pot at 3 ft/sec

**[0040]** As can be seen, the examples according to preferred embodiments of the invention (Example Nos. 20, 21, and 12) with AAP, HPA, and a second phosphonic acid (HEDP or PBTC) show much beter corrosion inhibition results than the comparative examples using only AAP and PBTC

(without any HPA). It is also noted that Comp. Ex. Nos. 18-19 resulted in corrosion rates greater than 3 MPY even when using 20 ppm total inhibitor (AAP and PBTC), which is higher than the corrosion rate achievable with preferred compositions according to the invention using substantially less total inhibitor, such as Example No. 11, which had a corrosion rate of 2.3 MPY using only 13.5 ppm total inhibitors (AAP, HPA, HEDP), and Example No. 16, which had a corrosion rate of 2.1 MPY using only 12.6 ppm total inhibitors (AAP, HPA, PBTC). Additionally, the corrosion rates of Comp. Ex. Nos. 18-19 are comparable to those in Comp. Ex. Nos. 13 and 15, which use AAP, HPA, and a second phosphonic acid, but the total amount of inhibitor needed to achieve the results in Comp. Ex. Nos. 18-19 (20 ppm total) is much higher than that needed in Nos. 13 and 15 (10.76 and 15.76 ppm total, respectively). The results of these experiments show that the addition of a second phosphonic acid, in combination with AAP and HPA, provides an unexpected synergistic effect that improves corrosion inhibition even when less total inhibitor is used and even in the presence of a biocide.

**[0041]** Those of ordinary skill in the art will understand that other suitable or equivalent chemical compounds and other treatment compounds, including other corrosion inhibitors, may be substituted for any of the above ingredients or added to any of the above ingredients within the scope of this invention. Compositions according to the embodiments of the invention are effective in inhibiting corrosion on metal components in water systems over a broad range of LSI values, including LSI <0, and without requiring the use of regulated toxic metals. These compositions are also effective at higher pH values (7-9) typically found in water systems, such as cooling towers and boilers, whereas some prior art inhibitors are ineffective or their effectiveness is reduced at such pH levels (for example, a polyaspartic acid/stannous salt treatment is effective only at pH 5-7). These compositions according to the invention also prevent reversion of organic phosphate to orthophosphate to maintain effectiveness in the presence of a biocide.

**[0042]** Other experiments using an electrochemical method were conducted to test compositions according to the invention for white rust prevention. The results in Table 9 below show synergistic effect of combining HPA and AAP (without another phosphonic acid) in reducing white rust formation as compared to use of each individual component (HPA alone and AAP alone). The cyclic voltammetry test was conducted in 0.1M sodium carbonate solution using zinc electrode. The measure of oxidation is the area under the oxidation curve peak observed; the lower the area the less oxidation occurs, meaning lower corrosion rate. The results are the averages of 6-10 experiments with standard deviation.

**[0043]** Table 9

| Inhibitor           | Concentration<br>[ppm active] | Measure of Oxidation<br>[Coulombs*10 <sup>-3</sup> ] |
|---------------------|-------------------------------|--|
| AAP                 | 50                            | 1.2 ± 0.2  |
| HPA                 | 50                            | 1.0 ± 0.1  |
| AAP/HPA (1:1 ratio) | 25 : 25                       | 0.8 ± 0.1  |

**[0044]** Additional spinner corrosion tests were carried out in stainless steel containers in high alkalinity water known to form white rust on galvanized surfaces to test the effectiveness of compositions according to preferred embodiments of the invention for the prevention of white rust formation. The water chemistry, characteristic of high alkalinity synthetic water, in these tests is detailed in Table 10 below. Four Hot Dip Galvanized steel coupons (HDG G70) with dimensions 1.0x4.0x0.02in were installed in each container on the holders hanging from a rotating shaft that rotates at 147 rotations/min that represents flow rate of 3-5 ft/s, depending on coupon distance from center of the rotating shaft. During the tests the water was aerated and maintained at constant temperature of 120F and constant volume (any evaporation was compensated with automatic addition of DI water when the water level dropped below a sensor level). Standard test duration was 48 hours. The active ingredients used in two comparative examples and three examples of preferred compositions according to the invention, along with corrosion rates, are listed in Table 11.

**[0045]** Table 10 - High alkalinity/no hardness water used in Spinner test experiments for white rust prevention

| Characteristic   | Value   | Unit                         |
|------------------|---------|------------------------------|
| pH               | 8.7-8.9 |                              |
| Conductivity     | 2300    | cP                           |
| Ca Hardness      | 0       | ppm, (as CaCO <sub>3</sub> ) |
| Mg Hardness      | 0       | ppm, (as CaCO <sub>3</sub> ) |
| Chlorides, Total | 250     | ppm Cl                       |
| M Alkalinity     | 200     | ppm, (as CaCO <sub>3</sub> ) |
| Sulfate, Total   | 500     | ppm, as SO <sub>4</sub>      |

**[0046]** Table 11 - Active Ingredients Composition and Galvanized Coupon Corrosion Rate

| Inhibitor  | Unit         | Comp. Ex. 22 - No Inhibitor | Comp. Ex. 23                  | Ex. 24                        | Ex. 25                        | Ex. 26                        |
|--|--------------|-----------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| AAP  | ppm active   | -                           | -                             | 15                            | 7.5                           | 15                            |
| HPA  | ppm active   | -                           | 7.5                           | 7.5                           | 2.5                           | -                             |
| HEDP   | ppm active   | -                           | 3.26 (3 ppm PO <sub>4</sub> ) | 3.26 (3 ppm PO <sub>4</sub> ) | 3.26 (3 ppm PO <sub>4</sub> ) | 3.26 (3 ppm PO <sub>4</sub> ) |
| TTA  | ppm TTA      | -                           | 4                             | 4                             | 4                             | 4                             |
| AA/AMPS Copolymer                                      | ppm active   | -                           | 4                             | 4                             | 4                             | 4                             |
| <b>Corrosion Results- Galvanized Coupons (HDG G70)</b> |              |                             |                               |                               |                               |                               |
| Corrosion Rate*  | MPY (mil/yr) | 53.7                        | 24.3                          | 9.9                           | 14.0                          | 10.7                          |

\*Average for 4 coupons from the same pot (two at 3 ft/sec and two at 5 ft/sec flow rate)

**[0047]** In order to calculate the corrosion rate using the weight loss method, the galvanized coupons from these tests were cleaned according to standard procedure by immersing coupons in concentrated ammonium acetate and rinsing. FIG. 4 shows photographs of the galvanized coupons after the spinner tests with the compositions described in Table 12, both before and after cleaning. The white deposit visible on the coupons before cleaning is white rust.

The damage of the galvanized layer due to corrosion, shown as dark spots, is visible on the coupons after cleaning. The blank (Comp. Ex. 22 – No Treatment) coupon was completely covered in white deposit and after cleaning most of the galvanized layer was removed with visible mild steel corrosion. The coupon treated with HPA and HEDP without an amino-acid based polymer (Comp. Ex. 23) showed substantial white rust formation, but was still a great improvement over the control (Comp. Ex. 22). Significantly better results were obtained with compositions in Examples 24-26. The best results were achieved with Ex. 24 using AAP, HPA at greater than 3 ppm, and a second phosphonic acid (HEDP). Although the use of HPA is important in inhibiting mild steel corrosion, its use is optional for white rust treatment. As can be seen from Example 26, the results of using AAP and HEDP without HPA were almost as good as the three combined. Accordingly, a preferred composition for treating white rust according to the invention comprises 2-15% amino-acid based polymer, 0-10% HPA, and 0-10% of a second phosphonic acid. Preferably, the amount of active amino-acid based polymer in a treatment composition according to the invention is at least 3ppm, more preferably 3 ppm – 50 ppm, and most preferably 5 ppm – 30 ppm, all as concentrations when added to the volume of water in the water system being treated. More preferably, the AAP is used in conjunction with HPA in an amount of at least 3 ppm, more preferably from 3 ppm - 50 ppm, and most preferably from about 3 ppm - 20 ppm and/or another phosphonic acid in an amount of at least 2 ppm more preferably from 2 ppm- 20 ppm, and most preferably from about 2 ppm - 10 ppm.

**[0048]** For treating white rust according to the invention, it is preferred to use both hydroxyphosphonoacetic acid and an amino-acid based polymer, and more preferably in conjunction with a second phosphonic acid, in the weight range amounts indicated above, but it has also been found that the use of an amino-acid based polymer or hydroxyphosphonoacetic without the other is beneficial at inhibiting white rust.

**[0049]** According to one preferred method of preventing corrosion of metal components and/or white rust on galvanized steel components in a water

system, a treatment composition according to the invention as described above is added to the water system at a preferred effective feed rate of 20ppm - 600 ppm, or more preferably 100 - 300ppm, of treatment composition depending on the treated water chemistry and the amount of optional components in the treatment composition. Preferably, a sufficient amount of treatment composition is added to the water system to provide effective active amounts of AAP of at least 3 ppm and of HPA of at least 3 ppm, both as concentrations when added to the volume of water in the water system being treated. More preferably, the amount of HPA is at least 3 ppm. More preferably, the treatment composition is added in a sufficient amount to provide effective active amounts of AAP between 3 ppm - 50 ppm, HPA between 3ppm - 50 ppm, and a second phosphonic acid between 2 ppm - 20 ppm when added to the water in the water system. Most preferably, these effective active amounts are 5ppm - 30 ppm AAP, 3 ppm - 20 ppm HPA, and a second phosphonic acid between 2ppm - 10 ppm when added to the water in the water system. For treating white rust, the use of HPA is optional, so the treatment composition used in a preferred method according to the invention may comprise AAP without any HPA and be added in amounts sufficient to provide these same concentration ranges of AAP in the water of the water system being treated. According to another preferred embodiment, the composition added to the water system comprises a fluorescent tracer so that the level of composition in the water system can be measured and monitored. Additional treatment composition is added to the water system as needed, based on the tracer measurements, to maintain an effective amount of treatment within the water system.

**[0050]** All ppm concentrations of the various treatments in the example tests described herein are concentrations when added to the water in the spinner test, to correlate to the concentrations when added to the water in the water system being treated. Unless specifically excluded, all references to acids herein and in the claims include water soluble salts of the acid, as will be understood by those of ordinary skill in the art. Those of ordinary skill in the art will also appreciate upon reading this specification, including the examples contained

herein, that modifications and alterations to the preferred embodiments of the composition and method for using the composition to treat water may be made within the scope of the invention and it is intended that the scope of the invention disclosed herein be limited only by the broadest interpretation of the appended claims to which the inventor is legally entitled.

**[0051]** What is Claimed:

1. A method of treating water systems to inhibit white rust formation on galvanized steel components in the water system, the method comprising adding an effective amount of:
  - an amino-acid based polymer; or
  - hydroxyphosphonoacetic acid or its water soluble salt; or
  - both an amino-acid based polymer and hydroxyphosphonoacetic acid or its water soluble salt to the water in the water system.
2. The method of claim 1 wherein the effective amount is an amount that when added to a volume of water in the water system provides an active concentration of at least 3 ppm of the amino-acid based polymer or at least 3 ppm of the hydroxyphosphonoacetic acid or both in the water system.
3. The method of claim 2 wherein the effective amount is an amount that when added to the volume of water in the water system provides an active concentration of 3 ppm – 50 ppm of the amino-acid based polymer or an active concentration of 3 ppm – 50 ppm of the hydroxyphosphonoacetic acid or both.
4. The method of claim 1 further comprising adding an effective amount of a phosphonic acid other than hydroxyphosphonoacetic acid to the water in the water system.
5. The method of claim 4 wherein both the amino-acid based polymer and hydroxyphosphonoacetic acid are added and wherein the effective amount is an amount that when added to a volume of water in the water system provides a combined active concentration of the amino-acid based polymer, hydroxyphosphonoacetic acid, and other phosphonic acid of at least 9 ppm in the water system.

6. The method of claim 1 where both the amino-acid based polymer and hydroxyphosphonoacetic acid are added and wherein the effective amount is an amount that when added to a volume of water in the water system provides a combined active concentration of the amino-acid based polymer and the hydroxyphosphonoacetic acid of at least 6ppm in the water system.

7. The method of claim 1 wherein the amino-acid based polymer is polyaspartic acid or a salt thereof.

8. The method of claim 1 wherein the amino-acid based polymer and hydroxyphosphonoacetic acid are combined in a treatment composition prior to addition to the water system and wherein the treatment composition comprises around 2%-15% by weight of the amino-acid based polymer and around 2% to 10% by weight of the hydroxyphosphonoacetic acid.

9. The method of claim 1 wherein the amino-acid based polymer, hydroxyphosphonoacetic acid, and a tracer are combined in a treatment composition prior to addition to the water system and wherein the method further comprises:

periodically measuring the amount of treatment composition in the water system based on a measurement of the tracer.

10. The method of claim 9 wherein the treatment composition further comprises one or more of a neutralizing amine, chlorine stabilizer, a scale inhibitor, a dispersion agent, another corrosion inhibitor, chelants, and anazole corrosion inhibitor.

11. The method of claim 8 further comprising adding additional treatment composition as needed to maintain an active concentration of the amino-acid based polymer of at least 3 ppm and an active concentration of the hydroxyphosphonoacetic acid of at least 3 ppm, wherein these concentrations are when added to a volume of water in the water system.

12. The method of claim 1 wherein the amino-acid based polymer and hydroxyphosphonoacetic acid are both added separately to the water system.
13. The method of claim 1 further comprising adding an effective amount of a phosphonocarboxylic acid.
14. The method of claim 13 wherein the effective amount is an amount that when added to a volume of water in the water system provides a concentration of at least 2 ppm of the phosphonocarboxylic acid.
15. The method of claim 14 wherein the phosphonocarboxylic acid is HEDP, PBTC, or both.
16. The method of claim 1 wherein no regulated metals are added to the water in the water system.
17. The method of claim 9 wherein the treatment composition does not include zinc or tin.

18. A composition for inhibiting corrosion or white rust on metal components in water systems, the composition comprising an amino-acid based polymer, hydroxyphosphonoacetic acid, and a second phosphonic acid.
19. The composition according to claim 18 wherein the second phosphonic acid is a phosphonocarboxylic acid.
20. The composition according to claim 18 wherein the amino-acid based polymer is polyaspartic acid or a salt thereof.
21. The composition according to claim 20 wherein the amino-acid based polymer is sodium polyaspartate.
22. The composition according to claim 18 wherein no regulated metals are included in the composition.
23. The composition according to claim 19 wherein the weight ratio of amino-acid based polymer to hydroxyphosphonoacetic acid is in a range of 90:10 to 10:90 and the weight ratio of combined amino-acid based polymer and hydroxyphosphonoacetic acid to phosphonocarboxylic acid is in a range of 90:10 to 60:40.
24. The composition according to claim 19 comprising around 2%-15% by weight of the amino-acid based polymer, around 2% to 10% by weight of the hydroxyphosphonoacetic acid, and around 2% to 10% by weight of the phosphonocarboxylic acid.
25. The composition according to claim 19 further comprising one or more of a neutralizing amine, chlorine stabilizer, a scale inhibitor, a dispersion agent, another corrosion inhibitor, chelants, anazole corrosion inhibitor, and a fluorescent dye tracer.
26. The composition according to claim 19 further comprising one or more monoethanol amine, a polycarboxylate polymer, a carboxylate/sulfonate

functional copolymer, benzotriazole, alkylbenzotriazole (tolyltriazole), and 1,3,6,8-Pyrenetetrasulfonic acid tetrasodium salt.

27. The composition according to claim 18 wherein the composition comprises an amount of amino-acid based polymer and hydroxyphosphonoacetic acid sufficient to yield at least 3 ppm active amino-acid based polymer and at least 3 ppm active hydroxyphosphonoacetic acid when added to a volume of water in the water system.

28. The composition according to claim 27 wherein the yield of active amino-acid based polymer is 3ppm – 50ppm and the yield of active hydroxyphosphonoacetic acid is 3ppm – 50ppm.

29. The composition according to claim 27 wherein the yield of active amino-acid based polymer is 5ppm – 30ppm and the yield of active hydroxyphosphonoacetic acid is 3ppm – 20ppm.

30. The composition according to claim 18 wherein the composition comprises an amount of polyaspartic acid or a salt thereof and hydroxyphosphonoacetic acid sufficient to yield at least 3 ppm active amino-acid based polymer and at least 3 ppm active hydroxyphosphonoacetic acid when added to a volume of water in the water system.

31. The composition according to claim 18 wherein the composition does not include zinc or tin.

32. A method of treating water systems to inhibit corrosion on metal components or white rust formation on galvanized steel components in the water system, the method comprising adding an effective amount of an amino-acid based polymer, hydroxyphosphonoacetic acid, and a second phosphonic acid to the water in the water system.

33. The method of claim 32 wherein the second phosphonic acid is a phosphonocarboxylic acid.

34. The method of claim 32 wherein the effective amount is an amount that when added to a volume of water in the water system provides an active concentration of at least 3 ppm of the amino-acid based polymer, at least 3 ppm of the hydroxyphosphonoacetic acid, and at least 2 ppm of the phosphonocarboxylic acid in the water system.

35. The method of claim 34 wherein the effective amount is an amount that when added to the volume of water in the water system provides an active concentration of 3 ppm – 50 ppm of the amino-acid based polymer, an active concentration of 3 ppm – 50 ppm of the hydroxyphosphonoacetic acid, and an active concentration of 2 ppm – 20 ppm of the phosphonocarboxylic acid.

36. The method of claim 34 wherein the effective amount is an amount that when added to the volume of water in the water system provides an active concentration of 5 ppm – 30 ppm of the amino-acid based polymer, an active concentration of 3 ppm – 20 ppm of the hydroxyphosphonoacetic acid, and an active concentration of 2 ppm – 10 ppm of the phosphonocarboxylic acid.

37. The method of claim 33 wherein the effective amount of the amino-acid based polymer, hydroxyphosphonoacetic acid, and phosphonocarboxylic acid is an amount that when added to a volume of water in the water system provides a combined active concentration of the amino-acid based polymer, the hydroxyphosphonoacetic acid, and phosphonocarboxylic acid of at least 9 ppm in the water system.

38. The method of claim 32 wherein the amino-acid based polymer is polyaspartic acid or a salt thereof.

39. The method of claim 33 wherein the amino-acid based polymer, and hydroxyphosphonoacetic acid, and phosphonocarboxylic acid, and a tracer are combined in a treatment composition prior to addition to the water system and wherein the method further comprises:

periodically measuring the amount of treatment composition in the water system based on a measurement of the tracer.

40. The method of claim 37 further comprising adding additional treatment composition as needed to maintain a concentration of the amino-acid based polymer of at least 3 ppm and a concentration of the hydroxyphosphonoacetic acid of at least 3 ppm, wherein these concentrations are when added to a volume of water in the water system.

41. The method of claim 33 wherein the phosphonocarboxylic acid is HEDP, PBTC or both.

42. The method of claim 32 wherein the water in the water system contains a biocide.

43. The method of claim 32 wherein the water in the water system has a pH greater than 7.

**AMENDED CLAIMS****received by the International Bureau on 02 August 2017 (02.08.2017)**

1. A method of treating water systems to inhibit white rust formation on galvanized steel components in the water system, the method comprising adding :
  - an amino-acid based polymer; or
  - hydroxyphosphonoacetic acid or its water soluble salt; or
  - both an amino-acid based polymer and hydroxyphosphonoacetic acid or its water soluble salt to the water in the water system.
  
2. The method of claim 1 wherein the adding step provides an active concentration of at least 3 ppm of the amino-acid based polymer or at least 3 ppm of the hydroxyphosphonoacetic acid or both when added to a volume of water in the water system.
  
3. The method of claim 2 wherein the adding step provides an active concentration of 3 ppm – 50 ppm of the amino-acid based polymer or an active concentration of 3 ppm – 50 ppm of the hydroxyphosphonoacetic acid or both.
  
4. The method of claim 1 further comprising adding a phosphonic acid other than hydroxyphosphonoacetic acid to the water in the water system.
  
5. The method of claim 4 wherein both the amino-acid based polymer and hydroxyphosphonoacetic acid are added and wherein the adding step provides a combined active concentration of the amino-acid based polymer, hydroxyphosphonoacetic acid, and other phosphonic acid of at least 9 ppm when added to a volume of water in the water system.
  
6. The method of claim 1 where both the amino-acid based polymer and hydroxyphosphonoacetic acid are added in an amount that provides a combined active

concentration of the amino-acid based polymer and the hydroxyphosphonoacetic acid of at least 6ppm in a volume of water in the water system the water system.

7. The method of claim 1 wherein the amino-acid based polymer is polyaspartic acid or a salt thereof.

8. The method of claim 1 wherein the amino-acid based polymer and hydroxyphosphonoacetic acid are combined in a treatment composition prior to addition to the water system and wherein the treatment composition comprises around 2%-15% by weight of the amino-acid based polymer and around 2% to 10% by weight of the hydroxyphosphonoacetic acid.

9. The method of claim 1 wherein the amino-acid based polymer, hydroxyphosphonoacetic acid, and a tracer are combined in a treatment composition prior to addition to the water system and wherein the method further comprises:

periodically measuring the amount of treatment composition in the water system based on a measurement of the tracer.

10. The method of claim 9 wherein the treatment composition further comprises one or more of a neutralizing amine, chlorine stabilizer, a scale inhibitor, a dispersion agent, another corrosion inhibitor, chelants, and an azole corrosion inhibitor.

11. The method of claim 8 further comprising adding additional treatment composition as needed to maintain an active concentration of the amino-acid based polymer of at least 3 ppm and an active concentration of the hydroxyphosphonoacetic acid of at least 3 ppm, wherein these concentrations are when added to a volume of water in the water system.

12. The method of claim 1 wherein the amino-acid based polymer and hydroxyphosphonoacetic acid are both added separately to the water system.

13. The method of claim 1 further comprising adding a phosphonocarboxylic acid.
14. The method of claim 13 wherein the adding step provides a concentration of at least 2 ppm of the phosphonocarboxylic acid in a volume of water in the water system.
15. The method of claim 14 wherein the phosphonocarboxylic acid is HEDP, PBTC, or both.
16. The method of claim 1 wherein no regulated metals are added to the water in the water system.
17. The method of claim 9 wherein the treatment composition does not include zinc or tin.

18. A composition for inhibiting corrosion or white rust on metal components in water systems, the composition comprising an amino-acid based polymer, hydroxyphosphonoacetic acid, and a second phosphonic acid.
19. The composition according to claim 18 wherein the second phosphonic acid is a phosphonocarboxylic acid.
20. The composition according to claim 18 wherein the amino-acid based polymer is polyaspartic acid or a salt thereof.
21. The composition according to claim 20 wherein the amino-acid based polymer is sodium polyaspartate.
22. The composition according to claim 18 wherein no regulated metals are included in the composition.
23. The composition according to claim 19 wherein the weight ratio of amino-acid based polymer to hydroxyphosphonoacetic acid is in a range of 90:10 to 10:90 and the weight ratio of combined amino-acid based polymer and hydroxyphosphonoacetic acid to phosphonocarboxylic acid is in a range of 90:10 to 60:40.
24. The composition according to claim 19 comprising around 2%-15% by weight of the amino-acid based polymer, around 2% to 10% by weight of the hydroxyphosphonoacetic acid, and around 2% to 10% by weight of the phosphonocarboxylic acid.
25. The composition according to claim 19 further comprising one or more of a neutralizing amine, chlorine stabilizer, a scale inhibitor, a dispersion agent, another corrosion inhibitor, chelants, an azole corrosion inhibitor, and a fluorescent dye tracer.
26. The composition according to claim 19 further comprising one or more monoethanol amine, a polycarboxylate polymer, a carboxylate/sulfonate functional

copolymer, benzotriazole, alkylbenzotriazole (tolyltriazole), and 1,3,6,8-Pyrenetetrasulfonic acid tetrasodium salt.

27. The composition according to claim 18 wherein the composition comprises an amount of amino-acid based polymer and hydroxyphosphonoacetic acid sufficient to yield at least 3 ppm active amino-acid based polymer and at least 3 ppm active hydroxyphosphonoacetic acid when added to a volume of water in the water system.

28. The composition according to claim 27 wherein the yield of active amino-acid based polymer is 3ppm – 50ppm and the yield of active hydroxyphosphonoacetic acid is 3ppm – 50ppm.

29. The composition according to claim 27 wherein the yield of active amino-acid based polymer is 5ppm – 30ppm and the yield of active hydroxyphosphonoacetic acid is 3ppm – 20ppm.

30. The composition according to claim 18 wherein the composition comprises an amount of polyaspartic acid or a salt thereof and hydroxyphosphonoacetic acid sufficient to yield at least 3 ppm active amino-acid based polymer and at least 3 ppm active hydroxyphosphonoacetic acid when added to a volume of water in the water system.

31. The composition according to claim 18 wherein the composition does not include zinc or tin.

32. A method of treating water systems to inhibit corrosion on metal components or white rust formation on galvanized steel components in the water system, the method comprising adding an amino-acid based polymer, hydroxyphosphonoacetic acid, and a second phosphonic acid to the water in the water system.

33. The method of claim 32 wherein the second phosphonic acid is a phosphonocarboxylic acid.

34. The method of claim 32 wherein the adding step provides an active concentration of at least 3 ppm of the amino-acid based polymer, at least 3 ppm of the hydroxyphosphonoacetic acid, and at least 2 ppm of the phosphonocarboxylic acid in a volume of water in the water system.

35. The method of claim 34 wherein the adding step provides an active concentration of 3 ppm – 50 ppm of the amino-acid based polymer, an active concentration of 3 ppm – 50 ppm of the hydroxyphosphonoacetic acid, and an active concentration of 2 ppm – 20 ppm of the phosphonocarboxylic acid.

36. The method of claim 34 wherein the adding step provides an active concentration of 5 ppm – 30 ppm of the amino-acid based polymer, an active concentration of 3 ppm – 20 ppm of the hydroxyphosphonoacetic acid, and an active concentration of 2 ppm – 10 ppm of the phosphonocarboxylic acid.

37. The method of claim 33 the adding step provides a combined active concentration of the amino-acid based polymer, the hydroxyphosphonoacetic acid, and phosphonocarboxylic acid of at least 9 ppm in a volume of water in the water system.

38. The method of claim 32 wherein the amino-acid based polymer is polyaspartic acid or a salt thereof.

39. The method of claim 33 wherein the amino-acid based polymer, and hydroxyphosphonoacetic acid, and phosphonocarboxylic acid, and a tracer are

combined in a treatment composition prior to addition to the water system and wherein the method further comprises:

periodically measuring the amount of treatment composition in the water system based on a measurement of the tracer.

40. The method of claim 37 further comprising adding additional treatment composition as needed to maintain a concentration of the amino-acid based polymer of at least 3 ppm and a concentration of the hydroxyphosphonoacetic acid of at least 3 ppm, wherein these concentrations are when added to a volume of water in the water system.

41. The method of claim 33 wherein the phosphonocarboxylic acid is HEDP, PBTC or both.

42. The method of claim 32 wherein the water in the water system contains a biocide.

43. The method of claim 32 wherein the water in the water system has a pH greater than 7.

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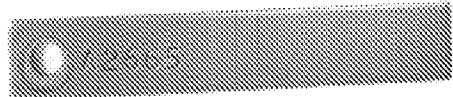
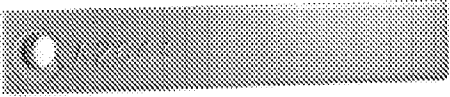




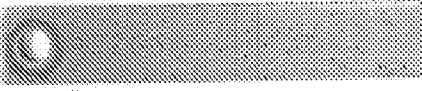









|                           | Carbon Steel Coupon   |  |
|---------------------------|---|--|
| Test                      | Flow Rate = 3ft/sec   | Flow rate = 5ft/sec  |
| Control<br>(no treatment) |    |    |
| Example 1                 |    |    |
| Example 2                 |    |    |
| Example 3                 |   |   |
| Comp. Ex.4                |  |  |
| Comp. Ex.5                |  |  |
| Comp. Ex.6                |  |  |
| Comp. Ex.7                |  |  |
| Comp. Ex.8                |  |  |
| Comp. Ex.9                |  |  |

FIG. 1

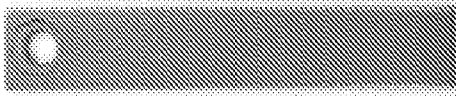

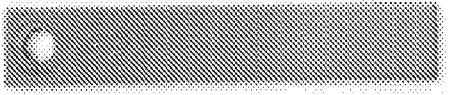





|             | Carbon Steel Coupon   |  |
|-------------|---|--|
| Test        | Flow Rate = 3ft/sec   | Flow rate = 5ft/sec  |
| Example 2   |    |    |
| Example 3   |    |    |
| Comp. Ex.4  |   |   |
| Comp. Ex. 7 |  |  |

FIG. 2

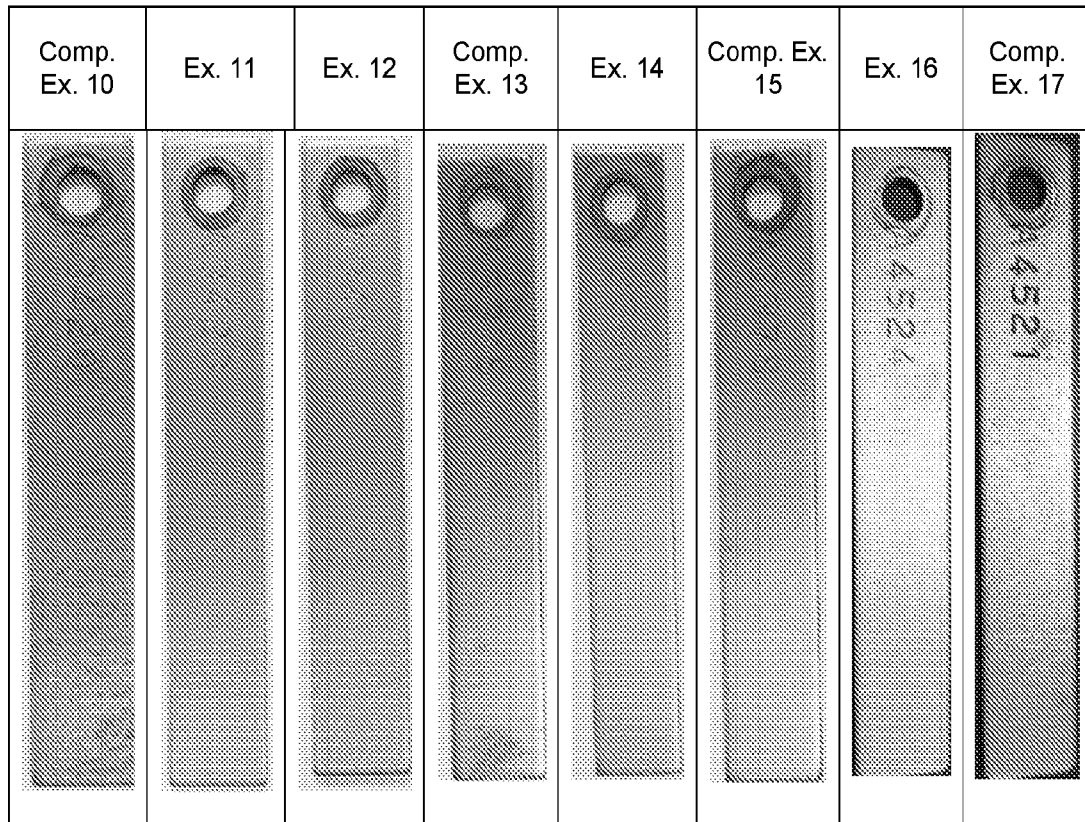


FIG. 3

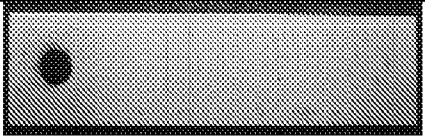
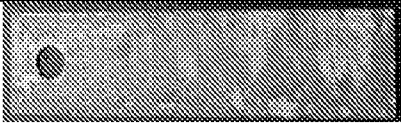
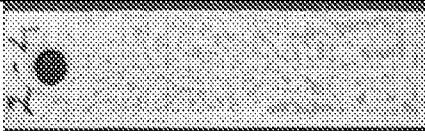
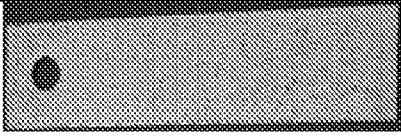
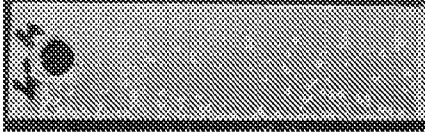
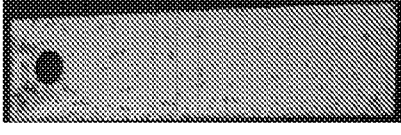
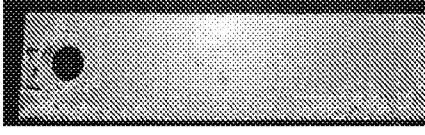

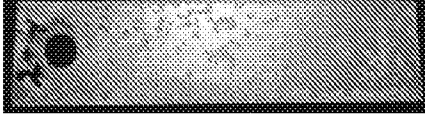

|                              | Galvanized Coupon   |  |
|------------------------------|---|--|
| Test                         | Before Cleaning   | After cleaning   |
| Comp. Ex. 22<br>No Inhibitor |    |    |
| Comp. Ex. 23                 |    |    |
| Example 24                   |  |  |
| Example 25                   |  |  |
| Example 26                   |  |  |

FIG. 4

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US17/24885

## A. CLASSIFICATION OF SUBJECT MATTER

IPC - C23F 11/10, 11/12, 11/14, 11/167, 11/18, C02F 5/04, 5/14 (2017.01)

CPC - C23F 11/10, 11/12, 11/124, 11/14, 11/167, 11/1676, 11/18, C02F 5/04, 5/14

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History document

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages  | Relevant to claim No.               |
|-----------|---|-------------------------------------|
| X         | US 2015/0118103 A1 (ERICKSON, DL et al.) 30 April 2015; paragraphs [0004]-[0009], [0024], [0038], [0042]-[0043], [0045], [0048]-[0049], [0053], [0062], [0064], [0082]  | 1-3, 7, 12, 16<br>----              |
| Y         |   | 4-6, 8-11, 13-15, 18-43             |
| Y         | US 5,294,371 A (CLUBLEY, BG et al.) 15 March 1994; ; column 1, lines 55-68 ; column 2, lines 1-11, 40-48; column 3, lines 41-51; column 4, lines 41-54; column 6, line 61 – column 7, line 5; column 8, lines 65-68 | 1, 6, 9, 11, 14-15, 17-23,<br>25-43 |
| Y         | US 6,585,933 B1 (EHRHARDT, WC et al.) 01 July 2003; column 17, lines 32-40; column 18, lines 19-23  | 9-10, 17, 39                        |
| Y         | CN 103710712 A (XI AN BOSSIN METAL TECHNOLOGY CO LTD) 09 April 2014; abstract   | 8, 11, 24                           |
| Y         | CN 102718333 A (SHANDONG TIANQING TECHNOLOGY DEV CO LTD) 11 July 2012; abstract; claim 1  | 23-24                               |
| A         | US 6,572,789 B1 (YANG, B et al.) 03 June 2003; entire document  | 1-43                                |
| A         | US 5,531,934 A (FREEMAN, MB et al.) 02 July 1996; entire document   | 1-43                                |
| A         | US 5,523,023 A (KLEINSTUCK, R et al.) 04 June 1996; entire document   | 1-43                                |

 Further documents are listed in the continuation of Box C. See patent family annex.

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"&amp;" document member of the same patent family

Date of the actual completion of the international search

31 May 2017 (31.05.2017)

Date of mailing of the international search report

14 JUL 2017

Name and mailing address of the ISA/

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