

Title of the Invention:-

Additive and method for removal of calcium from crude oils containing calcium naphthenate.

Field of the Invention:-

5 The present invention relates to an additive and method for removal of calcium from crude oils or blends thereof containing calcium naphthenate, wherein the additive is effective to remove the calcium not only at low pH but also at high pH of the wash water or the wash water for the desalter used in the crude oil processing systems.

10 In particular, the present invention relates to an additive and method for removal of calcium from crude oils or blends thereof containing calcium naphthenate, wherein the additive is effective to remove the calcium at low pH as well as at high pH varying from about 5 to 11 pH, particularly varying from about 5 to about 9 pH, more particularly varying from about 7 to about 9 pH of the wash water or the wash water for the desalter used in the crude oil processing systems.

15 **Background of the Invention:-**

20 The DOBA is a high acid crude oil originating from the Chad region of West Africa. The DOBA is known to contain calcium naphthenate and the amount of calcium naphthenate varies over a range from about 150 to about 700 ppm. In a typically supplied DOBA crude oil, the amount of calcium naphthenate may vary from about 250 – about 300 ppm.

 The DOBA is a heavy high acid crude oil with Total Acid Number [TAN] ranging upwards of 4.0 mg KOH/gm of sample and the API gravity is about 19. The sulfur content in DOBA is very low to nil.

25 The DOBA is typically a crude oil with a lot of residue in it and for proper blending, typically internationally, refiners blend it with very light crude oil or condensates to increase the API of the resulted blend to more than 30. Such blending with light crude oil or condensates helps to create sufficient light ends to help achieve product yields for the crude distillation unit. The most of light crude oil or condensates thus selected generally have very little to nil sulfur contents, which means the overall sulfur content still remains very low.
30 Further, the hydrogen sulfide (H₂S) being oil soluble is not present in relatively higher quantities in these types of blends.

 The pH of the wash water for desalter is generally adjusted by addition of or due to presence of alkaline medium, selected from the group comprising sodium hydroxide (NaOH or caustic), ammonia or amine compound, or mixture thereof. The pH of the wash water

(before mixing with crude oil) or of the wash water in the desalter generally varies from 5 to 11 pH, preferably from 5 to 9 pH, more preferably from 6 to 9 pH, even more preferably from 7 to 9 pH.

The inventor of present invention has observed that if solution of calcium naphthenate in an organic solvent, for example toluene having concentration of Ca of about 2247 ppm is treated with equal weight of water by heating to about 130 degree C in a Parr autoclave under autogenous pressure, and separated into organic and aqueous layers in a separating funnel, no black layer is formed at the interface in presence of water. When organic layer, as separated, was dried by evaporating toluene, its acid value was found to be very low of about 48.36 (mg KOH per gm). The low Acid Value indicates that calcium naphthenate does not hydrolyze appreciably merely in presence of water.

The inventor of present invention has further observed that when DOBA or its blend containing calcium naphthenate is treated with additives as known in the art, for example with glycolic acid, malic acid, citric acid, maleic anhydride, benzaldehyde (aromatic aldehyde) and glutaraldehyde (aliphatic di-aldehyde) it does not hamper removal of metals including calcium from such DOBA crude oil or its blend at low pH, i.e. at the pH after addition of the selected additive in the wash water, but without adjusting it with addition of alkaline medium.

The inventor has, experimentally, found that the efficiency of glycolic acid to remove calcium from crude oils containing calcium naphthenate is low, i.e. 79.3% at the pH of about 2.52 of the wash water containing the glycolic acid, which, surprisingly and unexpectedly, substantially reduces further to about 23.7% to 21%, to about 52.3% to 36.5%, to about 56.30% to 51.9% if the pH of the wash water or wash water in the desalter is increased to 5 or above 5 to 9 respectively due to the presence of sodium hydroxide, ammonia and monoethanolamine (MEA) in the wash water or wash water in the desalter.

The inventor has, experimentally, also found that the efficiency of malic acid to remove calcium from crude oils containing calcium naphthenate is low, i.e. 83.6% at the pH of about 2.3 of the wash water containing the malic acid, which, surprisingly and unexpectedly, substantially reduces further to about 24.3% to 15%, to about 54.2% to 45.7%, to about 73.4% to 61.9% if the pH of the wash water or wash water in the desalter is increased to 5 or above 5 to 9 respectively due to the presence of sodium hydroxide, ammonia and monoethanolamine in the wash water or wash water in the desalter.

The inventor has, experimentally, also found that the efficiency of citric acid to remove calcium from crude oils containing calcium naphthenate is low, i.e. 78.2% at the pH

of about 2 to 3 of the wash water containing the citric acid, which, surprisingly and unexpectedly, substantially reduces further to about 42.3% to 17%, to about 60.4% to 56.3% if the pH of the wash water or wash water in the desalter is increased to 5 or above 5 to 9 respectively due to the presence of sodium hydroxide and ammonia in the wash water or wash water in the desalter.

Furthermore, the inventor has observed that when malic acid or citric acid is employed, they form precipitates, and hence, their use also suffer from problems of fouling of the equipments.

The inventor has, experimentally, also found that the efficiency of maleic anhydride to remove calcium from crude oils containing calcium naphthenate is low, i.e. 83.5% at the pH of about 2 to 3 of the wash water containing the maleic anhydride, which, surprisingly and unexpectedly, substantially reduces further to about 43.9% to 15%, to about 53.0% to 41.3%, to about 73.3% to 51.4% if the pH of the wash water or wash water in the desalter is increased to 5 or above 5 to 9 respectively due to the presence of sodium hydroxide, ammonia and monoethanolamine in the wash water or wash water in the desalter.

The inventor has, experimentally, also found that the efficiency of benzaldehyde to remove calcium from crude oils containing calcium naphthenate is very low, i.e. 20.3% at the pH of about 3.4 of the wash water containing the benzaldehyde, which, itself being very low, no further experiments were conducted to see effect of alkaline media generally present in the wash water.

The inventor has, experimentally, also found that the efficiency of glutaraldehyde to remove calcium from crude oils containing calcium naphthenate is very low, i.e. 35.9% at the pH of about 4.2 of the wash water containing the glutaraldehyde, which, itself being very low, no further experiments were conducted to see effect of alkaline media generally present in the wash water.

Accordingly, the industry processing DOBA or its blends containing calcium naphthenate faces serious problems in removing calcium from such oils or their blends, particularly when pH of wash water for desalter or of the wash water in the desalter varies between about 5 to about 11, particularly varies between about 6 to about 11, more particularly varies between about 7 to about 9.

Problem to be solved by the Invention:

It is understood from the foregoing description that the prior art additives, which may be effective to remove calcium from DOBA crude oil containing calcium naphthenate at low pH, i.e. at the pH after addition of said additive in the wash water, but without

addition of alkaline medium, but their efficiency to remove calcium, surprisingly and unexpectedly, substantially reduces further, if the pH of the wash water or wash water in the desalter is increased to 5 or above 5 due to the presence of alkaline medium, selected from the group comprising sodium hydroxide (NaOH or caustic), ammonia or amine compound, or mixture thereof.

Therefore, the problem to be solved by present invention is to provide an additive and method for removal of calcium from crude oils or their blends containing calcium naphthenate, which should be effective to remove the calcium from crude oil or its blends not only at low pH, i.e. at the pH after addition of said additive in the wash water without addition of alkaline medium, but also at high pH of the wash water for the desalter used in the crude oil processing system, particularly when pH of wash water for desalter or of the wash water in the desalter varies between about 5 to about 11, particularly varies between about 6 to about 11, more particularly varies between about 7 to about 9.

Need of the Invention:

The mechanism of further reduced efficiency of prior art additives - glycolic acid, malic acid, citric acid, maleic anhydride, benzaldehyde and glutaraldehyde to remove calcium from crude oil containing calcium naphthenate at pH of about 5 or more, particularly at pH of about 5 to 11, more particularly at pH of about 6 to 11, even more particularly at pH of about 7 to 9 could not be visualized at present.

However, the problem to remove calcium from crude oil or its blends containing calcium naphthenate at low pH, i.e. at the pH after addition of the additive in the wash water without addition of alkaline medium as well as at high pH of about 5 or more still remains unresolved, particularly for a situation when pH of wash water for desalter varies between 6 to 11, more particularly varies between 7 to 9.

Therefore, there is a need to have an additive and method for removal of calcium from crude oils or its blends containing calcium naphthenate which is effective in removing the calcium not only at low pH, i.e. at the pH after addition of the additive in the wash water without addition of alkaline medium but also at high pH of about 5 or more of the wash water for the desalter used in the crude oil processing system, particularly under a situation when pH of wash water for desalter varies between 6 to 11, more particularly varies between 7 to 9.

Objects and Advantages of the Invention:-

Accordingly, the main object of the present invention is to provide an additive and method of its use which is effective for removal of calcium from crude oils or its blends

containing calcium naphthenate not only at low pH, i.e. at the pH after addition of the additive in the wash water without addition of alkaline medium but also at high pH of about 5 or more of the wash water for the desalter used in the crude oil processing system particularly under a situation when pH of wash water for desalter varies between 6 to 11, more particularly varies between 7 to 9.

Another object of the present invention is to provide an additive and method of its use which is effective for removal of calcium from crude oils or its blends containing calcium naphthenate at low pH, i.e. at the pH after addition of the additive in the wash water without addition of alkaline medium but also at high pH of about 5 or more of the wash water for the desalter used in the crude oil processing system particularly under a situation when pH of wash water for desalter varies between 6 to 11, more particularly varies between 7 to 9, wherein said high pH of 5 or more of wash water of desalter is due to presence of alkaline medium, selected from the group comprising sodium hydroxide (NaOH or caustic), ammonia or amine compound, or mixture thereof.

Still another object of the present invention is to provide a method for removal of calcium from crude oils or its blends containing calcium naphthenate at low pH, i.e. at the pH after addition of the additive in the wash water without addition of alkaline medium but also at high pH of about 5 or more of the wash water for the desalter used in the crude oil processing system particularly under a situation when pH of wash water for desalter varies between 6 to 11, more particularly varies between 7 to 9, wherein said high pH of 5 or more of wash water of desalter is due to presence of alkaline medium, selected from the group comprising sodium hydroxide (NaOH or caustic), ammonia or amine compound, or mixture thereof.

Other objects and advantages of the present invention will become more apparent when the following description is read in conjunction with following examples, which are not intended to limit the scope of present invention.

Description and Preferred Embodiments of the Invention:-

With aim to solve above-described industrial problem of the prior art, the inventor of present invention has found that when glyoxal is employed as an additive in processing of crude oils or its blends containing calcium naphthenate in presence of water, it not only removes the calcium from the crude oil or its blends at low pH, i.e. at the pH after addition of glyoxal additive in the wash water without addition of alkaline medium but, surprisingly and unexpectedly, it effectively also removes calcium from the crude oil or its blends at high pH of about 5 or more of the wash water for the desalter or at high pH of about 5 or

more of the desalter, and that's too without causing any problem including precipitations, and hence without causing fouling in the processing system.

Accordingly, the present invention relates to an additive capable of removing calcium from crude oil or its blends containing calcium naphthenate at low pH of about 3.5
5 +/- 0.5 as well as at high pH of about 5 or more of the wash water or wash water for the desalter used in the crude oil processing systems, characterized in that the additive is glyoxal.

It may be noted that the "low pH" as referred herein is the pH after addition of glyoxal additive in the wash water and without addition of alkaline medium (i.e. in absence
10 of alkaline medium). It has been observed that when about 0.488 gm of glyoxal is dissolved in about 75 gm of demineralized (DM) water its pH is about 3.5. Accordingly, depending upon concentration of glyoxal in the water (or wash water), its pH may vary from about 3 to about 4.

Therefore, as per present invention, the "low pH" has been referred as pH of about
15 3.5 +/- 0.5, as it is intended to include the pH of about 3 to about 4, which is the pH of solution of glyoxal in wash water at various concentrations of glyoxal.

It may also be noted that the "high pH" as referred herein is intended to include the pH which may be arrived at after addition of or due to presence of alkaline medium (or basic solution), selected from the group comprising sodium hydroxide (NaOH or caustic),
20 ammonia or amine compound, or mixture thereof. It has been observed that after addition of or due to presence of the alkaline medium (or basic solution) in the wash water, the pH of wash water increases to about 5 or more, and it generally varies between about 5 to about 11, particularly varies between about 6 to about 11, more particularly varies between about 7 to about 9 depending upon amount of the alkaline medium (or concentration of the basic
25 solution) added or present in the wash water.

Therefore, as per present invention, the "high pH" of wash water or wash water for the desalter used in the crude oil processing systems is intended to include wash water having pH of about 5 or more, particularly wash water having pH varying between about 6 to about 11, more particularly wash water having pH varying between about 7 to about 9,
30 wherein said "high pH" of wash water is due to addition or presence of alkaline medium (or basic solution), selected from the group comprising sodium hydroxide (NaOH or caustic), ammonia or amine compound, or mixture thereof in the wash water.

Accordingly, the present invention relates to an additive capable of removing calcium from crude oil or its blends containing calcium naphthenate at low pH of about 3 to

about 4, and also at high pH of about 5 or more, particularly at pH varying between about 6 to about 11, more particularly at pH varying between about 7 to about 9 of the wash water used in the crude oil processing systems, characterized in that the additive is glyoxal.

In another embodiment, the present invention relates to a method for removing
5 calcium from crude oil or its blends containing calcium naphthenate not only at low pH of about 3 to about 4, but also at high pH of about 5 or more, particularly at pH varying between about 6 to about 11, more particularly at pH varying between about 7 to about 9 of the wash water used in the crude oil processing system, characterized in that the crude oil or its blends containing calcium naphthenate is treated with an additive, and the additive is
10 glyoxal.

In yet another embodiment, the present invention relates to use of glyoxal for removal of calcium from crude oil or its blends containing calcium naphthenate not only at low pH of about 3 to about 4, but also at high pH of about 5 or more, particularly at pH varying between about 6 to about 11, more particularly at pH varying between about 7 to
15 about 9 of the wash water used in the crude oil processing system, characterized in that crude oil or its blends containing calcium naphthenate is treated with glyoxal.

In accordance with present invention the said high pH of wash water is due to addition or presence of alkaline medium, selected from the group comprising sodium hydroxide (NaOH or caustic), ammonia or amine compound, or mixture thereof in the wash
20 water for the desalter.

Accordingly, in accordance with present invention, the pH of the wash water for the desalter varies from about 5 to about 11 pH, particularly from about 6 to 11, more particularly from about 7 to about 11 pH.

In accordance with present invention, the additive of present invention is effective
25 particularly when pH of wash water for desalter is above 6, more particularly when pH of wash water for desalter varies between 7 to 9.

Accordingly, the present invention relates to an additive capable of removing calcium from crude oil or its blends containing calcium naphthenate not only at low pH of about 3 to about 4, but also at high pH of about 5 or more, particularly at pH varying
30 between about 6 to about 11, more particularly at pH varying between about 7 to about 9 of the wash water for the desalter used in the crude oil processing system, characterized in that the additive is glyoxal, wherein said high pH of wash water is due to addition or presence of alkaline medium, wherein the alkaline medium is selected from the group comprising

sodium hydroxide (NaOH or caustic), ammonia or amine compound, or mixture thereof in the wash water for the desalter.

In another embodiment, the present invention also relates to a method for removing calcium from crude oil or its blends containing calcium naphthenate not only at low pH of about 3 to about 4, but also at high pH of about 5 or more, particularly at pH varying between about 6 to about 11, more particularly at pH varying between about 7 to about 9 of the wash water for the desalter used in the crude oil processing system, characterized in that the crude oil or its blends containing calcium naphthenate is treated with glyoxal, wherein said high pH of wash water is due to addition or presence of alkaline medium, wherein the alkaline medium is selected from the group comprising sodium hydroxide (NaOH or caustic), ammonia or amine compound, or mixture thereof in the wash water for the desalter.

In yet another embodiment, the present invention also relates to use of glyoxal for removal of calcium from crude oil or its blends containing calcium naphthenate not only at low pH of about 3 to about 4, but also at high pH of about 5 or more, particularly at pH varying between about 6 to about 11, more particularly at pH varying between about 7 to about 9 of the wash water for the desalter used in the crude oil processing system, characterized in that crude oil or its blends containing calcium naphthenate is treated with glyoxal, wherein said high pH of wash water is due to addition or presence of alkaline medium, wherein the alkaline medium is selected from the group comprising sodium hydroxide (NaOH or caustic), ammonia or amine compound, or mixture thereof in the wash water for the desalter.

In accordance with one of the preferred embodiments of the present invention, the alkaline medium is preferably used as its aqueous solution.

In accordance with one of the preferred embodiments of the present invention, the glyoxal additive is added in the wash water tank in a mole ratio of additive to calcium concentration varying from about 1:0.9 to 1:4, preferably about 1:2.

In accordance with one of the preferred embodiments of the present invention, the crude oil and the glyoxal additive are reacted preferably at a temperature of about 80°C to 160°C.

In accordance with one of the preferred embodiments of the present invention, the glyoxal additive is identifiable by cas no. 107-22-2.

In one of the preferred embodiments, the present invention relates to an additive for removing calcium from crude oil or its blends containing calcium naphthenate in presence

of alkaline medium or basic solution at high pH of about 5 or above, particularly at pH varying from about 6 to about 11, more particularly at pH varying from about 7 to about 9, wherein

the additive is glyoxal;

5 the basic solution is preferably selected from the group comprising aqueous solution of sodium hydroxide, ammonia, monoethanolamine, or mixture thereof;

said pH of about 5 or above, preferably of about 6 to about 11 is of the wash water for the desalter used in the crude oil processing system;

10 the additive is added in the wash water tank in a mole ratio of additive to calcium concentration varying from about 1:0.9 to 1:4, preferably about 1:2.

In one of the another preferred embodiments, the present invention relates to a method for removing calcium from crude oil or its blends containing calcium naphthenate in presence of alkaline medium or basic solution at high pH of about 5 or above, particularly at pH varying from about 6 to about 11, more particularly at pH varying from about 7 to about 9, wherein

15 the crude oil or its blends containing calcium naphthenate is treated with an additive; the additive is glyoxal;

the basic solution is preferably selected from the group comprising aqueous solution of sodium hydroxide, ammonia, monoethanolamine, or mixture thereof;

20 said pH of about 5 or above, preferably of about 6 to about 11 is of the wash water for the desalter used in the crude oil processing system;

the additive is added in the wash water tank in a mole ratio of additive to calcium concentration varying from about 1:0.9 to 1:4, preferably about 1:2;

25 the crude oil and the additive are reacted preferably at a temperature of about 80 to 160°C.

It may be noted that the calcium concentration referred herein is based on concentration of calcium naphthenate present in crude oil to be treated.

In accordance with present invention, the glyoxal additive is used alone and not with an acid.

30 In accordance with present invention, the wash water is used in the desalter of crude oil processing systems.

In accordance with present invention, the calcium removal from crude oil or blends thereof includes removal of calcium from oil or its blends in oil production units comprising electrostatic separators or precipitators.

Generally, in the crude oil processing plants, the wash water is accumulated in a tank, and its pH is about 5 or above, preferably between about 6 to about 11, more preferably between about 7 to about 9, and such high pH is, generally, due to presence of basic solution, including sodium hydroxide, ammonia, nitrogen compounds, or amines, or mixtures thereof. In accordance with present invention, the present additive is added to this wash water having pH about 5 or above, preferably between 6 to about 11, more preferably between about 7 to about 9 before it enters the desalter. Upon addition of present additive – glyoxal, the pH of wash water goes down preferably by about 1 to 2 pH depending upon the amount of glyoxal added. It may be noted that in accordance with present invention, the present additive – glyoxal, is added alone and not with an acid to reduce the pH of wash water. The wash water after addition of present additive is allowed to enter the desalter of the plant where present additive (already added in wash water) reacts with calcium naphthenate and causes removal of the calcium therefrom. The pH in desalter is generally between about 6 to 11, preferably between about 6 to about 9. It has been observed that even if pH of desalter is about 7 or above, no additional acid is required to reduce the pH when present additive is used to remove the calcium from calcium naphthenate in crude oil or mixture thereof, because the present additive has been advantageously found to be substantially effective even if pH of desalter increases to 7 or above including pH of 9 to 11. No additional acid is also required to reduce the pH of wash water when present additive is used to remove the calcium from calcium naphthenate in crude oil or mixture thereof, because the present additive has been advantageously found to be substantially effective even if pH of mixture in the desalter after addition of wash water increases to 7 or above including pH of 9 to 11. Therefore, the present additive and the method employing it will neither require excess amount of present additive nor the additional acid, and hence, the process for removing calcium from crude oil employing present additive will not be expensive, and hence, is commercially viable.

It may be noted that during the reaction of present additive with calcium naphthenate in the desalter, a care is taken that pH in desalter does not go lower than 5 to avoid acid corrosion.

It may also be noted that the calcium removal from crude oil as referred herein includes removal of calcium from oil or its blends in the oil production units comprising electrostatic separators or precipitators.

Accordingly, it can be concluded that the prior art additives – glycolic acid, malic acid, citric acid, maleic anhydride, benzaldehyde and glutaraldehyde do not have required efficiency to remove calcium from calcium naphthenate in the crude oil or mixtures thereof, particularly when wash water also contains alkaline medium or basic solution, i.e. has pH of 5 or above, preferably pH varies between 6 to 11, more preferably pH varies between 7 to 9, and/or when pH of desalter is above 6, however, the present additive – glyoxal has been, surprisingly and unexpectedly, found to have substantially high efficiency to remove calcium from calcium naphthenate in the crude oil or mixtures thereof as compared to the prior art additives, particularly when wash water also contains alkaline medium or basic solution, i.e. has pH of 5 or above, preferably pH varies between 6 to 11, more preferably pH varies between 7 to 9, and/or when pH of desalter is above 6 even for shorter period of treatment in the desalter without causing any disadvantages including precipitation or fouling during the processing of crude oils.

It may be noted that pH in the desalter may increase to 7 or above depending upon the concentration of the alkaline medium or basic solution in the wash water. However, the present additive has been found to be effective even if pH in the desalter is between 5 to 11.

The present invention is now explained with the help of following experimental studies conducted by the inventor, which have been incorporated for explaining its best mode and are not intended to limit its scope.

Examples of the Invention:-

In following experimental studies, each additive – glyoxal (additive of present invention), glycolic acid, malic acid, citric acid, maleic anhydride, benzaldehyde and glutaraldehyde (additives of prior art) was individually charged with calcium naphthenate (Ca-naphthenate) solution in toluene into a stainless steel autoclave and reacted at 130°C.

In accordance with one of the embodiments, the solution of Ca-Napthenate was prepared in toluene followed by addition of selected additive and ultra pure water [demineralized (DM) water] without pH adjustment and with pH adjustment. The individual resulted solutions were heated to 130°C for 10 minutes followed by cooling to room temperature. The individual resulted reacted solution was poured into a separating funnel and shaken. The two separated layers were formed with top layer being the hydrocarbonaceous layer and the bottom layer being the aqueous layer. The top layer was analyzed for calcium (Ca) content using Inductive Coupled Plasma [ICP], and the dried sample from top layer was also analyzed for its Acid Value.

As per preferred method of experimental studies, about 75 grams of Ca-naphthenate in toluene having an amount of Ca of 2247 ppm in the hydrocarbon layer, and about 75 grams of DM water having amount of selected additive as per Tables, wherein amount of selected additive is expressed in its 100% active form. The mixtures were reacted for 10 mins, 20 mins and 30 mins. The pH of the solutions of additives and wash water were adjusted to 5, 6, 7, 8 and/or 9 by addition of alkaline medium selected from sodium hydroxide (NaOH), ammonia and monoethanolamine (MEA).

The Calcium removing efficiency for present additive and prior art additives without adjustment of pH after treatment for 10 mins was found to be:

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Additive	pH of solution in DM		% Efficiency for removal of Ca
	Water		
Glyoxal	3.5		99.9
Glycolic Acid	2.5		79.3
Malic Acid	2.3		83.6
Citric Acid	2.4		78.2
Maleic Anhydride	2.5		83.5
Benzaldehyde	3.4		20.3
Glutaraldehyde	4.2		35.9

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The above data confirms that present glyoxal additive has better efficiency to remove calcium from crude oils containing calcium naphthenate than the prior art additives. It is observed that additives benzaldehyde and glutaraldehyde, being aldehydes have very poor efficiency to remove calcium from crude oils containing calcium naphthenate. On the contrary, present glyoxal additive also being an aldehyde has far better efficiency to remove calcium from crude oils containing calcium naphthenate.

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In following Experiment Nos. 1 to 25, the pH of solution of additive in DM water was adjusted to pH 9, 8, 7, 6, and 5 by using sodium hydroxide, and in Experiment Nos. 26 to 50, the pH of solution of additive in DM water was adjusted to pH 9, 8, 7, 6, and 5 by using ammonia, and in Experiment Nos. 51 to 66, the pH of solution of additive in DM water was adjusted to pH 9, 7, 6, and 5 by using monoethanolamine (MEA) to simulate with a condition of wash water in crude oil processing plant, and the %Efficiency for removal of calcium has been given for treatment durations of 10 mins, 20 mins and 30 mins.

As %efficiency of present glyoxal additive in removing Ca was more than 99%, further experiments for treatment for 20 and 30 minutes were not performed for without adjustment of pH.

From the following Tables, it can be observed that the Ca content in the top layer is, surprisingly and unexpectedly, much lower for the layer obtained after treatment with additive of present invention as compared to the top layers obtained after treatment with prior art additives indicating better efficiency of present additive to remove calcium from crude oils or its blends containing calcium naphthenate.

The Acid Value of the dried sample obtained from the top layer after treatment with additive of present invention is higher than that of the dried samples obtained from the top layers after treatment with additives of prior art.

These experiments confirm that additive of present invention has much better efficiency to remove Ca from crude oil (or its blends) containing Ca-naphthenate even at low pH just after treatment of 10 mins (see above results for without adjustment of pH), and at high pH after treatment of about 10, 20 and 30 minutes [see following Tables 1 to 5 for sodium hydroxide, Tables 6 to 10 for ammonia and Tables 11 to 14 for monoethanolamine (MEA)], wherein the pH was adjusted to 5, 6, 7, 8 and 9.

It has been found that glyoxal and other prior art additives, i.e. glycolic acid, malic acid, citric acid, maleic anhydride, benzaldehyde and glutaraldehyde are effective in removing Ca from Ca-naphthenate (CaNaph) in crude oils at low pH of about 3 +/- 1.7, however, the efficiency of glyoxal is, surprisingly and unexpectedly, very high as compared to prior art additives, i.e. it is 99.9% for glyoxal against 79.3% for glycolic acid, 83.6% for malic acid, 78.20% for citric acid, 83.50% for maleic anhydride, 20.3% for benzaldehyde and 35.9% for glutaraldehyde.

The inventor has further found that the efficiency of all additives drops from their respective efficiency at low pH of about 3.0 +/- 1.7 on increase of pH of wash water to about 11, preferably to about 9, due to presence of basic medium or alkaline medium including NaOH, ammonia or amine in the wash water (Tables 15, 16 and 17).

However, the drop in efficiency of glyoxal is, surprisingly and unexpectedly, substantially very low as compared to drop in efficiency of prior art additives, i.e.

at pH 9 in presence of NaOH after 30 mins, the efficiency of glyoxal for removal of calcium drops from 99.9% to 88.0%, however, the efficiency of glycolic acid drops from 79.3% to 21.0%, and the efficiency of malic acid drops from 83.6% to 15.7%, and the

efficiency of citric acid drops from 78.20% to 17.0%, and the efficiency of maleic anhydride drops from 83.5% to 15.0%.

Similarly, at pH 8 in presence of NaOH after 30 mins, the efficiency of glyoxal for removal of calcium drops from 99.9% to 86.4%, however, the efficiency of glycolic acid drops from 79.3% to 21.5%, and the efficiency of malic acid drops from 83.6% to 17.2%
5 and the efficiency of citric acid drops from 78.20% to 17.9%, and the efficiency of maleic anhydride drops from 83.5% to 15.2%.

Similarly, at pH 7 in presence of NaOH after 30 mins, the efficiency of glyoxal for removal of calcium drops from 99.9% to 88.7%, however, the efficiency of glycolic acid drops from 79.3% to 21.7%, the efficiency of malic acid drops from 83.6% to 15.4%, and
10 the efficiency of citric acid drops from 78.20% to 18.1%, and the efficiency of maleic anhydride drops from 83.5% to 17.2%.

Similarly, at pH 6 in presence of NaOH after 30 mins, the efficiency of glyoxal for removal of calcium drops from 99.9% to 86.4%, however, the efficiency of glycolic acid drops from 79.3% to 22.5%, the efficiency of malic acid drops from 83.6% to 15.0%
15 and the efficiency of citric acid drops from 78.20% to 20.8%, and the efficiency of maleic anhydride drops from 83.5% to 30.8%.

Similarly, at pH 5 in presence of NaOH after 30 mins, the efficiency of glyoxal for removal of calcium drops from 99.9% to 87.1%, however, the efficiency of glycolic acid drops from 79.3% to 23.7%, the efficiency of malic acid drops from 83.6% to 24.3%
20 and the efficiency of citric acid drops from 78.20% to 42.3%, and the efficiency of maleic anhydride drops from 83.5% to 43.9%.

Similarly, at pH 9 in presence of ammonia after 30 mins, the efficiency of glyoxal for removal of calcium drops from 99.9% to 88.0%; however, the efficiency of glycolic acid drops from 79.3% to 36.5%; the efficiency of malic acid drops from 83.6% to 45.7%, and
25 the efficiency of citric acid drops from 78.20% to 56.3%, and the efficiency of maleic anhydride drops from 83.5% to 41.3%.

Similarly, at pH 8 in presence of ammonia after 30 mins, the efficiency of glyoxal for removal of calcium drops from 99.9% to 91.7%; however, the efficiency of glycolic acid drops from 79.3% to 37.7%; the efficiency of malic acid drops from 83.6% to 48.8%, and
30 the efficiency of citric acid drops from 78.20% to 58.9%, and the efficiency of maleic anhydride drops from 83.5% to 42.2%.

Similarly, at pH 7 in presence of ammonia after 30 mins, the efficiency of glyoxal for removal of calcium drops from 99.9% to 96.7%; however, the efficiency of glycolic acid

drops from 79.3% to 37.7%; the efficiency of malic acid drops from 83.6% to 48.2%, and the efficiency of citric acid drops from 78.20% to 59.0%, and the efficiency of maleic anhydride drops from 83.5% to 43.0%.

Similarly, at pH 6 in presence of ammonia after 30 mins, the efficiency of glyoxal
5 for removal of calcium drops from 99.9% to 98.8%; however, the efficiency of glycolic acid drops from 79.3% to 46.8%; the efficiency of malic acid drops from 83.6% to 47.9%, and the efficiency of citric acid drops from 78.20% to 59.2%, and the efficiency of maleic anhydride drops from 83.5% to 47.9%.

Similarly, at pH 5 in presence of ammonia after 30 mins, the efficiency of glyoxal
10 for removal of calcium drops from 99.9% to 99.3%; however, the efficiency of glycolic acid drops from 79.3% to 52.3%; the efficiency of malic acid drops from 83.6% to 54.2%, and the efficiency of citric acid drops from 78.20% to 60.4%, and the efficiency of maleic anhydride drops from 83.5% to 53.0%.

Similarly, at pH 9 in presence of monoethanolamine (MEA) after 30 mins, the
15 efficiency of glyoxal for removal of calcium drops from 99.9% to 80.0%; however, the efficiency of glycolic acid drops from 79.3% to 51.9%; the efficiency of malic acid drops from 83.6% to 61.9%, and the efficiency of maleic anhydride drops from 83.5% to 51.4%.

Similarly, at pH 7 in presence of monoethanolamine (MEA) after 30 mins, the
20 efficiency of glyoxal for removal of calcium drops from 99.9% to 84.4%; however, the efficiency of glycolic acid drops from 79.3% to 55.6%; the efficiency of malic acid drops from 83.6% to 68.3%, and the efficiency of maleic anhydride drops from 83.5% to 56.2%.

Similarly, at pH 6 in presence of monoethanolamine (MEA) after 30 mins, the
25 efficiency of glyoxal for removal of calcium drops from 99.9% to 88.6%; however, the efficiency of glycolic acid drops from 79.3% to 53.7%; the efficiency of malic acid drops from 83.6% to 66.2%, and the efficiency of maleic anhydride drops from 83.5% to 60.5%.

Similarly, at pH 5 in presence of monoethanolamine (MEA) after 30 mins, the
efficiency of glyoxal for removal of calcium drops from 99.9% to 90.0%; however, the
efficiency of glycolic acid drops from 79.3% to 56.3%; the efficiency of malic acid drops
from 83.6% to 73.4%, and the efficiency of maleic anhydride drops from 83.5% to 73.3%.

30 Therefore, the glyoxal has surprising and unexpected technical effects in removing the Ca from CaNaph in crude oils not only at low pH of about 3.0 +/- 1.7, but also at high pH varying from 5 to 11, preferably varying from 5 to 9, more preferably varying from 6 to 9, even more preferably varying from 7 to 9 in presence of basic medium including NaOH, amine or ammonia, and hence, overcomes the problems of prior art by providing a technical

solution in removing Ca from CaNaph in crude oils even in presence of basic medium or alkaline medium or at pH varying from 5 to 11, preferably varying from 5 to 9, more preferably varying from 6 to 9, even more preferably varying from 7 to 9.

It may be noted that the %drop in efficiency of glyoxal for removal of calcium is just about 11.9 to 13.5%, however, the %drop in efficiency of glycolic acid for removal of calcium is substantially very high of the range of about 70.11 to 73.52%, the %drop in efficiency of malic acid for removal of calcium is substantially very high of the range of about 70.93 to 81.58%, the %drop in efficiency of citric acid for removal of calcium is substantially very high of the range of about 73.4 to 78.26% for pH from 6 to 9, and about 45.91% for pH 5, and the %drop in efficiency of maleic anhydride for removal of calcium is substantially very high of the range of about 63.11 to 82.04% for pH from 6 to 9, and about 47.43% for pH 5 in presence of sodium hydroxide.

It may also be noted that the %drop in efficiency of glyoxal for removal of calcium is just about 0.6 to 11.9%, however, the %drop in efficiency of glycolic acid for removal of calcium is very high of the range of about 34.05 to 53.97%, the %drop in efficiency of malic acid for removal of calcium is very high of the range of about 35.17 to 45.33%, the %drop in efficiency of citric acid for removal of calcium is very high of the range of about 22.76 to 28.01%, and the %drop in efficiency of maleic anhydride for removal of calcium is very high of the range of about 36.53 to 50.54% in presence of ammonia.

It may also be noted that the %drop in efficiency of glyoxal for removal of calcium is just about 9.91 to 19.92%, however, the %drop in efficiency of glycolic acid for removal of calcium is high in the range of about 29 to 34.55%, the %drop in efficiency of malic acid for removal of calcium is high in the range of about 12.2 to 25.96%, and the %drop in efficiency of maleic anhydride for removal of calcium is high in the range of about 12.22 to 38.44% in presence of monoethanolamine.

These unexpected findings also confirm that glyoxal has substantially very high performance as compared to prior art additive when wash water comprises sodium hydroxide, and substantially high performance when wash water comprises ammonia, and better performance when wash water comprises monoethanolamine.

Therefore, from these experimental studies, it can be concluded that glyoxal additive of present invention is far better additive than prior art additives, as the calcium removing efficiency of glyoxal, surprisingly and unexpectedly, is substantially very high.

From the above findings, it may be noted that at high pH of 5 or more, the efficiency to remove Ca is reduced for all the additives, however, the reduction in efficiency of present

additive - glyoxal is, surprisingly and unexpectedly, much lower than prior art additives. These findings confirm that glyoxal is capable of overcoming above-described problems of the prior art.

From all of above Expts., it can be concluded that present additive – glyoxal has substantially improved efficiency as compared to prior art additives - glycolic acid, malic acid, citric acid, maleic anhydride, benzaldehyde and glutaraldehyde to remove the Ca from calcium naphthenate (CaNaph) in the crude oil or its blends not only at high pH of about 5 and about 6, but also at further high pH of about 7, about 8 and about 9 of the wash water, wherein said pH is due to the presence of NaOH, ammonia, monoethanolamine or mixtures thereof, particularly due to the presence of NaOH and ammonia or mixtures thereto, more particularly due to the presence of NaOH, which, in present experiments were added to wash water till said pH of about 5, 6, 7, 8 or 9 was achieved.

It may be noted that the drop in efficiency of present additive - glyoxal is, surprisingly and unexpectedly, substantially very low at said pH of about 5, 6, 7, 8, and 9 as compared to the prior art additives, i.e. glycolic acid, malic acid, citric acid, maleic anhydride, benzaldehyde and glutaraldehyde which confirms that the present additive is far better than prior art additives even at high pH of the wash water used in crude oil processing systems.

Table - 1 (pH 9.0 adjusted by NaOH)

Expt no.	Additive	Wt. of additive (gm)	After 10 mins				After 20 mins				After 30 mins			
			Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	% Efficiency for removal of Ca
1	Glyoxal	0.488	123.3	1010	55.0	197.7	292	87.0	199.43	270	42.0	1775	88.0	21.0
2	Glycolic Acid	0.640	42.48	1795	20.1	41.49	1798	20.0	30.24	1895	35.66	1865	15.7	17.0
3	Malic Acid	0.5645	31.34	1910	15.0	29.82	1900	15.4	28.25	1910	27.86	1910	15.0	15.0
4	Citric Acid	0.539	32.5	1895	15.6	34.73	1875	16.6						
5	Maleic Anhydride	0.412	32.97	1900	15.4									

Table - 2 (pH 8.0 adjusted by NaOH)

Expt no.	Additive	Wt. of additive (gm)	After 10 mins				After 20 mins				After 30 mins			
			Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	% Efficiency for removal of Ca
6	Glyoxal	0.488	193.24	300	86.6	193.6	295	86.9	190.95	305	42.21	1765	86.4	21.5
7	Glycolic Acid	0.64	42.96	1760	21.6	42.65	1755	21.9	29.7	1860	32.09	1845	17.2	17.9
8	Malic Acid	0.5645	30.33	1880	16.3	30.4	1865	17.0	29.25	1905	27.43	1905	15.2	15.2
9	Citric Acid	0.539	31.55	1870	16.8	34.76	1850	17.7						
10	Maleic Anhydride	0.412	31.71	1860	17.2									

Table – 3 (pH 7.0 adjusted by NaOH)

Expt no.	Additive	Wt. of additive (gm)	After 10 mins				After 20 mins				After 30 mins			
			Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca
11	Glyoxal	0.488	191.25	315	86.0	195.36	280	87.5	198.59	255	88.7			
12	Glycolic Acid	0.64	30.0	1890	15.9	43.98	1765	21.5	42.87	1760	21.7			
13	Malic Acid	0.5645	34.08	1915	14.8	32.93	1905	15.2	32.93	1900	15.4			
14	Citric Acid	0.539	34.30	1905	15.2	37.43	1890	15.9	37.78	1840	18.1			
15	Maleic Anhydride	0.412	41.77	1805	19.7	35.37	1900	15.4	34.56	1860	17.2			

Table – 4 (pH 6.0 adjusted by NaOH)

Expt no.	Additive	Wt. of additive (gm)	After 10 mins				After 20 mins				After 30 mins			
			Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca
16	Glyoxal	0.488	188.5	345	84.6	188.4	320	85.6	190.25	305	86.4			
17	Glycolic Acid	0.64	43.02	1760	21.7	43.25	1750	22.1	43.4	1740	22.5			
18	Malic Acid	0.5645	32.31	1900	15.4	29.7	1915	14.8	31.07	1910	15.0			
19	Citric Acid	0.539	48.12	1810	19.5	54.78	1770	21.2	53.81	1780	20.8			
20	Maleic Anhydride	0.412	61.9	1575	30.0	61.03	1560	30.5	62.0	1555	30.8			

Table – 5 (pH 5.0 adjusted by NaOH)

Expt no.	Additive	Wt. of additive (gm)	After 10 mins				After 20 mins				After 30 mins			
			Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca
21	Glyoxal	0.488	193.9	310	86.2	191.81	300	86.6	191.54	290	87.1			
22	Glycolic Acid	0.64	49.07	1685	25.0	49.44	1705	24.1	48.3	1715	23.7			
23	Malic Acid	0.5645	59.87	1595	29.0	50.56	1695	24.6	51.0	1700	24.3			
24	Citric Acid	0.539	95.03	1280	43.0	93.48	1290	42.6	92.77	1295	42.3			
25	Maleic Anhydride	0.412	98.23	1260	43.9	89.37	1300	42.1	97.15	1260	43.9			

Table – 6 (pH 9.0 adjusted by Ammonia)

Expt no.	Additive	Wt. of additive (gm)	After 10 mins				After 20 mins				After 30 mins			
			Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca
26	Glyoxal	0.488	158.75	560	75.1	183.7	330	85.3	187.01	270	88.0			
27	Glycolic Acid	0.64	94.36	1481	34.0	96.4	1467	34.7	101.34	1429	36.5			
28	Malic Acid	0.5645	101.93	1291	42.5	105.19	1261	46.86	108.76	1219	45.7			
29	Citric Acid	0.539	115.0	1080	51.9	123.0	1010	55.0	127.0	980	56.3			
30	Maleic Anhydride	0.412	66.0	1691	24.7	84.4	1350	40.0	85.1	1320	41.3			

Table – 7 (pH 8.0 adjusted by Ammonia)

Expt no.	Additive	Wt. of additive (gm)	After 10 mins				After 20 mins				After 30 mins			
			Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca
31	Glyoxal	0.488	191.3	215	90.4	195.3	195	91.3	196.8	185	91.7			
32	Glycolic Acid	0.64	95.5	1475	34.4	97.3	1445	35.7	100.54	1400	37.7			
33	Malic Acid	0.5645	103.7	1332	40.7	107.2	1220	45.7	114.0	1150	48.8			
34	Citric Acid	0.539	-	-	-	-	-	-	133.4	930	58.9			
35	Maleic Anhydride	0.412	-	-	-	-	-	-	96.5	1300	42.2			

Table – 8 (pH 7.0 adjusted by Ammonia)

Expt no.	Additive	Wt. of additive (gm)	After 10 mins				After 20 mins				After 30 mins			
			Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca
36	Glyoxal	0.488	210	113	94.8	211	90	96.0	211.3	75	96.7			
37	Glycolic Acid	0.64	92.7	1510	32.8	94.0	1465	34.8	99.8	1405	37.7			
38	Malic Acid	0.5645	104	1330	40.8	111.5	1200	46.6	113.7	1165	48.2			
39	Citric Acid	0.539	-	-	-	-	-	-	133.9	920	59.0			
40	Maleic Anhydride	0.412	-	-	-	-	-	-	101.2	1280	43.0			

Table – 9 (pH 6.0 adjusted by Ammonia)

Expt no.	Additive	Wt. of additive (gm)	After 10 mins				After 20 mins				After 30 mins			
			Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca
41	Glyoxal	0.488	215.2	40	98.2	215.7	35	98.4	218.3	25	98.8			
42	Glycolic Acid	0.64	96.5	1213	46	98	1202	46.5	105.5	1195	46.8			
43	Malic Acid	0.5645	109	1255	44.1	111	1205	46.4	113.2	1170	47.9			
44	Citric Acid	0.539	-	-	-	-	-	-	135	915	59.2			
45	Maleic Anhydride	0.412	-	-	-	-	-	-	110.9	1170	47.9			

Table – 10 (pH 5.0 adjusted by Ammonia)

Expt no.	Additive	Wt. of additive (gm)	After 10 mins				After 20 mins				After 30 mins			
			Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca
46	Glyoxal	0.488	218.1	25	98.9	218.5	20	99.1	219	15	99.3			
47	Glycolic Acid	0.64	105.2	1190	47.0	107.2	1150	48.8	113.2	1070	52.3			
48	Malic Acid	0.5645	112	1240	44.8	115	1120	50.2	121	1030	54.2			
49	Citric Acid	0.539	-	-	-	-	-	-	136.1	890	60.4			
50	Maleic Anhydride	0.412	-	-	-	-	-	-	121.3	1055	53.0			

Table – 11 (pH 9.0 adjusted by Monoethanolamine - MEA)

Expt no.	Additive	Wt. of additive (gm)	After 10 mins				After 20 mins				After 30 mins			
			Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca
51	Glyoxal	0.488	107.27	700	68.8	117.27	605	73.0	144.6	450	80.0			
52	Glycolic Acid	0.64	77.56	1113	50.5	66.05	1066	52.5	72.61	1081	51.9			
53	Malic Acid	0.5645	88.02	950	57.7	72.61	966	57.0	101.53	855	61.9			
54	Maleic Anhydride	0.412	68.6	1091	51.4	70.27	1006	55.2	63.38	1091	51.4			

Table – 12 (pH 7.0 adjusted by Monoethanolamine - MEA)

Expt no.	Additive	Wt. of additive (gm)	After 10 mins				After 20 mins				After 30 mins			
			Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca
55	Glyoxal	0.488	174.4	400	82.2	182.22	365	83.8	189.54	350	84.4			
56	Glycolic Acid	0.64	97.87	1090	51.5	95.62	1076	52.1	95.41	998	55.6			
57	Malic Acid	0.5645	103.11	906	59.7	100.2	770	65.7	100.3	712	68.3			
58	Maleic Anhydride	0.412	88.56	985	56.2	89.66	953	57.6	90.01	985	56.2			

Table – 13 (pH 6.0 adjusted by Monoethanolamine - MEA)

Expt no.	Additive	Wt. of additive (gm)	After 10 mins				After 20 mins				After 30 mins			
			Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca
59	Glyoxal	0.488	191.5	315	86.0	195.6	285	87.3	198.3	255	88.6			
60	Glycolic Acid	0.64	112.27	956	57.4	91.5	976	56.6	89.6	1050	53.7			
61	Malic Acid	0.5645	104.8	792	64.8	100.62	738	67.2	98.9	760	66.2			
62	Maleic Anhydride	0.412	93.21	953	57.6	99.97	942	58	105.02	888	60.5			

Table – 14 (pH 5.0 adjusted by Monoethanolamine - MEA)

Expt no.	Additive	Wt. of additive (gm)	After 10 mins				After 20 mins				After 30 mins			
			Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca	Acid Value (mgKOH/gm)	Ca in Top layer (ppm)	% Efficiency for removal of Ca
63	Glyoxal [present invention]	0.488	196.5	260	88.4	198.3	240	89.3	199.5	225	90.0			
64	Glycolic Acid	0.64	92.4	945	57.9	94.97	953	57.6	92.73	982	56.3			
65	Malic Acid	0.5645	108.33	605	73.0	106.57	695	69.0	108.97	598	73.4			
66	Maleic Anhydride	0.412	104.81	633	71.8	115.23	684	69.5	124.88	599	73.3			

Table 15

% Efficiency for removal of Ca under basic condition due to presence of NaOH, after 30 mins

Additive	at pH 3 +/- 0.7	at pH 9	% drop	at pH 8	% drop	at pH 7	% drop	at pH 6	% drop	at pH 5	% drop
Glyoxal	99.90	88.0	11.91	86.4	13.51	88.7	11.21	86.4	13.51	87.1	12.81
Glycolic acid	79.30	21.0	73.52	21.5	72.89	21.7	72.64	22.5	71.63	23.7	70.11
Malic acid	83.60	15.7	81.22	17.2	79.43	15.4	81.58	15.0	82.06	24.3	70.93
Citric Acid	78.20	17.0	78.26	17.9	77.11	18.1	76.85	20.8	73.40	42.3	45.91
Maleic Anhydride	83.50	15.0	82.04	15.2	81.80	17.2	79.40	30.8	63.11	43.9	47.43

Table 16

% Efficiency for removal of Ca under basic condition due to presence of Ammonia, after 30 mins

Additive	at pH 3 +/- 0.7	at pH 9	% drop	at pH 8	% drop	at pH 7	% drop	at pH 6	% drop	at pH 5	% drop
Glyoxal	99.90	88.0	11.91	91.7	8.21	96.7	3.20	98.8	1.10	99.3	0.60
Glycolic acid	79.30	36.5	53.97	37.7	52.46	37.7	52.46	46.8	40.98	52.3	34.05
Malic acid	83.60	45.7	45.33	48.8	41.63	48.2	42.34	47.9	42.70	54.2	35.17
Citric Acid	78.20	56.3	28.01	58.9	24.68	59.0	24.55	59.2	24.30	60.4	22.76
Maleic Anhydride	83.50	41.3	50.54	42.2	49.46	43.0	48.50	47.9	42.63	53.0	36.53

Table 17

% Efficiency for removal of Ca under basic condition due to presence of Monoethanolamine (MEA), after 30 mins

Additive	at pH 3 +/- 0.7	at pH 9	% drop	at pH 7	% drop	at pH 6	% drop	at pH 5	% drop
Glyoxal	99.90	80.0	19.92	84.40	15.52	88.60	11.31	90.00	9.91
Glycolic acid	79.30	51.9	34.55	55.60	29.89	53.70	32.28	56.30	29.00
Malic acid	83.60	61.9	25.96	68.30	18.30	66.20	20.81	73.40	12.20
Maleic Anhydride	83.50	51.4	38.44	56.20	32.69	60.50	27.54	73.30	12.22

Claims

1. An additive capable of removing calcium from crude oil or its blends containing calcium naphthenate at low pH of about 3 to about 4, and also at high pH of about 5
5 or more of the wash water for the desalter used in the crude oil processing systems, **characterized in that** the additive is glyoxal.
2. An additive as claimed in claim 1, wherein said high pH varies between about 6 to about 11, particularly between about 7 to about 9.
3. An additive as claimed in claim 1 or 2, wherein said high pH of wash water is due to
10 addition or presence of alkaline medium in the wash water.
4. An additive as claimed in claim 3, wherein said alkaline medium is selected from the group comprising sodium hydroxide (NaOH or caustic), ammonia or amine compound, or mixture thereof.
5. A method for removing calcium from crude oil or its blends containing calcium
15 naphthenate at low pH of about 3 to about 4, and also at high pH of about 5 or more of the wash water used in the crude oil processing systems, **characterized in that** the crude oil or its blends containing calcium naphthenate is treated with an additive, and the additive is glyoxal.
6. A method as claimed in claim 5, wherein said high pH varies between about 6 to about 11, particularly between about 7 to about 9.
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7. A method as claimed in claim 5 or 6, wherein said high pH of wash water is due to addition or presence of alkaline medium in the wash water.
8. A method as claimed in claim 7, wherein said alkaline medium is selected from the group comprising sodium hydroxide (NaOH or caustic), ammonia or amine
25 compound, or mixture thereof.
9. A method as claimed in any one of claims 5 to 8, wherein said glyoxal additive is added in a mole ratio of additive to calcium concentration varying from about 1:0.9 to 1:4, preferably about 1:2.
10. A method as claimed in any one of claims 5 to 9, wherein said crude oil or blends
30 thereof and glyoxal additive are reacted at a temperature of about 80°C to 160°C.
11. A method as claimed in any one of claims 5 to 10, wherein said glyoxal is used alone and not with an acid.
12. A method as claimed in any one of claims 5 to 11, wherein said wash water is used in the desalter of crude oil processing systems.

13. A method as claimed in any one of claims 5 to 11, wherein said calcium removal from crude oil or blends thereof includes removal of calcium from oil or its blends in oil production units comprising electrostatic separators or precipitators.
14. Use of glyoxal for removal of calcium from crude oil or its blends containing calcium naphthenate at low pH of about 3 to about 4, and also at high pH of about 5 or more of the wash water for the desalter used in the crude oil processing systems, **characterized in that** crude oil or its blends containing calcium naphthenate is treated with glyoxal.
15. Use of glyoxal as claimed in claim 14, wherein said high pH varies between about 6 to about 11, particularly between about 7 to about 9.
16. Use of glyoxal as claimed in claim 14 or 15, wherein said high pH of wash water is due to addition or presence of alkaline medium in the wash water.
17. Use of glyoxal as claimed in claim 16, wherein said alkaline medium is selected from the group comprising sodium hydroxide (NaOH or caustic), ammonia or amine compound, or mixture thereof.
18. Use of glyoxal as claimed in any one of claims 14 to 17, wherein said glyoxal is used alone and not with an acid.