Materials Science Research India Volume 01 No.(1) 35-44 (2003)

INHIBITION OF SCALES DEPOSITED IN OIL WELL

I-Synthesis and Evaluation of Some Surfactants and Organic Anions as Scale Inhibitors

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(Received, April 22, 2003)

ABSTRACT

One of the effective methods for controlling scale formation is the use of inhibitors The addition of scale inhibitor to the feed water would be an effective method to reduce or prevent scale formation in oil fields and water system. For this reason, this work pertain to study the effect of prepared antiscalants on the solubilization of sparingly soluble inortanic salts such as calcium carbonate and calcium sulfate. Different types of surfactants and organic anions based on phosphorylated and phosphomethlation of alkanolamine, and phophomethlation polyalkylene polyamine have been synthesized. The effect of static potential of prepared compound as scale inhibitors has bee evaluated using the standard test method (NACE). The results inticate that the amounts of soluble scales are strongly affected by inhibitor concentration. The effectiveness of inhibitors to prevent the nucleation and crystallization of the supersaturated calcium sulfate solutions are significantly higher than the corresponding calcium carbonate solutions.

Key words: Phosphorylated alkanolamine, alkanolamine methyl phosphonic acids, polyalkylene polyamine poly-(methyl phosphonic acids), and scale inhibitors.

INTRODUCTION

Inorganic scales that result from the depotition of solid salts from high brine supersaturated solutions injected into and/ or removed from underground petroleum bearing formations frequently lead to lost production or well abandonment. Deposits can plug the formation near the wellbore, tubing string, downhole safety valves and other valves, and casing perforations. The problem of scale formation is intensified at higher temperatures because of the peculiar inverse temperature-solubility characteristics of these minerals in water.

Deposition can be intiated by a variety of factors including pressure, pH, temperature, turbulence, surface characteristics, or mixing of incompatible fluids. Incompatiable fluids are frequently encountered during water flooding operations. A common factor that causes scale is pressure redact encountered by fluids as they enter the wellbore during production. The partial pressure of $C0_2$ decrease which can lead to the precipitation of $CaC0_3$.

The most common classes of chemical inhibitors are inorganic polyphosphates, organophosphorus compounds and organic polymers. The inorganic polyphosphates are sodium tripolyphosphate and'hexametaphosphate. Organophosphorus compounds are_ phosphonic acid and phosphate ester salts. The organic polymers used are generally low molecular weight acrylic acid

salts or modified polyacrylamides and copolymers thereof.

Phosphonates and polymers are more thermally stable than polyphosphates or phosphate esters. Polyphosphates and phosphate esters hydrolyze the phosphorus oxygen P-0 bond at high temperature forming orthophosphates, the metal salts of which may be more insoluble than the scales that they are intended to inhibit. Inorganic polyphosphates are seldom used as scale inhibitor in modern oil field separation. Accordingly, the organic polyphosphate are the most used for this purpose \ Unlike the P-0 bond, the P-C bond is not as susceptible to hydrolysis [2]. Phosphonate inhibitors, are most commonly used in the field today, due to several advantages, such as, their ability to inhibit scale at low concentration, their stability over a wide range of temperatures and pH and their ability to inhibit different types of scales in many reservoirs at different conditions [3].

Ralston[4] found that, the compounds containing a plurality of phosphomethylated amine groups, having at least three nitrogen's connected by ethylene groups, are efficient in preventing the deposition of scale from aqueous solution. The polyphosphomethylated polythyleneamine inhibitors containing 3 to 15 amine groups are effective even at high temperture. They have the following general formula: R_2N-$[CH_2CH_2$-$NR]_{nR}$, where R is CH_2-P =0 $(OM)_2$, n is integer of 2 to 14 and M indicates that the inhibitor is in water soluble form. The preferred scale inhibitors of this group start with at least four R groups. It has been found that, phosphomethylated polyamines containing three or six nitrogen atoms are completely stable in the acidic and in the sodium salt form.

In the present, paper different types of phosphorylated alkanolamine, alkanolamine methyl phosphonic acids as anionic surfactant and polyalkylene polyamine polymethyl phosphonic acids as organic anions have been synthesized to study their ability as scale inhibitors. The ability of prepared compound to retard the unwanted deposition of inorganic salts has been evaluated. The efficiency orders of these antiscalants upon chelating tendencies of calcium ion have been studied.

EXPERIMENTAL

The prepared scale inhibitors divided into two main groups anionic surfactant and organic anion. Six anionic surfactant based phosphorylated and phosphomethylated of alkanolamine, and three organic anion based on phosphomethylated polyalkylene polyamine have been synthesized as described below.

1. Preparation of Alkylamine phosphates(phosphorylated Alkanolamine).

One mole of alkanolamine (monoethanolamine, diethanolamine or triethanolamine) was allowed to flowdropwise from a dropping funnel into a three-necked flask containing 3 moles of 85% phosphoric acid. The rate of introduction was adjusted so that the temperature raised to about 80-90°C, and remained within this range. After all of the alkanolamine has been introduced, the reaction flask was connected to a vaccum pump until the free water was distilled of at 80°C and 0.1 mm of mercury pressure. The temperature of the reaction mixture was then reaised gradually to 180-190°C, and additional water was distilled off[5]. The prepared products were, N,N-diphosphono ethylamine phosphate, N-phosphono diethylamine diphosphate, and N,N,N-triethylamine triphosphate, and designated as S1, S2 and S3, respectively.

2. Preparation of: I- Alkanolamine Methyl Phosphonic Acids, II- Polyalkylene Polyamine Poly-[Methyl Phosphonic Acids].

were prepared by a Mannich-type reaction using phosphorous acid, formaldehyde, and ammonia or amines [6-7]. Amine based on)morpholine, monoethanolamine and diethanolamine, diethylene triamine, pentaethylene hexamine, and undecylethylene dodocylamine were used in this study. In this respect, each hydrogen atom of the amino group reacts with 1.15 mole of phosphorous acid, 4 moles of hydrochloric acid, 5.5 moles of water and 3 moles of formaldehyde. The prepared products were morpholino methyl phosphonicacid, ethanolamine N,N-di-[methyl phosphonic], diethanolamine N-methyl phosphonic acid, Diethylene Triamine N-penta-[methyl phosphonic acid], pentaethylene hexamine N-octa-[methyl phosphonic acid], and undecylethylene dodecylamine N-tetradecyl-fmethyl phosphonic acid], they were designated as C1, C2, C3, P1, P2 and P3, respectively.

3. Laboratory Evaluations.

The ability of synthesized compounds to retard the unwanted deposition of inorganic salts has been evaluated. The efficiency orders of these antiscalants upon chelating tendencies of calcium ion have been measured using National Association of Corrosion Engineers (NACE) standard test methods[8]. In this respect a series of solutions "a, b" or "c, d" were prepared. Solution "a, b" consisting of 7.36g/L $NaHC0_3$and 12.15g/L $CaCl_2$-$2H_20$, 3.68g $MgCl_2$-$6H_20$ in 33g NaCI in 1L distilled water, where solution "c, d" consisting of 11.10g/L$CaCl_2$-$2H_2O$ and 10.66g NaSO/L in 7.5g NaCI in 1L distilled water, respectively. The prepared scale inhibitors and commercial (Petrolite S.C. Inhibitor, SPILL. 2127) were dosed 10-100 ppm into brine solutions "a, b" or "c, d" before heating, respectively. After mixing, the solution were placed in oven at 70°C for 24 hours, and allowed for cooling upto 25°C.The scaling ion concentrations were then measured by Inductively Coupled Plasma Emission Spectroscopy (ICP) to determine the concentration of calcium ions remaining in solution.

RESULTS AND DISCUSSION

The deposition of calcium sulfate and calcium carbonate on oil field systems indicated that the initial stage of such deposition consists of the nucleation of crystals adhering to the metal surface. One of the effective methods for controlling scale formation is the use of inhibitors. It has been shown that the addition of scale inhibitors to the feed water would be an effective method to reduce or prevent scale formation in oil field systems. Accordingly, the scale inhibitors used in this study can be classified into three groups: phosphorylated alkanolamine, phosphomethylated alkanolamine and phosphomethylated polyamine. The efficiency of those antiscalants upon cheating tendencies of calcium ion has been studied.

Synthesis and Conformation of Structures.

Three types of phosphoryla'ted alkanolamine are synthesised according to the method described before. This method is based on the possibility of reaction of phosphoric acid with terminal -OH or -NH groups. This series included N,N-diphosphono ethylamine phosphate, N-phosphono diethylamine diphosphate, and N,N,N-tri ethylamine triphosphate. Furthermore according to Mannich- reaction [9-10], six inhibitors are synthesised. Mannich-Type reaction are carried according to the following equation.

$$R_{3\,n}NH_n + n\,CH_20 + n\,HP(0)(OH)_2 \rightarrow R_{3\cdot n}N[CH_2P(0)(OH)_2]_{n+}nH_20$$

Three inhibitors based on phosphomethylated alkanolamine and the corresponding inhibitors are morpholino methyl phosphonic acid, ethanolamine N,N-di-[methylphospho<nic acid] and diethanolamine N-methyl phosphonic acid. Finally the other inhibitors based on phosphomethylation for polyalkylene polyamine which have the general formula:

H_2N (CH_2CH_2-NH)$_n$H. The corresponding inhibitors are diethylene triamine N-penta-[methyl phosphonic acid] at n=2, pentaethylene hexamine N-octa-[methyl phosphonic acid] at n=5 and undecylethylene dodecylamine-N-tetradecyl [methyl phosphonic acid] at n=11.

Surface Properties of Prepared Inhibitors.

The surface tensions of the prepared inhibitors were measured by Dognon tensiometer. The recorded results are 34mNnr^1, 29mNnr^1, 27mNm-\ 36mNm-\ 33mNrrv\ 30mNnr^1, 53mNnr^1, 56mNnr^1, and 60mNnr^1 for S1, S2, S3, C1, C2, C3, P1, P2 and P3, respectively. The results indicate that phosphorylated and phosphomethylation of alkanolamine have more surface properties than phosphomethylation polyalkylene polyamine.

Chemical Analysis of Prepared Scale Inhibitors

A comprehensive study was performed using infra-red, mass spectroscopy, molecular weight and elemental analysis for the objective of justifying the chemical structure of prepared compounds.

Elemental Analysis

Elemental analyses were done using Perkin-Elmer-2400 elemental analyzer. The elemental analyses and molecular weight of thr prepared inhibitors provide that the chemical structures are as the following;

S1[$C_2H_{10}P_30_{10}N$]: C, 8.02: H, 3.50; P, 31.04; N, 4.9; mol. wt., 302.16.

S2[$C_4H_{14}P_30_{11}N$]: C, 14.13; H, 4.36; P, 27.31; N, 4.10; mol. wt., 347.25.

S3[$C_6H_{18}P_30_{12}N$]: C, 19.02: H, 4.82; P, 24.36; N.3.90; mol. wt., 391.02.

C1[$C_5H_{12}P0_4N$]: C, 33.79: H, 6.76; P, 17.44; N, 7.88; mol. wt., 181.13.

C2[$C_4H_{13}P_30_7N$]: C, 19.46: H, 5.27; P, 25.11; N, 5.68; mol. wt., 249.10.

C3[$C_5H_{14}P0_5N$]: C, 30.31: H, 7.07; **P,** 15.64; N, 7.07; mol. wt., 199.14.

P1 [$C_9H_{28}P_50_{15}N_3$]: C, 19.30: H, 5.00; P, 28.02; N, 7.60; mol. wt., 575.10.

: P2[$C_{18}H_{66}P_80_{24}N_6$]:C, 22.24: H, 5.32; P, 25.32; N, 8.60; mol. wt., 985.65.

P3[$C_{36}H_{112}P_{14}0_{42}N_{12}$]: C, 24.12: H, 5.27; P, 24.18; N, 9.39; mol. wt., 1807.4.

Therefore, the data indicate that the elemental analyses are in good accord with that expected theoretically.

Infra-red

Fourier Transform Infrared Spectrophotometer Model Infinity, Mattson Instrument measured the I.R. of some inhibitors. It has been found that the spectrum of the prepared inhibitors are very complex and difficult to interpret due to the multiplicity of phosphomethylation bands. Therefore, it was impossible to assign a definite portion of spectrum for desired products, although a certain number of bands seem to be associated most probably of desired compounds. So the most functional group of S1 represent medium broad between 2400-2200 cm^{-1} and strong band at 974 cm^{-1} this may be for P=0(OH) group, stretching vibration at 1277 cm^{-1} this attribute to P=0 phosphine oxide band, stretching vibration at 1510, 1384 and 765cm^{-1} this assign for P-O-C bond and stretching vibration at 1331cm^{-1} assign to N-P bond. C2 show stretching Vibration bands at 3653,1075, 944 and broad band at 2325 cm^{-1} which indicate to the P-OH and P(0)OH linkage, stretching vibration bands at 1370cm^{-1} this attribute to the formation of P-CH_2 linkage, band between 1436 cm^{-1} and 1485cm^{-1} indicate that methylene groups attached to the nitrogen atom. Finally P2 appear stretching vibration bands at 1180 cnr^1 for P=0, bands at 910-

1040 cm^1 for P-OH and band at 1300 cm^1 for N-P bond. Accordingly, the bands observed from I.R. spectra oi S1, C2 and P2 are coincidence with that found in literature and indicating the successful preparation reaction'[11]'.

Mass Spectra

The mass spectra were measured by Shimadzu single focusing mass spectrometer. The mass spectrum of S3 show many pathway peaks resulting from cleavage of C-C bond next to each oxygen or nitrogen atoms. S3 records a parent peak at m/e = 389 with 6.2% abundance. !t shows a prominent peak at m/e = 278 with 100% adbundance, this may be atrributed to the loss of one CH_2OP $(0)(OH)_2$ group which have m/e = 111. In addition to C-C bond cleavage a homologous series of peaks at m/e =167 and 56 of progressively decreasing intensities of 65.09% and 27.73% respectively, may be resulting from the cleavage of the other two methylene phosphonic acid groups. The presence of peaks at m/e = 292, 308 may reflects the cleavage of one $-OP(0)(OH)_2$ or one $P(0)(OH)_2$ group from the parent compound.

The mass spectrum of C2 indicating that the presence of peak at m/e = 218 (26.28%) is due to cleavage of C-C bond next to the oxygen atom, and loss of $-CH_2OH$ (m/ e =31) from the parent compound which posses m/e = 249 (6.93%).The progressive cleavage of C-N bond from the last precursor led to loss of the adjacent CH_2 group which corresponds to the peak at m/e = 204 (27.28%). Another pathway is represented by a peak at m/e =137(47.73%) which may be attributed to a loss of $P(0)(OH)_2$ group (m/e =81) from the parent after losing $-CH_2OH$ group. The peak at m/e =154 (100%) may be attributed to loss of one methylene phosphonic acid group (m/e = 95) from the parent compound. The loss of the other methylene phosphonic acid may be represented by a peak at m/e =59 (10.78%). Finally, the peak at m/e =164 (26.89%) may confirm the loss of five hydroxyl groups from the parent compound.

Molecular Formulae

From the previous analysis it could be postulated that the molecular formulae of the synthesized scale inhibitors can be elucidated and the results are shown in Table 1. This Table shows that the elemental experimental values are in a good accord with that expected theoretically.

Evaluation of the Prepared Inhibitors in Preventing Scale Deposition.

The study was carried out to investigate the role of the prepared scale inhibitors on the amount of calcium ion remained in the scalable solution. The efficiency values were measured for all prepared inhibitors at different inhibitor concentrations using National Association of Corrosion Engineers (NACE) standard test methods.

Effect of Concentration on the Inhibitor Efficiency.

The prevention of calcium sulfate and carbonate scales are summarized in Tables 2-3. The data show that, the inhibition efficiency in both calcium sulfate and carbonate increases, as the inhibitor concentrations are increased.

In case of phosphorylated alkanolamine (S1 -S3), it is clear that above 50 ppm up to 100 ppm inhibitor concentration, the soluble calcium ions in $CaSO_„$ solutions is slightly increases from 17.43 up to 17.82% respectively. Whereas the percentage of soluble calcium ions in $CaC0_3$ solutions is significantly increased from 5.13 to 7.02 %, as the scale concentrations increase from 50to 100 respectively.

The data also indicate that, there is an optimum inhibitor concentration for all phosphorylated alkanolamines series in both calcium sulfate and carbonate which is almost 50 ppm after which no significant inhibition is observed. The integration of

Table-1: Designation and molecular formulae of the synthesized inhibitors.

Scale inhibitors	Formula
S1 N,N- diphosphono ethylamine phosphate	$(M)_2$-N-CH_2-CH_2-0-M
S2 N- phosphono diethyiamine diphosphate	M-N-(CH_2-CH_2-0-M)$_2$
S3 N,N,N, triethyl amine triphosphate	M-0-CH_2-CH_2-N(CH_2-CH_2-0-M)$_2$
C1 Morpholino methyl phosphonic acid.	/—v O N-CH_2M >—f
C2 Ethanolamine N,N, di-[methyl phosphonic acid]	HO-CH_2-CH_2-N-(CH_2-M)$_2$
C3 Diethanolamine N-methyl phosphonic acid	M-CH_2-N-(CH_2-CH_2-OH)$_2$
P1-P3 Where n=2-> P1, n=5-> P2 andn=11->P3.	(MCH_2)$_2$-N-[CH_2-CH_2N-CH_2-M-]$_n$-CH_2-M M= P(0)(OH)$_2$

Table- 2: Efficiency % of the prepared and commercial scale inhibitors for $CaS0_4$ at different concentrations.

Conc. ppm	Inhibitor Type										
	S1	S2	S3	C1	C2	C3	P1	P2	P3	1*	2*
5	0.10	11.76	11.37	0.66	2.57	0.87	21.7	48.0	52.5	13.4	38.1
10	1.57	20.57	20.23	3.00	3.13	3.11	52.5	78.5	76.7	20.1	68.4
20	7.42	73.32	44.51	5.40	7.86	5.19	59.1	82.8	94.5	27.9	80.5
30	10.03	85.53	65.64	6.78	45.23	13.06	67.4	92.1	95.3	40.6	86.8
40	14.07	94.65	84.14	7.98	84.92	24.74	79.4	94.8	97.4	61.8	89.9
50	17.43	98.04	94.28	13.48	91.74	40.22	83.5	97.1	98.8	80.4	94.6
75	17.47	98.12	96.66	15.94	91.98	40.31	87.7	99.0	99.4	93.3	97.2
100	17.82	98.87	98.52	16.63	92.38	40.57	92.2	99.3	99.9	96.1	98.6

Table- 3: Efficiency % of the prepared and commercial scale inhibitors for $CaC0_3$ at different concentrations

Conc. ppm	Inhibitor Type										
	S1	S2	S3	C1	C2	C3	P1	P2	P3	1*	2*
5	1.43	4.94	1.74	1.49	5.27	1.84	17.3	24.8	25.2	0.2	19.2
10	2.43	10.24	4.32	1.81	5.46	3.05	18.3	25.0	25.4	0.6	19.3
20	2.81	12.69	7.22	2.22	9.57	3.72	19.2	25.8	26.2	1.6	20.2
30	3.39	12.93	10.18	3.80	12.54	3.85	22.4	29.0	29.8	2.8	23.2
40	4.86	15.97	10.65	5.98	12.54	8.20	22.6	30.7	32.2	4.3	23.3
50	5.13	16.53	15.38	9.10	13.97	13.22	28.2	35.4	37.0	7.6	25.9
75	6.40	17.75	17.07	9.28	17.78	14.16	32.4	38.2	37.5	22.5	26.1
100	7.02	18.98	18.86	10.05	18.94	14.34	34.7	41.1	42.3	23.9	26.1

1*= CPHET 2* = Petrolite Spill .2127

results indicates that, the rank of efficiency is S2>S3>S1.

The efficiencies of phosphomethylated alkanolamine C1, C2 and C3 as scale inhibitors for $CaSO_4$ and $CaCO_3$ are also increased with increasing the inhibitor concentration up to an optium value (50 ppm). The rank of efficiency order of these series isC2>C3>C1.

The efficiencies of polyethlene polyamine polymethyl phosphonic acids (P1.P2 and P3) are proceed as the same manner of previous series indicating an optimum inhibitor concentration of 50 ppm. It was observed that the efficiency is about 100% prevention of calcium sulfate when P2 and P3 inhibitor were used with 100 ppm concentration. The obtained data indicate that, the order of the efficiency is P3 > P2> P1. It is observed that, the efficiencies of P2 and P3 are aproximately equal although the number of phosphonyl groups is 8 and 14, respectively.

Efficiency of Scale Inhibitors at Optimum Concentration.

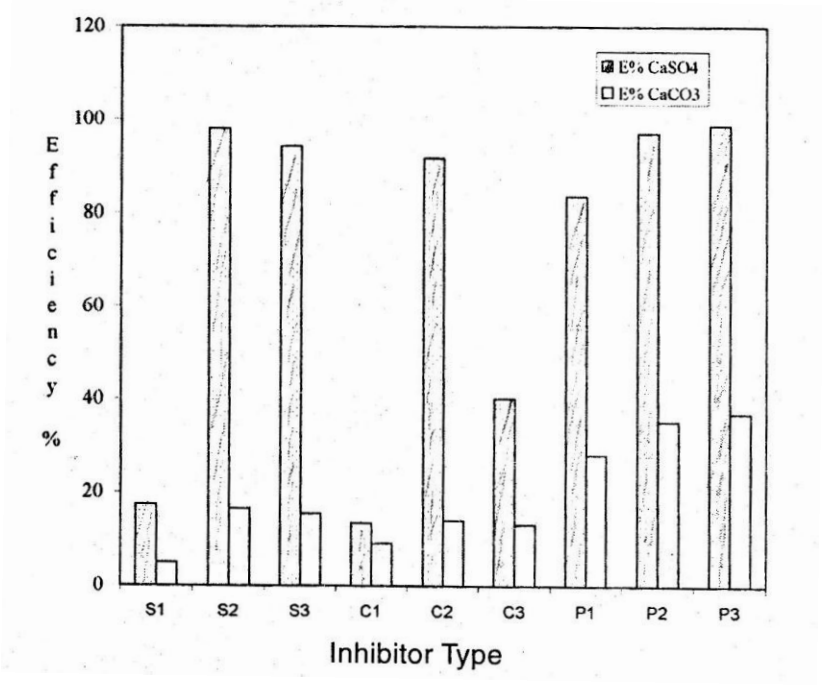
Figure 1 represents the efficiency of each inhibitor at its optimum concentration, for the prevention of both sulfate and carbonate scales. The efficiencies of S2 and S3 are approximately 5.5 times greater than that of S1 with respect to calcium sulfate scales. On the other hand, those values are decreased to 3 times and 0.7%, respectively in case of calcium carbonate scales.

It was found that there is no significant effect are recorded in prevention of both of calcium sulfate and carbonate scales when the concentration of inhibitors are increased to their double value.

The efficiency of C2 is greater than C3 and C1 by 2.25 and 6.8 times, respectively, with respect to calcium sulfate. Morever, there is only 4% difference between both C2 and C3 over C1 in case of $CaC0_3$ scales.

It is found that in the polyethylene polyamine polymethyl phosphonic acids series the multiplicaton of the optimum concentration enhances the efficiency against carbonate by a value ranging between 5 to 6.5% for all types of inhibitors. This means that, better efficiencies against

Figure (1): Efficiency of prepared scale inhibitors on the prevention of calcium sulfate and calcium carbonate at their optimum concentration (50 ppm)



carbonate precipitation can be achieved using higher inhibitor concentration. For example using 500 ppm of P2 can raise the efficiency against carbonate scale to about 64%.

Generally, It can be seen that as the scale inhibitors concentration are increased, the inhibition efficiency increases and the overall growth rate is some what reduced.

Selection of the Most potent Inhibitors.

Scale inhibitors can be evaluated by laboratory testing to determine their relative effectiveness. Although it is difficult to establish the minimum effective concentration required for a specific field application, the relative ratings of different inhibitors established in the laboratory are generally valid in the field. Several factors must be considered when selecting a scale inhibitor.

The comparison between all the prepared inhibitor at different concentration indicates that S2, C2 and P2 gives the highest efficiency for deposition of calcium sulfate and carbonate scales. Furthermore, P2 is the most potent scale inhibitor in all prepared compounds. It exhibits a higher efficiency against both sulfate and carbonate scales even at very low concentrations. This efficiency approaches a complete prevention of calcium sulfate deposition and it is 2 to 3 times greater than the efficiency of the nearest competitive inhibitor in the prepared chemical against calcium carbonate precipitation. Accordingly, P2 is selected to be the inhibitor applied in all posterior studies and applications.

Comparison between the Prepared Scale Inhibitor P2 and Two Types of Commercial Inhibitors.

I- Using N ACE Test Method Arfificial Brine Water.

Two types of commercial inhibitors (Petrolite SP-2127 and CPHET) are chosen to make a comparison with P2 scale inhibitor.

The efficiencies of those inhibitors are evaluated against precipitation of both calcium sulfate and calcium carbonate, and the results are given in Tables (2-3). The efficiencies of the competitive inhibitors at 100 ppm inhibitor concentration with respect to calcium carbonate are 41.1, 23.9 and 26.1 for P2, CPHET and Petrolite SP- 2127, resectively. This means the mastery of P2 over both commercial inhibitors by 17.2% and 15.0% for CPHET and Petrolite SP-2127, respectively.

II- Using N ACE Test Method Natural Brine Sea Water.

An application comparison was also made between P2 and Petrolite SP-2127 using natural brines sea water provided from Gulf of Suez, and formation water obtained from GUPCO well S.GH-376.The results of the comparison are presented in Table 4. The results proved the previous conclusion. The use of natural brines lead to a reduction in the inhibition efficiency of P2 and SP-2127 by a value ranging from 13% to 15%, respectively. This may be attributed to the presence of other types of divalent ions in the natural brines such as barium, strontium, or magnesium, which can consume a part of the inhibitor used.

It is interesting to note that the prepared inhibitors exhibit strong inhibitory effects for calcium sulfate at relatively low concentration, meanwhile some of them have medium inhibitory effect for $CaC0_3$. Same behavior is observed with a commercial inhibitor.

CONCLUSION

Three categories of scale inhibitors are synthesized. Alkylamine phosphates based on phosphorylation of mono, di, and triethanolamines. Alkanolamine methyl phosphonic acids based on phosphomethylation of morphline, monoethanolamine and diethanolamine. Poiyalkylene polyamine polymethyl phosphonic acids based on phosphomethylation of diethylene triamine, pentaethylene hexamine and undecylethylene dodecylamine. The molecular formulae of the synthesized inhibitors were elucidated via elemental analysis and the results were in a good accord with that expected theoretically .

Efficiency of the prepared inhibitors was studied at different inhibitor

Table- 4: Comparison between P2 and Petrolite SP-2127 using natural brines (seawater and July-69 formation water) at different inhibitor concentration and 70°C

Inhibitor	Inhibitor Type	
Concentration, ppm	P2	Petrolite SP- 2127
5	12.66	3.14
10	25.58	15.21
20	39.79	29.72
30	56.85	45.13
40	67.18	55.66
50	79.84	75.53
75	82.95	80.77
100	86.69	83.77

concentrations considering NACE standard method for evaluation. The results indicate the prevention of both calcium sulfate and calcium carbonate increases as the concentration of the inhibitor increases up to the optimum concentration (50ppm).

The rank of efficiency of alkylamine phosphates series are S2>S3>S1 and related to both molecular structure and molecular weight of the inhibitor. The rank of efficiency order of phosphomethylated alkanolamine is C2>C3>C1 .The data indicate that, the order of the efficiency is P3 > P2 > P1. It is very clear that using 50 ppm of P2 or P3 prevents the calcium sulfate and calcium carbonate to approximately 100% and 42%, respectively.

The results showed the highest efficiency of P2 than other prepared scale inhibitors although it has high surface tension with respect to them.

The results showed the mastery of P2 over both commercial inhibitors Petrolite SP-2127 and CPHET in preventing both scales.

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