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# Scale Inhibitor Evaluation and Optimization

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# تقييم موانع الترسيب المستخدمة في الحقول النفطية

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تعتبر عمليات الاسترداد الإضافي من العمليات المهمة في مجال استخراج النفط في الحقول المنتجة محلياً، وتشمل هذه العملية حقن طبقة المكمن المنتجة للنفط بالمياه من اجل المحافظة على ضغطه. غير أن عدم تطابق هذه المياه مع مياه التكاوين قد يؤدي إلى ترسيب العديد من مكوناتها على هيئة قشور وترسبات مثل كربونات الكالسيوم وكبريتات الكالسيوم وكبريتات الباريوم وكبريتات السترانشيوم والتي تؤدي إلى انسداد بعض أنابيب إنتاج النفط وتلف في بعض المعدات مثل المضخات وصمامات الأمان.

في هذه الدراسة تم إجراء إختبارات معملية للعديد من موانع الترسيب المستخدمة محليا لاختيار الأمثل منها من حيث الأداء والكفاءة وفق الطرق القياسية، وأيضاً تم استخدام بعض النماذج الرياضية لحساب وتقدير إمكانية تكون هذه الترسبات ومقارنتها بالنتائج المعملية.

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**Abstract:** *Secondary oil recovery represents a major part of oil production in many local oilfields. It involves injection of a source water to maintain the reservoir pressure. The source water will eventually mixed with formation water as it breakthrough to production well. Mixing of incompatible brines leads to precipitation of various types of mineral scaling compounds such as barium sulfate, strontium sulfate, calcium sulfate or calcium carbonate. This scale deposits at formation face, production tubing, subsurface valves, perforation may restrict fluids flow that result in production rate curtailment. A laboratory work is currently underway to set up a standard procedure for scale inhibitor selection. This paper presents the result of evaluating different types of commercially available scale inhibitors intended for use under down hole and surface production facilities conditions. In addition, a computer scaling modeling is performed to asses the compatibility of injection and formation brines at different ratios and various temperature and pressure conditions.*

## INTRODUCTION

Most water handling problems in oil and gas production arise from the fact that water is an excellent solvent [1]. In oilfield both source water and formation water contain considerable quantities of dissolved solids, suspended solids and dissolved gases. As conditions of temperature and pressure change, many dissolving compounds may become insoluble to some degree, precipitate from water and may form scale.

Two major types of scales are commonly encountered in water handling operations [2], these being carbonate and sulfate based scales. The formation of carbonate scales (calcite ($CaCO_3$) is usually associated with changes in pressure,

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temperature, pH, and dissolved $CO_2$, as water passes from surface into the formation or from formation to surface facilities. Sulphate scale formation [gypsum ($CaSO_4.2H_2O$), anhydrite ($CaSO_4$), celestine ($SrSO_4$) or barite ($BaSO_4$)] is often associated with potential incompatibilities between formation and injection water and to a lesser extent on temperature and pressure. The forecast of these incompatibility effects on the future oilfield operation should cover type, extent and location of all future location of all future damage due to chemical incompatibility problems.

The usual method of scale prevention is to apply scale inhibitor that generally fall into one of the four main classes polyphosphates, phosphate esters, phosphonates and polymers [3] .These four types are known as threshold chemicals that inhibit scale at a concentration well below equimolar amounts. Each type of chemical has a certain application subject to laboratory and field trials before continuous application. For an effective scale control program, the inhibitor should be present at all times in the water being treated. Furthermore, it is important that the inhibitor should be added to the system at a location upstream of the point where scale deposition starts to occur. Different types of commercial scale inhibitors are being tested under static and at reservoir conditions. This paper presents part of scale inhibitor evaluation intended to cover most of scale inhibitors used in local oil fields. Also, in house software program is developed to asses and predict the self scaling or incompatible mixing of formation and injection water. This prediction covers the type extent and location of all expected scale deposition.

### Scale Inhibitor Evaluation

To be suitable for scale inhibition [4], an inhibitor must:

- Inhibit scale formation at low concentration.
- Be stable at reservoir conditions.
- Be compatible with injection and formation waters /and all types of chemicals used in oilfields.
- Have a reasonable solubility at reservoir conditions.
- Be measurable quantitatively at low concentration.
- Have low toxicity and high biodegradability.
- Have low cost.

These requirements formed the bases for screening criteria and tests. Four commercial scale inhibitors labeled as A,B,C and D (Table 1, and reference 5) are evaluated according to the procedure outlined in NACE Standard ( NACE – TM0374-2001) (test method and laboratory screening tests to determine the ability of scale inhibitors to prevent the precipitation of calcium sulfate and calcium carbonate from solution)[5]. Synthetic supersaturated solutions that represent actual injection and formation waters are used since no meaningful results can be obtained using oilfield brines.

The main objective of this test is to screen scale inhibitors under accelerated condition and provide relative performance rankings. Any product fail this test will be eliminated for further testing. The effectiveness of each product is measured by its ability to keep the calcium ions in the solution.

**Table 1. Scale inhibitors tested.**

| Scale inhibitors | Chemical composition |
|---|---|
| A | Blend of phosphonates and polymer |
| B | Neutralised sodium salt of phosphonate |
| C | Phosphate ester |
| D | Organic phosphonate |

## RESULTS AND DISCUSION

### 1. Scale Inhibitor Evaluation Test

Tables 2 and 3 show the results of these tests. The percentage inhibition (m) was calculated according to:

$$m = \frac{C - C_e}{C_o - C_e} \times 100$$

**Table 2. Brine composition.**

| Ion | Formation water mg/l | Injection water mg/l |
|---|---|---|
| $K^+$ | 437 | 90 |
| $Mg^{+2}$ | 950 | 130 |
| $Ca^{+2}$ | 8940 | 450 |
| $Sr^{+2}$ | 383 | 10 |
| $Ba^{+2}$ | 1.3 | 0.2 |
| $Na^+$ | 26133 | 1000 |
| $Cl^-$ | 56733 | 1800 |
| $Br^-$ | 401 | 0.0 |
| $(HCO_3)^-$ | 196 | 756 |
| $(SO_4)^{-2}$ | 605 | 757 |

**Table 3. Calcium sulfate percent inhibition %.**

| Concentration/ Scale inhibitor | 1 mg/l | 3 mg/l | 5mg/l | 10mg/l | 20 mg/l |
|---|---|---|---|---|---|
| A | 35.48 | 83.87 | 87.09 | 100 | 100 |
| B | 75.92 | 77.77 | 81.85 | 83.33 | 83.33 |
| C | 82.75 | 90.52 | 93.10 | 93.10 | 93.10 |
| D | 68.42 | 89.47 | 92.98 | 97.37 | 97.37 |

Where: $C_e$ is the equilibrium divalent cation concentration in the absence of inhibitor
$C_o$ is the initial divalent cation concentration.

The same results are also shown graphically for better comparison in Figures 1 and 2. For most oilfield application, a minimum effective dosage for threshold inhibitor is in the range of 1 – 5 mg/l which is sufficient to prevent mineral scaling. Therefore; all products are acceptable for preventing sulfate scaling. However, only inhibitor C is superior to the others to inhibit calcium carbonate.

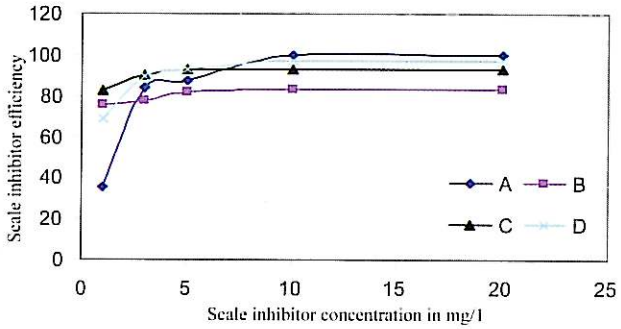



Fig. 1. Percentage inhibition of ($CaSO_4$) from static test.

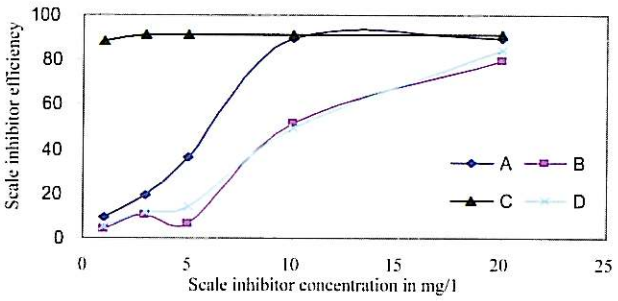



Fig. 2. Percentage inhibition of ($CaCO_3$) from static test.

## 2. Computer Scale Prediction

In house developed prediction model , based on Odd and Tomson method[6], has been carried-out for one oilfield to asses the self- scaling or incompatibility mixing, at three locations (down hole ,wellhead and manifold). All the relevant data, water composition and gas composition of brine at equilibrium in the reservoir are considered. The data is shown in Table 2. Effects of the pressure and temperature changes associated with the production, and the resulting changes in equilibrium composition are modeled. In this manner potential scaling problems and the driving forces for scale formation are identified. The saturation index (SI) is a measure of scaling tendency. However, if the sign is positive, the brine has a scaling potential, a negative sign indicates the brine is under- saturated.

Figures 3 and 4 illustrate the predicted calcium carbonate and calcium sulfate saturation index as the source water (injection water) mixes with formation water at bottom hole, well head and manifold conditions. The results indicate that calcite scaling is likely at well head and manifold. This is due to reduction in pressure, evolution of $CO_2$ and increase in pH of the brine. The calcium sulfate scaling is unlikely under the same condition at the three locations.

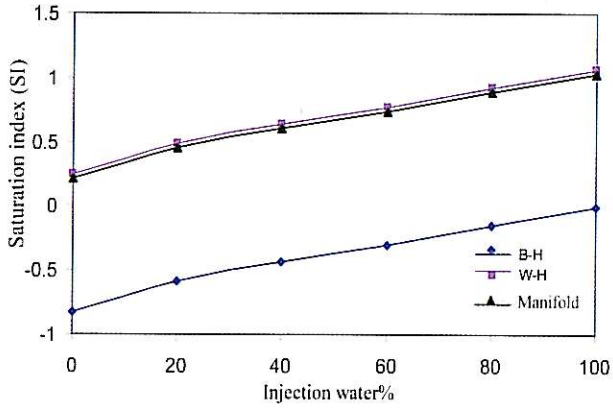



Fig. 3. Calcium carbonate scaling tendency.

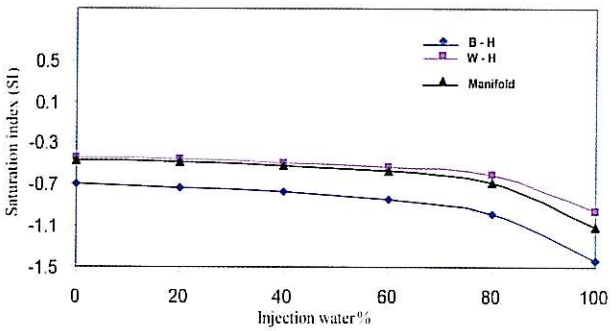



Fig. 4. Calcium sulfate scaling tendency.

## CONCLUSIONS

Laboratory static test NACE standard procedure was followed to evaluate the performance of four candidate scale inhibitors labeled A, B, C, and D intended to be used in local oilfields. All four products are acceptable in preventing calcium sulfate while only product C is acceptable for calcium carbonate inhibition. The use of computer model can greatly aid in selection and optimization of scale inhibitors for downhole or surface application. The second phase of the scale inhibition tests will focus on evaluating these products under dynamic conditions (Table 4).

**Table 4. Calcium carbonate percent inhibition %.**

| Concentration/ Scale inhibitor | 1 mg/l | 3 mg/l | 5mg/l | 10mg/l | 20 mg/l |
|---|---|---|---|---|---|
| A | 9.09 | 19.48 | 36.36 | 89.61 | 89.61 |
| B | 3.85 | 10.26 | 6.41 | 51.28 | 79.49 |
| C | 88.43 | 91.16 | 91.16 | 91.16 | 91.16 |
| D | 5.19 | 11.69 | 14.29 | 49.35 | 84.42 |

## ACKNOWLEDGEMENT

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