

## Effect of Temperature on Scale Formation around the Wellbore and Hole Cleanup for Reconditioned Drilling Mud

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### Abstract

Oil based muds are very complex fluids composed from water, oil, organophilic clays and various additives. Their very good filtration and lubricating properties make their use beneficial in numerous drilling operations.

Formation and deposition of scale in wellbore and porous media due to extensive use of oil based mud for drilling at different pressures and temperature is a problem that results in production decline. A variety of models are presently being used in the oil industry for prediction of scaling tendency and scale precipitation inside the wellbore and immediate wellbore region. Some of the precipitated BaSO<sub>4</sub> scale escapes through the pore spaces to render havoc to flow in the production string. This research is an experimental study that presents a **Solution [X]** (based on experimental analysis) for effective wellbore and open hole clean up of a producing well drilled with Oil Based Mud at different temperatures, especially at offshore locations where seawater is mostly encountered. Results from this study shows that cleanup using referred **Solution [X]** at low temperatures yields high success cleanup rate of BaSO<sub>4</sub> scale precipitation as well as when used at high temperature regardless of the effect of temperature change on solubility of BaSO<sub>4</sub> scale.

### INTRODUCTION

Scale can be described as any crystalline deposit (salt) resulting from the precipitation of mineral or inorganic compounds present in water. A typical precipitation of inorganic compounds may include the reaction of anhydrite (CaCO<sub>3</sub>), gypsum (CaSO<sub>4</sub>.H<sub>2</sub>O), hemihydrates (CaSO<sub>4</sub>. $\frac{1}{2}$ H<sub>2</sub>O), barite (BaSO<sub>4</sub>), celestite (SrSO<sub>4</sub>), magnesium sulphide (MgSO<sub>4</sub>), originating from mixing sea water with brine and rock. It could also be the precipitation of iron hydroxide gel (Fe(OH)<sub>3</sub>) originating from the acid dissolution and other iron minerals such as pyrrhotite (FeS), pyrite (FeS<sub>2</sub>), hematite (Fe<sub>2</sub>O<sub>3</sub>), magnetite (Fe<sub>3</sub>O<sub>4</sub>) and siderite (FeCO<sub>3</sub>).

Pitzer K.S<sup>1</sup> developed general equation for electrolyte mean activity coefficient. This equation is based on the theory of interaction of the ions that are involved in the formation of scale. The equation accounts for both long and short range electrostatic interactions between ions and the effects of solvent types on scales formation tendency.

Fadairo et al<sup>2</sup> presents an analytical model based on existing thermodynamic model for predicting brine mobility, hydrocarbon mobility and mobility ratio of water flooded reservoir with possible incidence of scale precipitation and accumulation. The key operational and reservoir/brine

parameter which influence the mobility ratio such as salt concentration in the brine, produced water rate, pressure drawdown and reservoir temperature were identified through the model. Results of their study shows that the mobility ratio of a water flooded reservoir remains constant until water breakthrough and achieves an increasing local maximum at 10% pore volume injected water as the flow rate of produced water increases with a significant rise beyond the critical flow rate observed at mobility ratio of 1.

Haarberg *et al*<sup>3</sup> gave an equilibrium model which is capable of predicting the formation of CaCO<sub>3</sub> scales. They were able to give a detailed description of the model used in calculating the effect of pressure on CaCO<sub>3</sub> precipitation but variation of permeabilities of the porous medium caused by this precipitation was not accounted for in the model.

Production problems caused by mineral scale in oil and gas production operations is a problem that has been known for long, barium sulphate scale was identified as the most difficult scale to control among numerous scaling problems. This is as a result of the low solubility of barium sulphate in most fluids and the commensurate low reactivity of most acids with barium sulphate scale.

This paper presents a **Solution [X]** (based on experimental analysis) for effective wellbore and open hole clean up of a producing well at different temperatures, especially at offshore locations where seawater is mostly injected. An analytical model for the prediction of BaSO<sub>4</sub> scale build up rate under an idealized flow condition as derived by Fadairo *et al* (2008) was used for prediction of scale formation. We observe technical issues that influence the impact of BaSO<sub>4</sub> scale deposition on inflow performance and also identify key parameters that influence the magnitude of BaSO<sub>4</sub> scale deposition. Using this model as a predictive tool, the effective planning for BaSO<sub>4</sub> scale treatment (clean up) using **Solution [X]** during production operations is applied.

### EXPERIMENTAL ANALYSIS

In developing this solution, the properties of an oil based mud, a reconditioned oil based mud and the mechanism of impairment to flow that is caused by deposition of scale both inside the well bore, behind the casing walls and at the pore throats is considered to be of importance. Some key factors considered are;

- Movement/transportation of precipitated salt (scale) to the region of deposition
- Changes in both temperature and pressure conditions as oil and water are being produced from the reservoir which

will bring about a change in the solubility of solid salt in the reservoir.

- The volume of the pore spaces where scale are deposited
- The degree of resistance to flow caused by the deposited scale which is as well governed by the relative permeability of the fluid phase

Based on the factors above the components for **Solution [X]** were ascertained and combined at appropriate ratios under careful laboratory procedures and supervising.

**Formulation:**

Product	Concentration	Density
	%	SG
XXX	20.0%	1.1140
<b>CaCl<sub>2</sub> Brine</b>	32.0%	1.2120
XXX	10.0%	1.0491
XXX	5.0%	1.1800
Water (Free Water)	32.0%	1.0000
Corrosion Inhibitor	1.0%	0.8920
	100%	1.16

*Final density*                      *XXX*

Equipment used in carrying out the experimental procedures include,

- A 4-scale metal mud balance
- Retort kit
- Rotational Viscometer
- API Filter Press
- Aloxide Disc
- Roller oven
- Heating Chamber
- Back loaded mud samples
- Pre mud samples/Freshly built mud

**EXPERIMENTAL PROCEDURE**

Step 1. Mud property determination

Step 2. Scale formation and precipitation rate determination

The scale formation and precipitation for each mud type was determined using the model as proposed by Fadairo et al (2008) at varying temperature values

Step 3. Mud sample heated for varying time from 1hr to 14days respectively

Step 4. Mud filtration rate determined for each sample

Step 5. Mud cake deposition on Aloxide disc

Step 6. Disc soaked in **Solution [X]** for varying time until complete wash out occurs

Test 1

This clean up test was carried out using freshly built mud (BLEND A)

Test 2

This clean up test was carried out using back loaded mud (BLEND B)

Test 3

This clean up test was carried out using reconditioned mud (BLEND C)

Test 4

This is compatibility test (this test is to certify the immiscibility between **Solution [X]** and reservoir fluid (crude)

Using our double ended cell, sample of refined mud filter cake on a 40 micron aloxide disk is obtained via HTHP process. The aloxide disk containing with the filter cake is immersed in the soaking solution, and remove every 30mins/1hrs to evaluate the rate of destruction

**RESULT ANALYSIS**

Phase stability

Approximately 400 ml of the final Solution [X] formulation shall be transferred to a beaker and tested at 145°F to check for phase stability, for 24hrs. The samples should remain single phase

Initial soaking blend



Soaking blend after 24 hour



**Test 1.** This clean up test was carried out using freshly built mud (BLEND A)  
The pictures below illustrate the filter cake destruction after exposing the filter cake/scale to **Solution [X]** for 8hrs 30mins.





There was a complete clean-up after **8hrs 30mins** in the soak solution.  
\*We had a total break through time of 2hrs.

**Test 2.** This clean up test was carried out using back loaded mud (BLEND B)

The pictures below illustrate the filter cake destruction after exposing the filter cake to the new formulation for 10hrs.







There was a complete clean-up after **10hrs** in the soak solution

\* We had a total break through time of 2hrs 45mins

**Test 3.** This clean up test was carried out using Reconditioned mud (BLEND C)

There was a complete clean-up after 8hr 10mins in the soak solution

\* We had a total break through time of 2hrs 05mins

**Test 4.** This is compatibility test (this test is to certify the immiscibility between **Solution [X]** and reservoir fluid (crude))

- 1) Prepared 600mls each of Solution [X] using the following formulations as stated previously
- 2) Decanted 25%, 50% & 75% of respective crude samples into each labelled glass cylinders and filled up with Solution [X] and shake sample.
- 3) Stood beakers upright and visually check for separation/precipitation/emulsion at room temperature (26 deg C) before placing sample beakers into water baths to heat at 145°f for 30mins.

**Results:**

Sample Description	Crude	
Crude API / SG	31 / 0.87	
Crude Grade	Light Oil	
Temperature / Time	145°F for 30mins	
Emulsion Formation	No	
Separation	Yes	
Precipitation	No	
<b>TEST SAMPLE</b>	<b>A</b>	<b>B</b>
Emulsion Formation	No	No
Separation	Yes	Yes
Precipitation	No	No

### Visuals:



### CONCLUSION

A solution that reliably cleans the wellbore and unplugs formation of  $\text{BaSO}_4$  scale formed either during or after a drilling operation has been developed. Qualities of the solution includes the following:

- The **Solution [X]** was able to clean up the filter formed and render water wet the associated solids
- No visible phase separation was observed before and after **Solution [X]** blend was heated for over 24 hours at 145degrees Fahrenheit in a water-bath. The sample passed the test criteria maintaining a single phase.

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