Innovative Fluid System for Dissolving Lead Scales – Fluid Development and Field Trial in a Geothermal Well

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ABSTRACT

For a geothermal project in Denmark, our customer planned to treat lead scales clogging the bunter sandstone reservoir (TVD: 2500 – 2600 m; BHT: 63°C). Through extensive laboratory research, we developed a new fluid system specially customized to dissolve actual bailer samples. The premium quality of the first trial and hence the supreme efficiency of this state-of-the-art system was verified by lab and field results.

1. INTRODUCTION

Scale formation may decrease flow potential of geothermal wells reducing project profitability. For premium results, remedial treatments, as well as fluid recipes should be diverse and optimized according to the respective reservoir conditions. Nonetheless, it is often common practice to employ standard hydrochloric acid-based solutions, even for persistent and more complex precipitates. This paper presents the development of an innovative fluid system specially customized for dissolving lead (Pb^{2+}) scales and highlights its field trial in a geothermal well.

The first component of this new system is a salt dissolved in water providing clay control and pH-adjustment. The second is a biodegradable acid, which shows low environmental impact (Lummer et al. 2015).

2. LAB EXPERIMENTS

Solubility tests were performed with actual scale samples from the geothermal well. After an exposure time of 3 hours at 63°C, the weight loss of the material was gravimetrically determined.

Metal coupons were cut, polished and rinsed using butyl glycol prior to corrosion testing. Weight loss of the metal sample was measured after an exposure time of 3 hours at 63°C. All corrosion tests were performed at a differential pressure of 1,000 psi N_2. Here, the fluid volume / metal surface area ratio was held constant at 5.7 mL/cm².

Weight increase of elastomers were measured after an exposure time of 40 hours at 63°C. Fluid compatibility with synthetic formation water (composition in accordance with the customer) was tested with live and spent acid.

3. LAB RESULTS

In hydrochloric acid, dissolved lead-ions form $PbCl_2$-precipitates at lower temperature (see Figure 1).

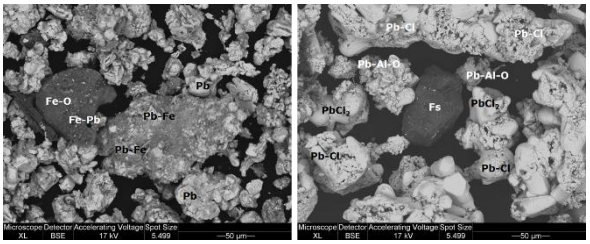

Figure 1: Lead scale before (left) and after (right) contact with HCl.

In contrast, Pb^{2+} remains highly soluble in the new system rendering it most preferable for descaling purposes. Table 1 summarizes the results of solubility testing with actual lead scale samples.

Table 1: Solubility of lead scale in different fluid systems, as determined after 3 hours at 63°C.

Fluid	Composition	Scale Solubility, %
1	H_2O + STB-502 (Step 1)	27
2	SSB-007 (Step 2)	31
1 + 2	Step 1 followed by Step 2	38

This innovative fluid composition provides compatibility with elastomers and synthetic formation water. (see Figure 2 and 3) Additionally, it is extremely low corrosive (< 0.05 lbs/ft²).

Beaker	Content	Ratio	Element/Ion	Concentration in FW, mg/L
1	Formation Water (FW)	90 mL / 0 mL	Sodium, Na^+	54,000
2	FW + Fluid 1	45 mL / 45 mL	Calcium, Ca^{2+}	23,600
5	FW + Fluid 2	85 mL / 5 mL	Magnesium, Mg^{2+}	2,910
6	FW + Fluid 2	89 mL / 1 mL	Chloride, Cl^-	137,000

Figure 2: Compatibility testing with formation water (FW).

Fluids	Increase in weight of Nitrile after 40 hours @ 63°C, wt%
H_2O	0.7
H_2O + 25 kg/m³ STB-502	0.8

Fluids	Increase in weight of Nitrile after 40 hours @ 63°C, wt%
SSB-007 (20%)	0.8
HCl (15%)	0.9

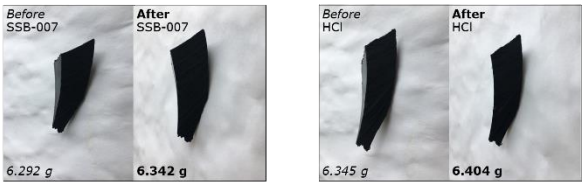

Figure 3: Compatibility of different fluids with Nitrile, as determined after 40 hours at 63°C.

4. FIELD TRIAL

Chemical injection via tubing targeted eight different zones in the perforated liner section of the Bunter sandstone formation (TVD: 2500 – 2600 m; BHT: 63°C). In the course of the three treatment steps planned for this application, cup tools provided fluid separation and diversion. Figure 4 shows equipment on site and pumping schedule.

Wash Interval	Pre-Flush (brine), m³	STB-502, m³	Displacement (brine), m³	SSB-007, m³	Displacement (brine), m³	Over-Flush (brine), m³
1	15.0	2.7	10.0	4.0	10.0	20.2
2	15.0	1.7	10.0	2.6	10.0	13.0
3	15.0	0.4	10.0	0.6	10.0	2.9

Figure 4: Equipment on site and pumping schedule.

The superior chemical properties of this biodegradable treatment fluid system combined with an optimized pumping schedule resulted into an greatly improved injectivity of the geothermal well (see Figure 5).

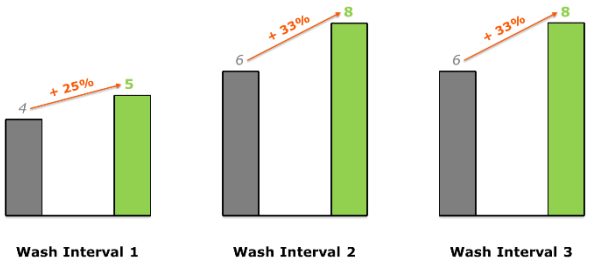

Figure 5: Injectivity index in L/min/bar before (grey) and after (green) fluid treatment.

5. CONCLUSIONS

Based upon excessive lab testing and vast field experience, the biodegradable acid system presented here was specifically customized to meet unique project-related demands. Its biodegradability, low corrosion tendency and excellent compatibility profile complement this state-of-the-art treatment fluid. system.

Table 2: Summary

New fluid system for dissolving lead scale
✓ Very effective chemical injection via tubing
✓ Premium fluid diversion employing cup tools
✓ Successfully stimulated Bunter sandstone formation
✓ Supreme chemical properties of fluid system resulted into a greatly improved performance

REFERENCES

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