

## **How To Acquire A Reliable Scale Inhibitor MEC Value Based On Laboratory Testing Results – A Field Case Study**

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### **ABSTRACT**

Laboratory scale inhibitor performance tests have been widely accepted to screen products and determine the minimum effective concentrations (MEC) of selected products for field treatment. The dynamic tube-blocking test is the most common lab testing method used to obtain an inhibitor MEC number because the testing temperature, oxygen level, pH, and pressure can be well controlled to duplicate the field scaling conditions. A new benchtop testing method, the Kinetic Turbidity Test (KTT), has drawn increased attention for scale inhibitor evaluation and MEC determination under some scaling circumstances due to its ability to monitor the formation and growth of mineral scales continuously throughout the test duration.

In west Texas, a well being evaluated had failed three times within 1.5 years because of the formation of scale on the ESP pump, even though it had an aggressive squeeze treatment with the inhibitor residuals of 20 ppm and above. Both lab dynamic tube-blocking tests and KTT results show that 5 ppm of the selected scale inhibitor would be sufficient to prevent the formation of scales for a general produced water sample. However, under the worst scaling scenario according to historical produced water data, KTT results indicate that more than 30 ppm of scale inhibitor is required to achieve an effective scale treatment, whereas the dynamic tube-blocking test MEC is still well below 20 ppm. This paper is intended to give some insight on the field treatment failure analysis by comparing the difference between the MEC obtained from different testing methods at various scaling conditions. The other possible reasons that may cause treatment failure, such as uneven scale inhibitor distribution at different producing zones and inhibitor residual samples contamination, are also included in this study.

**Key words:** dynamic tube-blocking test, Kinetic Turbidity Test, Scale inhibitor, MEC

## INTRODUCTION

The formation of mineral scales is one of the most problematic threats to the oil and gas operations which can lead to loss of production, increased lifting costs and assets deterioration.<sup>1</sup> Mineral scales can precipitate at any locations within an oil and gas production system and create blockage in perforations, production tubulars, pumps, and surface equipment. The formation of scale deposits can be attributed to the mixing of incompatible waters from different production zones or physical and chemical condition changes associated with produced water transporting from reservoir to wellhead and further to processing facilities.<sup>2,3</sup> The most efficient method to control scale deposition is the use of scale inhibitors that can catalytically prevent the precipitation of mineral scales. These chemical scale inhibitors are able to prevent the formation of scale at a treatment dosage that is typically hundreds to thousands times less than the concentration required for acid or chelate treatment, and thus are referred to as “threshold” inhibitors. For a given produced water, the threshold concentration required to prevent the formation of scale is one of the most important terms used to guide the design and deployment of scale inhibitor treatment programs, and it is normally referred to as the minimum effective concentrations (MEC) in the oil and gas industry.

Conventionally, there are two laboratory testing approaches adopted throughout the industry. One is the static “bulk” or “bottle” test, and is a common testing procedure that can be found in the NACE standards TM 0197-97. The static bottle test is widely used to compare the performance of different scale inhibitors, but it is difficult to duplicate the field scaling conditions if the test needs to be under pressure or the testing temperature is higher than 100°C. Moreover, static bottle testing is not convenient to maintain testing brine pH in the presence of bicarbonate and needs extra effort to create anaerobic testing condition to prevent the oxidation of dissolved Fe<sup>2+</sup>. Another major testing method is dynamic tube-blocking test, which was originally developed for scale inhibitor selection targeted on boiler, water pipe and desalination processes.<sup>4</sup> A typical dynamic tube-blocking test is to monitor the differential pressure change across a testing coil with a small diameter right after a scaling cationic water is mixed with a scaling anionic water. Any differential pressure increase is attributed to the formation of precipitates from the combined water that form within the testing coil. Dynamic tube-blocking test can simulate the dynamic fluid system as it exists in oilfield production and is able to overcome the pressure, temperature limitation, and pH, anaerobic condition maintenance issue which are common in static bottle test.<sup>5</sup> As a result, this method has been routinely used for scale inhibitor performance evaluation and MEC determination under oilfield environments.

The static bottle test is easy to prepare and obtain acceptable accurate results. However, it is time-consuming to use titration or ICP to obtain scaling ion concentration for inhibitor efficiency calculation, and the visual observation during the bottle test is subjective.<sup>6</sup> To overcome these drawbacks, the Kinetic Turbidity Test (KTT) Method has been developed lately and widely used for scale inhibition testing.<sup>7-11</sup> KTT can monitors testing brine turbidity changes caused by the formation of scales with up to 12 samples, in one round of testing. Compared with the conventional static bottle test, this method provides an effective and rapid way to differentiate the performance of scale inhibitors.

In this paper, the inhibition performance of different scale inhibitors is evaluated via both KTT and dynamic tube-blocking test. The scale inhibitor MEC number obtained from these two different methods are used to compare with field observation to address the possible reason for field inhibitor treatment failure. This work is intended to give some insight on how to interpret the laboratory inhibition testing results to guide field treatment at various scaling conditions.

## EXPERIMENTAL PROCEDURE

Kinetic Turbidity Testing is conducted with an ultraviolet-visible (UV-Vis) spectrophotometer, which measures the absorbance of the sample solutions at a certain wavelength. Up to 12 sample cells are arranged in a multi-sample holder with magnetic stirring in all cells. Samples can be tested simultaneously at temperatures ranging from 4°C to 95°C with specifically designed cuvettes that are usually made of quartz. Each cuvette has a small recess on the bottom to hold a small magnetic stir bar.

To conduct the test, a cuvette is placed in the first cell holder with 3 mL of deionized water to establish the baseline for turbidity. For sample preparation, anion brine is first added to the sample cuvettes. Various concentrations of inhibited anion brine are then added to each of the remaining cuvettes to attain the desired range of scale inhibitor dose rates. Immediately before the start of the test, cation brine is then added to each of these cuvettes thus completing the synthetic brine, initiating ionic interactions, and reaching final scale inhibitor dosage. The spectrophotometer measure absorbance every 2 minutes, with a 5-second measurement time per cuvette over a 2-hour period. The testing period can be longer based on the requests or requirements. The absorbance versus time data is used to determine the rate of reaction. This function records scale formation kinetics and differentiates scale inhibitor performance by observing how fast absorbance increases. The faster the absorbance increase observed, the faster the scale formation. The wavelength for analysis of turbidity is 350 nm.

Dynamic tube-blocking tests were performed using a typical automated tube-blocking apparatus. Two non-scaling brine components are mixed in this test. One component contains twice the final concentration of all anionic components other than chloride; the other contains twice the final concentration of all cationic components other than sodium. Both brine components contain a rationed amount of sodium chloride in order to give the two brines approximately equal densities which enable them to mix quickly. When mixed with a 1:1 ratio, the two components reconstitute the scaling water. The inhibitors are mixed at fixed concentrations in portions of anionic brine. Prior to inhibitor addition, the anion solution is adjusted to desired pH by sparging CO<sub>2</sub> and N<sub>2</sub> gas. The inhibitor concentrations are at least twice the highest concentrations to be tested. Inhibited anionic brine is subsequently mixed with uninhibited anionic brine in various proportions via automated pumps to yield various lower concentrations of inhibitor in the anionic brine. This inhibited anionic brine mixture is combined with the uninhibited cationic brine in a 1:1 ratio to give the final inhibitor concentration and create a scaling condition.

The anionic and cationic components are heated by passing through separate 3.0-meter-long heat exchange tubes in an oven. Then the heated components enter a mixing tee. The mixture immediately runs through a 1.0-meter-long capillary tube (also referred to as the testing coil or scaling coil) with an inner diameter of 1.0 mm. The differential pressure across this capillary tube is measured while the scaling brine flows at a constant rate. An increase in differential pressure indicates that solids are forming in the tube and adhering to the tubing wall. The flow rate of the scaling brine is fixed at 10.0 mL/min.

## RESULTS

### Average Scaling condition

In west Texas, a well has failed three times within 1.5 years due to the formation of scale on the ESP pump. This well had an aggressive scale inhibitor squeeze treatment right after the scale issue was identified. The scale inhibitor residuals were monitored periodically after the squeeze. The inhibitor return concentrations were at 20 ppm or above as this well experienced failure again (Figure 1). The first set of average produced water composition and downhole conditions show that this well only has a moderate calcium carbonate scale issue (Table 1).

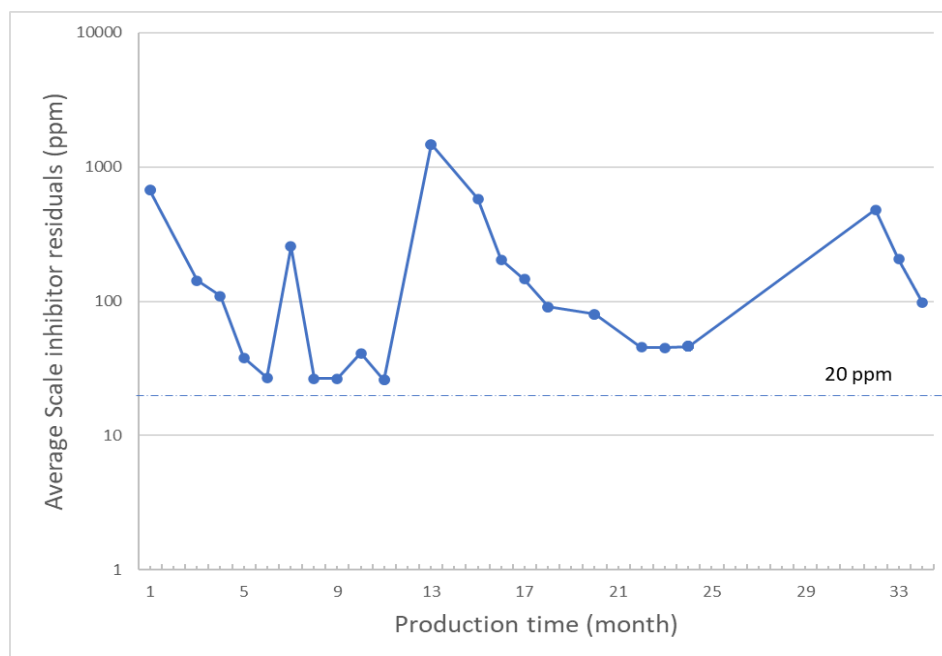


**Figure 1: Scale inhibitor residuals trend during production**

**Table 1: Average Produced Water Composition and Downhole Condition**

| Ions                                     | Unit                                  |          |
|------------------------------------------|---------------------------------------|----------|
| Na <sup>+</sup>                          | mg/L                                  | 15,050.7 |
| K <sup>+</sup>                           | mg/L                                  | 295.9    |
| Mg <sup>2+</sup>                         | mg/L                                  | 778      |
| Ca <sup>2+</sup>                         | mg/L                                  | 2,294.8  |
| Sr <sup>2+</sup>                         | mg/L                                  | 46.8     |
| Ba <sup>2+</sup>                         | mg/L                                  | 0        |
| Fe <sup>2+</sup>                         | mg/L                                  | 0        |
| Cl <sup>-</sup>                          | mg/L                                  | 26,298   |
| SO <sub>4</sub> <sup>2-</sup>            | mg/L                                  | 2,591.9  |
| HCO <sub>3</sub> <sup>-</sup> Alkalinity | mg/L as HCO <sub>3</sub> <sup>-</sup> | 1,952    |
| Downhole pressure                        | psi                                   | 1,000    |
| Downhole temperature                     | °F                                    | 130/170  |
| pH, measured (STP)                       |                                       | 7.0      |
| Calcite scale saturation index           |                                       | 1.78/2.0 |

Since the scale deposit was found on the surface of the downhole ESP pump, and the ESP pump temperature may be higher than bulk solution temperature, the laboratory testing temperature was adjusted from 130°F to 170°F to simulate this temperature variation. As a result, the calcite saturation increased from 1.78 to 2.0 accordingly. Scale inhibitor A has been squeezed in the field for this well to control the formation of scales, and its performance was evaluated via KTT and dynamic tube- blocking test. The dynamic tube-blocking test shows that 5 ppm of Scale inhibitor A is sufficient to prevent the formation of scale (Figure 2), and there is no brine turbidity increase is recorded within 30 minutes based on KTT result (Figure 3) as 5 ppm of inhibitor A is applied.

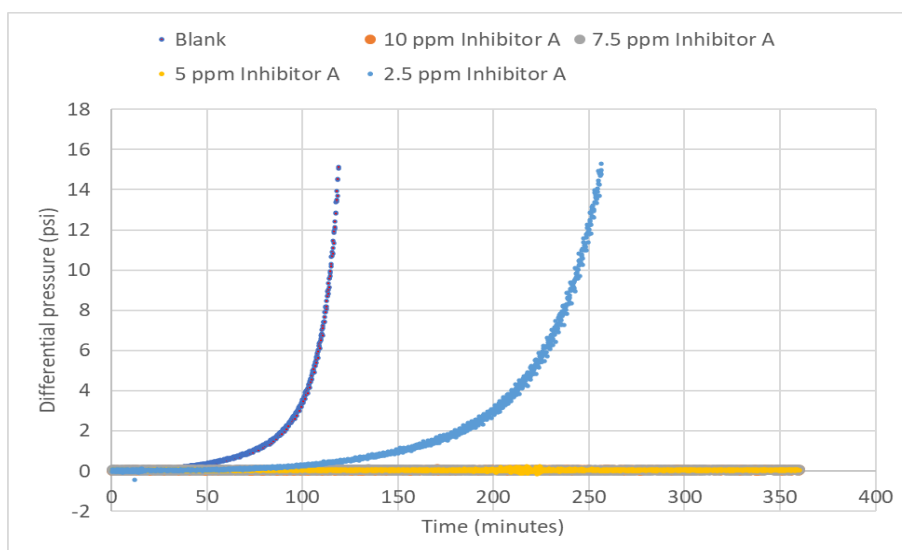


**Figure 2: Dynamic tube-blocking test for scale inhibitor A at 170°F, calcite SI=2.0.**

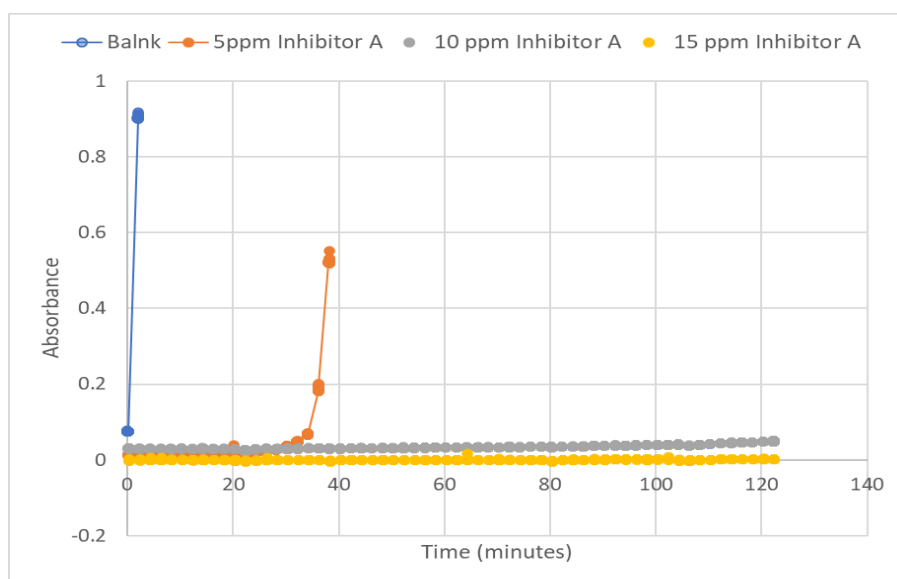


**Figure 3: KTT result for scale inhibitor A at 170°F, calcite SI=2.0.**

One major difference between dynamic tube-blocking test and KTT/static bottle test is the testing residence time. The residence time for tube-blocking test is generally less than 5 seconds, whereas the residence time for KTT can last up to 22 hours. Intuitively, if a scale inhibitor can provide longer than 5 seconds inhibition time, it should pass the dynamic tube-blocking test. Therefore, there is always a concern that dynamic tube-blocking test may not be appropriate to demonstrate the oilfield scale inhibition where a long residence time is expected<sup>5</sup>. The required inhibition time ranges can change from minutes to hours depending on the well parameters and operation conditions, typically about 20 min.<sup>12</sup> However, in many field practices, the MEC obtained from dynamic tube-blocking test seems adequate to prevent scale formation. In this case, an acceptable 30 minutes static protection time can be reached as the MEC is set at 5 ppm based on dynamic tube-blocking test. One possible reason is that the ratio of metal coil surface area to scaling brine volume during a dynamic tube-blocking test is much higher than the container internal wall surface to scaling brine volume ratio in KTT or static bottle test, and thus more scale inhibitor may be required to pass the dynamic tube-blocking test.