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Underdeposit Corrosion (UDC) Testing and Mitigation Methods in the Oil and Gas Industry

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Foreword

This technical committee report presents an overview of the various methods used in the oil and gas industry to test and mitigate underdeposit corrosion (UDC) occurring in corrosive pipeline environments when solids are present and carbon steel is used. The testing techniques are different in nature and in design and therefore assess and evaluate UDC in different ways. It is not the intent of this report to favor one method over another. The objective is to provide industry users with some tools and means from which to choose when confronted with such an issue. The choice of methods relates mainly to the type of application at hand and how well the methods apply to such situations. The user is cautioned that the testing discussed in this report may not be representative or applicable to all pipeline conditions. UDC testing under majority hydrocarbon conditions or in the presence of wax, asphaltenes, and biofilms is still in its infancy and was excluded from this report.

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Introduction

Failures caused by UDC occurrence have been reported in the oil and gas industry in various applications. The solid deposits to be addressed in this report are limited to sand, scale, and corrosion products inside pipelines. Wax, asphaltenes, and biofilms certainly affect UDC; however, they are beyond the scope of this report. Accelerated corrosion under iron sulfide and iron carbonate films is thought to cause pitting initiation and propagation in CO_2 and H_2S containing environments. Pipeline mechanical cleaning becomes a key issue and is usually achieved using aggressive pigging programs on a regular basis. Moreover, corrosion inhibitors have the potential to prevent this type of corrosion, or at least minimize the pigging frequency. It is general practice to establish laboratory testing protocols that are able to assess UDC and evaluate the performance of a given inhibitor in protecting the pipe wall in the presence of solids on the surface.

Examples of UDC Testing Methods

Bubble Test Method

The standard bubble test is probably the simplest laboratory testing method used to assess UDC at ambient pressure. It simulates stagnant conditions and is capable of accommodating any type of solids, as the solids are simply dropped to the bottom of the test cell. The main objective of this test is to assess how the presence of solids affects the efficiency of the corrosion inhibitor to provide protection as a result of either inhibitor adsorption/loss to solids or competition between solids and the inhibitor to cover the steel surface.

Test Apparatus

Figure 1 shows a photo of a typical bubble test apparatus. The test vessel hosts fluids and electrodes (reference, working, and counter) as well as the gas bubbling tube and the temperature controller. It sits on a magnetic stir mantle and is normally wrapped with heat tape to operate at a given temperature range. As shown, and because of glassware arrangement, the bubble test is typically operated at ambient pressure and temperatures below boiling point.

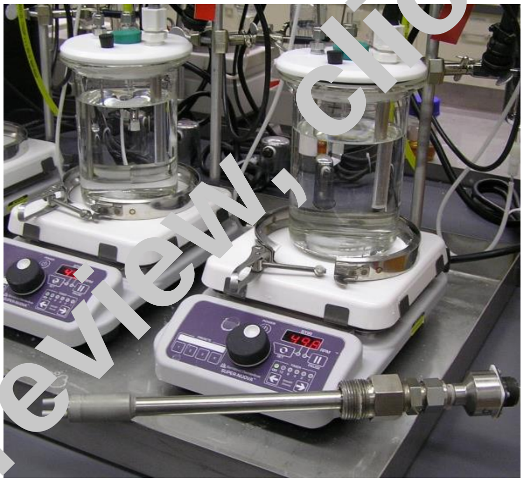

Figure 1: Photo of bubble test apparatus

Test Procedure

This test is normally designed in various ways, depending on the purpose of the investigation, the solids present in the system, and the corrosion measurement technique. The following is an example of a test procedure that is typically used to assess the effect of sand presence on inhibitor performance.

1. Two test vessels (vessel 1 and vessel 2) are used, one for testing without solids and one with solids.
2. Linear polarization resistance (LPR) electrodes are prepared by polishing the carbon steel working electrode, and then rinsing with non-aqueous solvents and drying. The reference electrodes are usually rinsed with xylene, then acetone. One set of electrodes is used for each chemical to be tested. Weight of the working electrodes is normally recorded if weight-loss measurements are to be made. The electrodes are not inserted into vessel at this time.
3. Solids are weighed and placed in vessel 1.

4. Volumes of brine and oil are then added.
5. The stirrer bar is placed in vessel 1 and the stirrer is activated. The immersion heater is then activated and the temperature set at the desired value.
6. The CO_2 sparge is usually started at this point.
    - The electrodes are inserted and connected to the multiplexer.
    - The electrochemical acquisition software is started.
    - Usually, the vessel is allowed to sparge, and the electrochemical acquisition software is programmed for LPR measurements for 1 h (uninhibited case).
7. The LPR program is paused after 1 h.
8. Normally, the desired amount of chemical is injected into the water phase in the vessel or on top of the oil phase, if oil/condensate is used.
9. The test is allowed to run for 48 h.
10. If weight-loss measurements are to be made, then the working electrode is cleaned and weighed. The average general corrosion rate is commonly calculated from the weight-loss measurements.

<u>Data Collection and Analysis</u>

Figure 2 is a picture of the test vessel used, including solids. The working electrode does not commonly touch the solids (e.g., the sand in this case). Typical performance curves obtained from the test are shown in Figure 3. In this case, a total of eight inhibitors were tested for performance when 10 grams of solids were present. The horizontal section of the curves represents the pre-corrosion step (for 3 h) before adding the inhibitor. This is an indication of a high blank corrosive environment (corrosion rate of about 250 mpy [.635 mm/y]). Once the inhibitor is injected, corrosion rate drops and reaches a low level at steady state. As shown in Figure 3, different inhibitors perform differently in the presence of sand. Inhibitor 1 is the worst performer, and inhibitor 8 showed the best performance. The lack of performance is likely because of the loss of inhibitor to the solids.

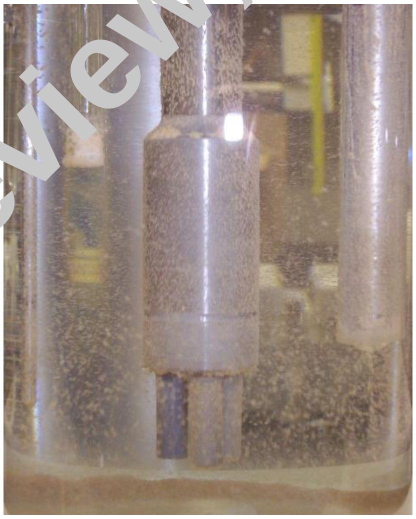

Figure 2: Bubble test used for UDC.