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Field Monitoring of Corrosion Rates in Oil and Gas Production Environments Using Electrochemical Techniques

Foreword

This report provides generally accepted procedures and practices used in oil and gas production environments to monitor internal corrosion rates using electrochemical techniques. Internal corrosion rates are monitored for various reasons including to understand the current status of the system, to optimize corrosion inhibitor concentration, and to estimate corrosion inhibitor efficiency. The infrastructures of the oil and gas production environments include casing pipe, downhole tubular, acidizing pipe, water generators, water injectors, wellhead, production pipelines, gas dehydration facilities, oil-separating facilities, and storage tanks. The typical environments of these infrastructures consist of varying amounts of oil, gas, water (formation water or production water), temperature, pressure, flow, corrosive species (carbon dioxide [CO_2], hydrogen sulfide [H_2S], oxygen [O_2]), microbes, solids, acetic acid, and ionic species (sulfates, carbonates, and bicarbonates).

The main advantage of electrochemical techniques is that they provide the corrosion rate as the corrosion occurs, i.e., they are instantaneous and online techniques. Using the data, the effectiveness of a corrosion inhibitor is instantaneously obtained and the concentration optimized readily. However, for more quantitative analysis, the data from electrochemical techniques are analyzed based on field operating conditions. Variations in pressure, temperature, production (i.e., volume of oil, water, and gas), composition of acid gases (CO_2 and H_2S), and solids also influence the electrochemical measurements.

*Chair Sankara Papavinasam, CorrMagnet Consulting Inc., Ottawa, ON

This report provides guidance for using electrochemical techniques to evaluate the performance of corrosion inhibitors in oil and gas production environments. It summarizes the specific areas where these techniques excel as well as those areas where their use is limited in the field. The data from the electrochemical monitoring techniques is used to identify corrosion mechanisms and/or trends that will aid in selecting effective inhibitors and optimizing their concentrations (or application frequency) within a system.

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Introduction

Infrastructure in oil and gas production environments commonly experiences internal corrosion. Therefore, a significant portion of integrity management is devoted to controlling internal corrosion. NACE SP0106,[1] SP0206,[2] SP0208,[3] and SP0210[4] provide overall guidelines to assess internal corrosion and strategies to control it.

Application of corrosion inhibitors is one of the primary internal corrosion control strategies for carbon steel infrastructure in oil and gas production environments. Periodic monitoring of corrosion is an essential part of corrosion control. More than forty techniques are available to monitor and measure internal corrosion. NACE Publication 3T199[5] provides general characteristics, benefits, and limitations of these techniques, as well as procedures to convert the measured parameter to a corrosion rate and hence, corrosion inhibitor efficiency.

Because corrosion takes place in the aqueous environment by electrochemical principles, electrochemical techniques play a vital role in monitoring internal corrosion. These are sensitive monitoring techniques that detect corrosion-related changes as they occur and permit remedial actions to be taken before significant damage occurs. They are defined as direct (i.e., measure the corrosion rate directly), intrusive (i.e., place a probe inside the environment to monitor the corrosion), and real-time measurements (i.e., provide instantaneous corrosion rate, see ASTM[(1)] standards G96[6] and G102).[7]

Section 1: Electrochemical Techniques

Electrochemical techniques involve application of an electrochemical signal to the specimen, commonly known as a working electrode (WE), and measurement of the response of the electrode to that signal. The application of an electrochemical signal moves the potential of the WE from the potential it has developed in contact with the environment (commonly known as corrosion potential). When the potential of the WE is moved from its corrosion potential, the WE is said to be polarized. For this reason, most electrochemical techniques are called polarization techniques.

To apply an electrochemical signal onto the WE, another electrode known as an auxiliary electrode (AE) or counter electrode (CE) is used. During electrochemical measurements, this CE is polarized in the opposite direction of the WE, i.e., if the WE is polarized in the noble (positive) direction, the CE is polarized in the active (negative) direction.

The potential of a single electrode cannot be measured; only the difference between two electrodes can be measured. For this reason, a third electrode, known as a standard reference electrode (RE), is used. The standard REs have stable and reversible potentials. Table 1 presents some commonly used reference electrodes, their reversible potential, and factors to convert potential with respect to one reference electrode to the potential with respect to another reference electrode. Though standard REs are commonly used in the laboratory and have been demonstrated in the field,[8] nonstandard REs (made of material used as a WE) is used in the field. The RE is electronically connected to the WE through a high-impedance voltmeter. The high-impedance voltmeter limits the current to a sufficiently low value to not polarize the RE significantly.

[(1)] ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.