

THIS MONTH: PIPELINE CORROSION

MAY 2012

MMP MATERIALS PERFORMANCE

CORROSION PREVENTION AND CONTROL WORLDWIDE

Interpretation of Indirect Inspection Data in the ECDA Process

**Installing a Deep Anode
Groundbed in a Marsh
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**Materials and Corrosion
Control in Desalination
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Management with Forensic
Corrosion Engineering**

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CORROSION PREVENTION AND CONTROL WORLDWIDE

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Material Matters

Biocorrosion probe monitors microbiologically influenced corrosion of carbon steel



The biocorrosion probe is shown mounted on the side of a geothermal pipeline. Photo courtesy of CFG Services.

In the 1980s, the oil and gas industry discovered that pitting and crevice corrosion on carbon steel (CS) pipelines and well casings were caused by sessile bacteria such as sulfate-reducing bacteria (SRB) and thiosulfate-reducing bacteria (TRB).

To address microbiologically influenced corrosion (MIC) in CS pipelines and equipment, a research team led by Catherine Cotiche, corrosion department manager with CFG Services (Orléans, France), a French geothermal engineering firm and subsidiary of earth sciences

research center BRGM (Bureau de Recherches Géologiques et Minières), has developed an in situ biocorrosion sensor system to monitor MIC and the efficiency of biocide treatments. This research and development project was launched in 1999 by CEP&M (Comité d'Etudes Pétrolières et Marines), the French governmental advisory committee for oil and gas research and development, with 50% funding support from FSH (Fonds de Soutien aux Hydrocarbures), the French funding organization for the hydrocarbon industry.

While the presence of a biofilm does not necessarily result in biocorrosion, biofilms that contain SRB and TRB may trigger localized corrosion phenomena, says Cotiche. She explains that sulfidogenic bacteria, such as SRB and TRB, reduce sulfates and thiosulfates into sulfur. These bacteria play a crucial role in corrosion because they modify the local physical and chemical characteristics of the fluid and internal surface of the pipeline. SRB and TRB colonies can be found in patches along a CS pipeline, and this non-uniform distribution of bacteria results in the formation of differential aeration cells that create differences in electrical potential and consequently cause corrosion currents that may lead to pitting or cracks. The products of the bacteria's metabolism (HS^- anions) also can lead to the formation of iron sulfides, which may increase the energy dissipation of a pipeline fluid (known as head losses).

Industry uses chemical treatments to mitigate internal biocorrosion in CS

Information on corrosion control and prevention

pipelines. However, says Cotiche, an efficient tool was needed to monitor the corrosion rate induced by microorganisms and the effectiveness of biocide treatments. Existing methods to measure corrosion induced by microorganisms can be limited because they may not quantify the actual risk of biocorrosion in real time and in situ.

For example, visual inspections or inspections with cameras for detecting internal corrosion and corrosion under deposition are limited, and shutting down the pipeline for inspection is necessary. Analysis of corrosion coupons—samples made with the same metal as the pipeline that are immersed in the fluid and then analyzed—requires laboratory facilities and results are not immediate. Bioprobes that sample a piece of biofilm have the advantage of quantifying the bacterial activity responsible for corrosion, but the corrosion is not directly quantified and analysis of the sample takes time. Bacterial tests, quantifications of planktonic SRB and TRB in culture media, do not numerate sessile bacteria (which are directly involved in corrosion phenomena) and may underestimate the real risk of biocorrosion. Plus, the results are not obtained in real time.

Other instruments use probes to monitor the growth of biofilms, but a biofilm is not necessarily responsible for corrosion, Cotiche says. Consequently, in order to ensure plant equipment is protected, large quantities of biocides may be injected into a pipeline, often with high environmental and economic impacts.

The biocorrosion sensor system developed by the researchers monitors, in situ, the biocorrosion rate of a CS pipeline due to the presence of a biofilm. The instrumentation comprises a probe with built-in electronics as well as remote electronics. The monitoring technology is based on

pit generation by anodic polarization on a small surface electrode (anode) that is short-circuited with a large surface electrode (cathode). By correlating this artificial corrosion with the presence of a biofilm, the risk of biocorrosion can be evaluated, says Cotiche. The signal delivered by the device directly relates to the corrosion speed of the artificial pit created by anodic polarization, and the intensity of this pit is directly linked to the corrosivity of the biofilm present on the anodic surface.

The biocorrosion sensor system is made up of three main elements: an electrochemical probe, a remote control unit, and a software package. The electrochemical probe is mounted directly to the pipeline with a 1-in (25-mm) gas connection. A CS anode is immersed into the pipeline fluid and the probe body connected to the pipe plays the role of the cathode. If the pipe is not CS, a dual electrode probe is used.

The electronic unit on the probe head is integrated in an explosion-proof box. The remote control unit, which can be powered by available electricity, rechargeable batteries, or a 20-W solar panel, manages the sensor system instrumentation either locally or by long distance using a Global System for Mobile (GSM) communication modem. The software sets up measurement cycles and recovers monitoring data, which are presented as graphs. The biocorrosion sensor system can also control a pump that injects biocides into the pipeline.

To measure biocorrosion rates of a CS pipeline, the biocorrosion sensor system progresses through three basic operational phases. During the first phase, the probe is immersed in the fluid and the system evolves toward electrochemical equilibrium, where the state of the small

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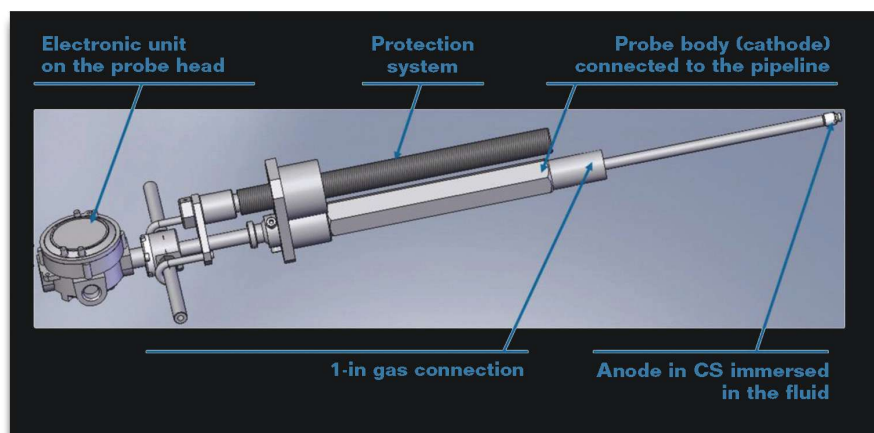
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Schematic of the biocorrosion probe. Image courtesy of CFG Services.

electrode surface mirrors the state of the pipeline surface. The biofilm forms on the small electrode during this phase, which takes a few days. During the second phase, a corrosion pit is created by applying an anodic current to the surface of the probe's small electrode.

The artificial corrosion pit is similar to the natural corrosion induced by bacteria. The duration of this phase is <15 min. In the final phase, which can last several days depending on pitting corrosion, the probe's two electrodes are short-circuited and corrosion current is gener-

ated by the electrochemical cell. The intensity of the current delivered by the electrochemical cell is measured and converted into a biocorrosion rate of mm/y, which represents the general corrosion rate of the CS. If the bacterial corrosion remains active, the corrosion rate remains around a few mm/y. If not, the corrosion rate tends to drop to a few $\mu\text{m/y}$.

The position of the probe in the pipeline is crucial and impacts the instrumentation's signal. In addition to the bacterial nature of the fluid in the pipeline, other physical parameters can affect bacteria proliferation and impact the biocorrosion rate, including flow rate, fluid temperature, operating conditions, and the geometry of the pipeline. Additionally, Cotiche notes, probes should be installed at locations within a pipeline circuit where chemical, bacterial, and physical conditions may vary.

Biocorrosion monitoring tests were conducted by CFG Services between September 2005 and March 2006 on a French oil processing plant. These tests were performed with a dual electrode probe on a 6-in (152-mm) separated water reinjection pipe made of Duplex 2205 stainless steel (UNS S32205). Test results led to the conclusion that the biocide injections did not fully deactivate the pitting corrosion sustained by bacteria, and between two biocide treatment phases, the pitting corrosion reactivated to attain a level comparable to that before the treatment.

These monitoring tests also demonstrated that the biocorrosion sensor instrumentation facilitates the optimization of the biocide treatments in terms of concentration, frequency, and duration. This method was also tested on a geothermal plant in Meaux, France. The biocorrosion probe was made available commercially in 2009.

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