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Advanced Procedures for Analysis of Coupons used for Evaluating and Monitoring Internal Corrosion

► An introduction to obtaining the maximum informational value from corrosion coupons

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1 A New Look at Corrosion Coupons

Introduction

Historical

A recent article in the Oil and Gas Journal, Field Use Proves Program For Managing Internal Corrosion In Wet-Gas Systems, by R. Eckert and B. Cookingham, introduced an improved coupon analysis protocol based on electron microscope examination of the exposed coupons. While the concept of in-depth analysis of corrosion coupons is not entirely new, the article points out some significant benefits from applying this analytical protocol to pipelines and gathering systems. It is likely that others in the oil and gas industry may want to investigate the use of these procedures. This introductory paper is meant to provide guidance for those seeking to apply the latest in coupon analysis technology to their own systems.

The scientific basis for the analytical procedures described here and in the OGJ article was first published in 1991 by Dr. Henry C. Aldrich, et al, in “Microbially Influenced Corrosion and Biodeterioration”, a collection of papers presented at the University of Tennessee that same year. Dr. Aldrich led a team of researchers at the University of Florida who was working with the Gas Research Institute’s Microbially Influenced Corrosion group. Coupons of pipe steel were exposed to mixed bacterial cultures in the laboratory for various periods of time, then analyzed using Scanning Electron Microscopy (SEM), Energy Dispersive x-ray Spectroscopy (EDS), and Transmission Electron Microscopy (TEM). Data from the laboratory-exposed coupons was compared to data collected from coupons exposed in actual pipeline systems. The research showed that for very short exposures (< 100 hours), unique corrosion initiation features that correlated to the test environment consistently appeared on the coupons. For the biotic tests, small clusters of pits, which correlated to the locations of bacterial colonies, were noted in the SEM examinations. Similarly, for the abiotic control tests, only general etching type attack was noted in the SEM examinations. Finally, short-term coupon exposures in actual pipeline environments (known to have bacteria) were shown to have microscopic corrosion initiation features nearly identical to the laboratory coupons exposed to biotic environments.

While the techniques developed at the University of Florida appeared to be highly beneficial for identifying the cause of corrosion initiation, few in the natural gas industry attempted to apply the technology due to concerns over cost and the complexity of the analytical procedures.

Today, with increased regulation, liability and public awareness of pipeline safety issues, the justification for more sophisticated internal corrosion tools is solidified. Additionally, the techniques described here are applicable to a wide variety of situations including cooling water systems, chemical processing, tank monitoring, plant support piping and in other industries where internal corrosion of liquid handling facilities is a concern.

Benefits

The most important question of course, is: *what will this technology do for me*? The answer is, if applied correctly, this technology will determine the <u>cause</u> of corrosion initiation in a system. Lets examine the two pieces of information this coupon technology will provide; cause of corrosion initiation and exposure time-frame sensitivity.

EM Coupons: Corrosion Initiation

There is little correlation between the data collected from the specialized coupons described here, and that from traditional “weight loss” coupons. Henceforth in this article, the coupons for specialized analysis will be termed EM Coupons. The acronym “EM” first came about because the coupons were applied in <u>**e**valuating</u> potentially corrosive conditions, and <u>**m**onitoring</u> the effectiveness of mitigative measures. From a regulatory standpoint, evaluation coupons are simply another assessment tool (such as ER probes, compositional analysis, etc.) that operators can apply to investigate the conditions in their pipeline system. The evaluation of corrosivity is not considered to be a mandatory, regulated activity, unless; (1) corrosion that affects integrity has been identified, and/or (2) a corrosion mitigation program is implemented in response to the discovery of corrosion.

The cause of corrosion initiation on EM coupons is determined using SEM at typical magnifications of 1000X. Thus, a coupon that visually appears to be in perfect condition after a short-term exposure may well show significant initiation features upon microscopic examination. The corrosion initiation mechanism can be categorized between biotic, and various forms of abiotic attack. The level of categorization depends on the amount of information available about the operating environment.

Understanding the cause of corrosion initiation helps pipeline operators to select the most appropriate mitigation techniques. Initiation type is the most important piece of information collected from EM coupons. Further, looking primarily at initiation precludes some of the statistical error inherent in any coupon program, particularly where pitting corrosion is the most prevalent concern.

Time-frame Sensitivity

EM coupons are typically installed for short periods of time as compared to traditional weight-loss coupons. The exact exposure time depends greatly on the nature of the system being monitored, however it is typically on the order of several weeks vs. several months. In certain cases, EM coupons have even been exposed for a matter of days.

Time-frame sensitivity means that the data collected from the coupon is directly related to the period of time over which it was exposed. With shorter exposure periods, operators can better define the environmental conditions that may have contributed to the corrosion observed. In contrast, traditional weight-loss coupons may be exposed for 6 months to a year. If severe corrosion is observed on the coupon, it is much more difficult to relate it to the conditions which caused it. This is particularly important in gathering systems where operation is seasonal or the nature of the fluids changes significantly over short periods of time. This time-frame sensitivity is also valuable in evaluating the effects of mitigation treatments.

Other Benefits

Other important data is also obtainable from EM coupons, such as determining whether protective (or non-protective) scales form on the internal surfaces of the pipe, the nature and extent of biofilm growth, quantitative evaluation of corrosion and pitting, and the chemical species potentially involved in the corrosion reaction.

A key advantage of EM coupon technology is that the analyses performed on the coupon can be directed toward the anticipated or typical corrosion problems experienced in the system being monitored. For example, in an open cooling water system, the analysis may focus primarily on biofouling. Focusing the type of analysis toward the problem saves time, reduces expense and provides relevant information that operators can use to make informed decisions.

Finally, the ability to identify and treat the root cause of internal corrosion will certainly result in significant cost savings for most users of this technology. Consider how treatment chemicals (inhibitors or biocides) are typically applied. Often, a recommendation is made (perhaps by the chemical vendor) to achieve some constant level of chemical residual in the system. Where EM is impossible or impractical, this may be the only option. However, in many cases, this form of treatment is looked on as a form of insurance with the belief that as long as "recommended" chemical levels are maintained, everything will be fine. In reality, continuous chemical treatment cannot guarantee a leak-free system, and in some cases, this approach has exacerbated certain corrosive conditions or promoted resistance of microorganisms to chemicals.

Costs

As in all things, increased value is usually associated with increased costs. Moving beyond traditional weight-loss coupons to the use of EM coupon technology will result in higher analytical costs, while offering the potential for significantly lower operating costs by reducing wide-spread chemical mitigation treatment and corrosion repair costs.

Materials and Installation Costs

EM coupons may cost 20-30% more than weight-loss coupons due to special finishing and packaging requirements. Installation costs will be essentially the same as for any type of coupon program. In fact, EM coupons may often be installed in place of traditional weight-loss coupons using the same mounting devices. Removal costs for EM coupons will be higher than traditional coupons since they must be shipped in a preservative solution via next day air service to the processing laboratory.

Analytical Costs

Laboratory analysis of EM coupons could average nearly $500 per coupon depending on the types of analysis performed. Laboratory costs include preservation of the coupon, replication, cleaning, optical and SEM examinations, possibly EDS and epifluorescent microscopy of the embedment for bacteria. Typically, there are cost savings realized when higher volumes of coupons are processed at one time.

2 Application of EM Coupons

Establishing a Program

Getting Organized

Choose Your Target

The first step in getting organized is to carefully choose the facilities to be targeted for evaluation. This could be a section of piping with a long history of leaks due to internal corrosion, somewhere that potentially corrosive liquids or gases are taken into the system, or an area where it is difficult/costly to set up mitigation treatments. The point is, while EM coupons can provide highly valuable information to help solve your problem, there is also a cost associated with this technology that must be justifiable. It is also beneficial to work with a section of piping or pipeline facility for which adequate historical information is available in regard to the nature of the materials transported, previous cleaning and mitigation treatments, and leak history. Choosing EM locations based on a risk-management approach is also valid. Finally, while EM coupons have thus far found the greatest application in systems that transport liquids and gas, the concept may also be suitable for other operating environments.

Once a system has been selected for evaluation, obtain as much background information about it as possible, then review the data to identify representative locations for coupon installation. Perhaps there are already corrosion coupon locations on the systems that can be used for EM coupons. Ideal coupon sites will typically be located near any potentially corrosive inputs to the system or where liquids can collect, for example; well heads, liquid separators, and drips.

Develop a Plan

Once a target system has been chosen and coupon sites are identified, the next important step is to develop a plan that covers the field, analytical and management parts of the program. The field plans need to include responsibilities, training, provision of materials and funds, personnel and communication. Analytical plans should identify where the coupons will be analyzed, what procedures will be used, what data will be collected, reporting and costs. Finally, it is also beneficial to include some form of management plans to identify who will review all of the data, the process of making recommendations, and the method of communicating and implementing mitigation and additional monitoring steps.

All this planning may sound like extraneous work, however; for EM coupons to be used successfully, excellent communication regarding the program is essential.

Coupons

Materials and Design

Coupon Materials

Research has shown that corrosion initiation on low carbon steel is closely associated with the microstructure, and even more so, the size and distribution of inclusions. Chemical composition and thermo-mechanical history of the material provide the greatest influences on microstructure and the nature of inclusions in steel. Since EM coupon technology is based on the type of microscopic corrosion initiation features that appear after exposure, it makes sense to match the coupon material as closely as possible to the pipe or facility being monitored. Although most vintage pipeline steels are straightforward in composition (i.e., akin to AISI 1010 steel), their thermo-mechanical history is not always the same as hot rolled bar stock, from which most corrosion coupons are made. Therefore, whenever possible, it is worthwhile to use actual pipe from the system being monitored, or at least the same grade and vintage, to make EM coupons.

Coupon Design

Design criteria for EM coupons are somewhat flexible, however the following issues must be addressed in the final design;

- ✓ Coupons must fit existing installation hardware, or new hardware should be designed.
- ✓ Providing flat surfaces is essential for analysis. Ideally, two large, parallel surfaces, as in a rectangular coupon, are ideal. Round bar type coupons are not practical.
- ✓ The flat surfaces, which will be used for microscopic examination, must have a 600 grit wet ground finish; with all grind marks laying in one direction.
- ✓ The coupon should fit easily and securely into a vial or other small container that will prohibit the flat examination surfaces from contacting the side of the container.
- ✓ The size and shape of the coupon should be convenient for the analytical lab to work with. It must fit into their electron microscope, etc.

In general, the EM coupon surface area does not need to be as large as for traditional coupons, since the area being examined at high magnification is statistically significant even for relatively small coupons. A coupon measuring 1/8" thick X ½" wide X 1-1/2" long would be acceptable.

Preparation and Handling

Coupon Preparation

EM coupons are machined like any other corrosion coupon. Final finishing is more critical however, as the surfaces will be examined at magnifications to 1000X after exposure. Therefore, the final finishing and cleaning steps are more sensitive to quality and will involve more time and expense. After wet surface grinding to final dimensions, a 600 grit wet ground finish is applied to the flat examination surfaces of the coupon. Care must be taken to remove all evidence of the previous machine grinding step. The lay of the final grind should all be in one direction.

Immediately after wet grinding, the coupon is cleaned to remove all grinding debris, then rinsed in pure ethanol (not denatured – it can leave a film), dried with compressed nitrogen and packaged in a dry nitrogen atmosphere. No corrosion inhibitor is used on the coupon or packaging, as this could potentially affect the resulting corrosion observed during exposure, and create non-representative results. Packaged EM coupons can be stored in a desiccator until needed. Placing desiccant directly into the bags containing the coupons can result in corrosion and is not advised.

Handling and Shipping

Assuming that a rectangular EM coupon is used, it is imperative that the two largest flat surfaces not be handled during installation, removal or shipping. Those surfaces will be subjected to examination under high magnification; therefore, any disturbance to the surfaces can result in erroneous data. Field personnel must be thoroughly instructed regarding the importance and criticality of coupon handling. The surfaces must not be touched, scraped, rinsed off, handled with tools, or altered in any way. Exposure to air should always be minimized, and the coupon should not be allowed to dry out during removal.

Timeliness in shipping the coupons from the installation site to the laboratory for analysis is also critical. The desired result is that no change occurs to the coupon condition from the time it is removed until the time it is preserved in the laboratory. Obviously, this is not a simple undertaking, however there are some ways to minimize changes during shipping.

First, shipping from field to lab must always be done immediately after coupon removal, and always using the fastest means possible, such as next day air shipment. Second, the coupons must be shipped either in the liquid they were exposed to in-situ, or using a special preservative media to minimize biological and chemical changes. The simplest method is to use a small vial that the coupon fits securely into, and completely fill the vial with liquid from the test environment. If this is not practical, a sterile, anaerobic preservative media can be prepared for shipping the exposed coupons. The preservative must be customized to the test environment in regard to salt levels and pH to prevent gross changes to the corrosion or biofilm during shipment. These steps are still required even if there is no concern for microbial corrosion whatsoever.

The coupons must also be shipped “on ice” using cold packs. This stops the growth of bacteria for the most part, without destroying them. Care must be taken not to freeze the coupon liquid or the biofilm may be ruined.

3 Laboratory Procedures

Preservation

Key to Maximizing Data

What is Coupon Preservation?

Preservation is an important step in EM coupon technology. First, this process is used to preserve any biofilm and corrosion deposits in a form that does not significantly alter their chemical and spatial characteristics. Second, preservation maintains any biofilm/corrosion deposits in a form that is usable for subsequent analysis. Third, preservation is used to remove the deposits from a coupon in a way that does not physically alter any corrosion initiation features on the coupon surface. Finally, the preservation process maintains a one-to-one correspondence between biofilm/corrosion deposits and the actual corrosion itself on the coupon.

The preservation process is based on standard histological procedures used in cell science research. As mentioned earlier, this process was first adapted for use on steel coupons by Dr. Henry Aldrich at the University of Florida in 1991. Since then, preservation has been performed on thousands of coupons exposed in natural gas gathering facilities.

Coupon preservation produces two things; a coupon that is suitable for electron microscope examination, and an embedment of the biofilm/corrosion deposits that can be analyzed using several different means. With these two pieces of physical evidence, the cause of corrosion initiation can be thoroughly investigated in the laboratory.

Materials and Equipment

EM coupon preservation does not involve the use of any expensive equipment, although having a vacuum pump available helps the procedure to go much quicker. At minimum, sufficient standard laboratory glassware and pipettes are needed to prepare and transfer the preservation chemicals. Since formaldehyde is used in the procedure, a fume hood or well-ventilated area must be available for at least the beginning of the process.

EM coupons can be preserved in their shipping vials in most cases, since the vial is supposed to be close fitting to the coupon and keep the examination surfaces of the coupon from contacting anything. Pipettes are used to transfer the preservation chemicals into and out of the vials. For efficiency, a vacuum system can be used to remove the spent chemicals from the vials.

The chemicals used in the preservation are described in the next section.

Procedures for Preservation

Preservation should be performed as soon as possible after the coupons are received at their processing location. In some cases it is possible that preservation could be performed directly at field locations, eliminating the shipping step. Field preservation, if possible, is highly desirable. The longer a coupon has been removed from its exposure environment, the greater the likelihood that its true condition could change, resulting in misleading analytical data.

The preservation procedure described here has been used for coupons exposed to environments containing brine and hydrocarbons. This procedure may need to be optimized for different environments. The preservation process requires the following components; sterile deionized water, sterile phosphate buffer solution, 2% Formalin solution, pure ethanol (not denatured), LR White (medium) acrylic resin, and accelerator catalyst to cure the LR White. The acrylic resin, LR White, is manufactured by the London Resins Corporation, and is available from several electron microscopy suppliers.

The preservation procedure is given below. All reagents must be quickly and carefully transferred by pipette into and out of the vials containing the coupons. Do not touch the coupon surfaces and do not allow the coupon to dry out between steps. Add the liquids to the vials gently to avoid damaging the biofilm or washing off corrosion deposits.

	Step	Time (minutes)
1)	2% Formalin	10
2)	Phosphate buffer solution	10
3)	Sterile deionized water	10

	Step	Time (minutes)
4)	25% Ethanol/ 75% deionized water	15
5)	50% Ethanol/ 50% deionized water	15
6)	75% Ethanol/ 25% deionized water	15
7)	95% Ethanol/ 5% deionized water	15
8)	30% LR White/ 70% ethanol	60
9)	70% LR White/ 30% ethanol	60
10)	100% LR White	60
11)	100% LR White with Accelerator Catalyst	final step

Embedment Removal and Coupon Cleaning

Once the coupon has gone through the preservation procedure, its condition is stable and embedment removal can be performed at any time.

Removal of the embedment begins with trimming all excess acrylic resin from around the edges of the coupon. Obviously, if weight loss measurements are to be taken from the coupon, trimming away the resin must be done very carefully. In practice, since EM coupons are usually installed for very short exposure times, it may be more practical to dispense with the weight loss measurement altogether. Removing the resin from any boltholes on the coupon is also beneficial. Once all of the excess resin is removed, the following procedure is used to remove the embedment from the coupon:

1) Pack the coupon and embedment in dry ice for 10 minutes. (Use of liquid nitrogen usually results in fragmentation of the embedment, rending it difficult to work with.)

2) Remove the coupon and embedment from the dry ice and immediately immerse it into a large beaker of hot water (140º F). The different rates of thermal expansion of the steel and acrylic result in the embedment coming cleanly away from the coupon surface.

3) If the embedment remains attached, use a thin spatula or knife blade to carefully work it loose. Avoid any contact with the surfaces to be examined!

4) Upon removal of the embedment, place the coupon into 100% acetone. *Once the embedment is removed, the coupon must be handled with care to prevent oxidation*.

5) Soak the coupon in acetone for 24 hours to help loosen and remove any remaining bits of resin.

6) Final cleaning procedures depend on the condition of the exposed coupon: heavily etched coupons will tend to retain more acrylic residue. For most coupons, gentle swabbing with a cotton tipped applicator while the coupon is immersed in acetone will remove all of the acrylic residue without harming the surface. After drying with compressed, dry nitrogen, the coupon will be ready for examination.

After the cleaning procedure, store the coupons in a desiccator and avoid exposure to conditions that could alter the surfaces to be examined. Handle the coupons with latex gloves to avoid potentially corrosive fingerprints.

There are no special storage or handling requirements for the embedments. All biofilm and corrosion products are encapsulated within the resin. The embedments may be stored in plastic bags or envelopes.

Coupon Analysis

Overview

The primary difference between EM coupons and traditional weight-loss coupons is the depth and extent of analysis performed on the EM coupon. The analytical techniques selected for EM coupon analysis depends in part on the type of system being monitored, and on the objectives of the corrosion control program. For instance, evaluating a compressor jacket cooling water system may emphasize different analytical techniques as compared to an oil pipeline. An overview of what types of analysis can be performed on EM coupons is given here; however keep in mind that all techniques may not be used in every case. The inclusion of both macroscopic and microscopic examinations should be given the highest priority in any program using EM coupons.

Along with thoughtful selection of analytical techniques, the analytical methods themselves and the means of data handling and interpretation should be established prior to initiating a EM coupon program. Organization and consistency are key components in making a EM coupon program successful. Each coupon can potentially provide over 30 pieces of information, which must be compiled in a format useable by corrosion engineers.

Engineering and management must establish how this data will be used, how it will be correlated with other operating information about the system, and how mitigation recommendations will be made. All of these elements are part of a EM coupon program that will provide true value.

Macroscopic Condition

Optical Microscopy

Optical microscopy of EM coupons can be performed using a stereomicroscope capable of 10X magnification. The embedment and cleaning procedure, in most cases, exposes a metal surface free of scale and deposits that would hinder interpretation of the effects of corrosion. The overall goal of optical microscopy is to indicate the macroscopic condition of the coupon; that is, to provide some immediate sense of how severe the conditions are in the environment being monitored. Most EM coupons have relatively short exposure times; therefore they may show little change from their as-installed condition. In fact, when EM coupons show significant corrosion attack, the chances of identifying the type of corrosion initiation via SEM examination greatly decrease. Thus, observing little or no corrosion during optical microscopy of a EM coupon has no bearing on the value of subsequent analytical methods

ASTM, NACE and other publications provide excellent practices and standardized methods for coupon analysis, and should be used for reference. It is also helpful to establish internal standards and criteria that are particularly meaningful for the user's segment of industry. For example, if scaling is a particular concern, special attention should be given to documenting the type, thickness, porosity, frangibility, etc. of any scale observed. Likewise, when isolated pitting is the primary concern, analysis of pit shape, diameter, depth, distribution and relationship to other types of corrosion should be analyzed. The main point is that relevant data from optical examination should be consistently obtained using established procedures.

As a minimum, it is suggested that optical microscope analysis include classifying various degrees of etching and pitting, a rating system for severity, determining the maximum pit size and depth (or thickness loss due to general attack), and pit density determination. There are certainly other pieces of data that can be collected as well, depending on the system being monitored and the level of detail needed. The results of the optical microscope exam will be used to help interpret other EM coupon analytical findings and provide a real-world correlation with operating conditions.

Microscopic Condition

Scanning Electron Microscopy

SEM examination of EM coupons is extremely useful in helping to diagnose the cause of micro-pit initiation, particularly when coupled with knowledge of the operating environment and the embedment examination results. For pipeline systems where a variety of possible chemical species and physical or biological conditions could potentially contribute to corrosion, information about the exact source of corrosion initiation is vital. As stated earlier, EM coupons are typically exposed for a short amount of time as compared to traditional weight-loss coupons. During these short exposures, it is common to observe very little corrosion in the optical examination, yet obtain useable corrosion information from the SEM examination. The information obtained from SEM exam speaks to the types of corrosion initiation events occurring on the coupon surface.

SEM examination of EM coupons is typically performed at magnifications ranging from 500 to 2000X using secondary electron and/or backscattered electron imaging modes. A predetermined “path” on the coupon surface is covered during the examination to ensure consistency. Scanning is performed at lower magnifications and feature investigation is accomplished at higher magnifications. Thorough and systematic documentation of the conditions observed is critical. With the current state of electronic image technology, rapid and inexpensive documentation is readily achievable.

Observation data from the SEM exam should be acquired using predetermined analytical procedures. The shape, size, and distribution of microscopic corrosion initiation features, along with classification of the corrosion (i.e. isolated pits, connected pits, general etching, scaling, etc.) should be included in the data collected. Once analytical experience is gained with SEM examination of EM coupons from a given operating environment, it is likely that certain pit initiation morphologies (which have been substantiated by other analytical data) can be classified as well. For instance, it has been shown that SEM examination can distinguish between biotic pit initiation and that resulting from abiotic conditions for a given system.

Although the analyst or corrosion engineer must be careful when extrapolating macro-corrosion effects from microscopic corrosion features, when combined with data from the optical and embedment exams, the primary cause of corrosion in the system being monitored can be determined. Field experience has proven the value of using microscopic corrosion initiation analysis to control internal corrosion in wet gas systems

Chemical Data

Energy Dispersive X-ray Analysis

A variety of micro analytical techniques may be used to determine the elemental chemical nature of the deposits and corrosion products contained in the embedment. The most popular and easily accessible is EDS; Energy Dispersive x-ray Analysis. Besides determining the chemical species associated with the bulk deposits removed from the coupon, most EDS systems can also provide mapping that shows where certain species are concentrated. This data is extremely useful when correlated with the pit initiation data obtained in the SEM exam. Knowledge of the chemical elements directly associated with pit or corrosion sites can help analysts pin down the corrosion mechanism in many cases. Remember, the embedment provides a one-to-one correlation between the deposits/biofilm on the coupon, and the corrosion associated with those materials. When the scale or deposit layer is particularly thick, the embedment can be cross-sectioned and analyzed to show compositional changes that occur in the deposits with depth. This information can help show what happened to the coupon over the exposure period.

Microbial Data

Epifluorescent Microscopy

The embedments themselves can be treated with biological stains and examined using epifluorescent microscopy. Water-based reagents can be used on the embedments with great success due to the nature of the LR White resin. Examination of the embedment surface that was directly in contact with the coupon is performed using oil immersion techniques. A working magnification of at least 1000X is needed, with 1500X being a better choice for resolving embedded cells. The biofilm is not disturbed by examination.

As in all the previously described analyses, a systematic, predetermined approach to embedment analysis is desirable so that consistent data is provided to the end user. Microbiologists must work with engineers and corrosion personnel to provide analytical data in a meaningful format. For example, all that the corrosion engineer may need to know is whether bacteria are present, the relative number, and if colonization is observed.

Other Techniques

More technically sophisticated examination methods may also be justified in some cases, particularly when more information about the biofilm is needed. These methods include TEM – Transmission Electron Microscopy, phase contrast optical microscopy of thin sections, and immuno-labelled staining techniques to identify specific organisms. One advantage of the embedment method is that the embedment can always be retrieved for future analysis, if so desired.

Culture methods can also be used if EM coupons are installed in pairs and one is used to take cultures from. Direct staining and examination of exposed coupons has also been reported to be useful.

Follow Up

This article is intended to introduce the concept of using corrosion coupons in a way that can optimize the useful data obtained from coupons. Developing a company-specific EM coupon program takes considerable effort, however the potential cost savings and integrity benefits are tremendous. Adopting an EM coupon program is likely to;

- ✓ Reduce mitigation chemical costs by targeting specific problem areas and treating with the proper chemical type and volume.
- ✓ Improve operating integrity by reducing internal corrosion problems.
- ✓ Help meet regulatory requirements for corrosion monitoring.
- ✓ Reduce routine field-testing of liquids, as in the use of MIC test kits.
- ✓ Identify the true cause of internal corrosion and eliminate guessing.

While this technology may not be applicable in every situation, there are many pipeline systems that could benefit from the use of EM coupons. The use of EM coupons continues to expand throughout industry today. Perhaps now is the time to investigate this corrosion control tool for your own applications.

CC Technologies, is prepared to help you evaluate this technology to help meet your internal corrosion evaluation and monitoring needs. We can bring our expertise and technical resources to bear to help you in any stage of evaluation and implementation of a EM coupon program. Contact us by phone 614-761-1214 or email: info@cctechnologies.com