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CAUSES OF EXTERNAL CORROSION ON COATED AND CATHODICALLY PROTECTED PIPELINES

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ABSTRACT

Each time a pipeline is exposed and inspected companies should properly evaluate external corrosion to determine the reason why the corrosion occurred. Too many times external corrosion is blamed on lack of cathodic protection (CP), when there are other causes that are not properly evaluated. Proper evaluation of external corrosion includes using several methods to determine why external corrosion exists even though NACE criteria are met for cathodic protection at the site.

Case histories will be presented that discuss the causes of why coated pipelines with "adequate" cathodic protection continue to have external corrosion. In other cases, the CP may not seem to be adequate, but no corrosion is found. These case histories will show some of the proper techniques to evaluate external corrosion and what caused the corrosion to exist. Each type of coating has properties that can be defined as either CP "shielding" or "non-shielding".

Key words: Cathodic protection, shielding coatings, non-shielding coatings, external corrosion, pipelines

EXTERNAL CORROSION ON PIPELINES

There are several reasons why corrosion is present on the external surfaces of pipelines that are coated and cathodically protected. Each time the external surface of a pipeline is exposed, that surface should be properly evaluated to determine if corrosion is present, active or inactive and why that corrosion occurred.

When one examines the SP0169 – 2007 version we find that there is very little guidance to help determine how and when external corrosion developed. According to the proposed revision Draft #1e (July 2008) corrosion is considered to be controlled when the rate of corrosion is reduced to an average of 25 µm/y (1 mil/y) in soils and waters in the field at ambient temperatures.[i] This is a very difficult guideline to measure on a pipeline system. What is more important is to determine why we are still having external corrosion on pipelines even though SP0169 – 2007 criteria are satisfied. The other question is why external corrosion is not a problem when the same criteria are NOT met, especially the polarized -850 mV and the -850 mV with consideration for IR drop.

Adequate CP has been defined in several different ways. Most agree that if at least 100 mV of polarization is achieved from the native potential, protection is adequate. For the purpose of this paper this criterion will be used as the definition of adequate cathodic protection.

WHY EXTERNAL CORROSION OCCURS ON PIPELINES

Disbonded Coatings

The most significant corrosion problem on coated and cathodically protected pipelines is that of disbonded pipeline coatings that shield cathodic protection when disbondments occur and water penetrates between the coating and the pipe. All coatings can and will disbond for various reasons. Poor application procedures, soil stress, temperature and a variety of other reasons can cause coatings to disbond.[ii, iii, iv, v, vi, vii, viii, ix]

All coatings must have the ability to shield CP when properly adhered to the pipe. The problem happens when a disbondment occurs and water penetrates between the coating and the pipe. This problem exists more for certain types of coatings than for others. Some coatings will shield CP current in some situations and not in others. (See case histories 1 and 2) The relative tendency of pipeline girth weld coatings to shield cathodic protection (CP) current was studied in the laboratory.[x] A key consideration should be "Will the coating shield CP if the bond fails?"[xi] However, all coatings experience some disbondment and, therefore, the behavior of a disbonded coating is important in the overall performance of a coating system.[xii] Even with adequate cathodic protection (CP), corrosion can occur under most disbonded coatings.[xiii]

Holidays and Coating Damage

If a pipeline coating is adhered properly to the pipe surface and remains that way for the life of the pipeline, external corrosion is typically not an issue. Of course there can be situations where direct current (DC) or alternating current (AC) causes corrosion to occur at holidays or at weak spots in the coating.

If holidays or damage occur during the coating application, during construction or during the burial of the pipeline, these areas can become spots where corrosion can occur, but are not usually a corrosion problem if CP is adequate.

One problem that occurs with many types of coating systems is that of cathodic disbondment. If the coating does not withstand the rigors of the electrochemical process occurring at the cathode (pipe surface), then disbondments can occur.

One problem that exists with the proposed changes in the criteria as quoted in SP0169 is that many companies will be using more and more stringent criteria trying to meet a polarized -850 mV or more negative potential at all sites on the pipeline system. This will cause more cathodic disbondment that may lead to more shielding of the CP current from the pipe by coatings that shield.

A non-shielding coating will allow the CP current to protect the steel even if disbondment occurs. Slightly more CP will be required, but no significant corrosion will occur on the pipelines under normal circumstances.

Holidays should be located and repaired as the pipe is being installed in the ditch, but a proper repair with the proper repair material must be performed. Many times the repair material will lose adhesion and may shield the CP allowing corrosion to occur.

AC and DC Stray Current Interference

Corrosion caused from AC or DC stray current interference can be very rapid, causing significant damage to metal surfaces from which the current discharges into the electrolyte. This type of corrosion will cause failure long before the design life of the system is reached.

If not detected and corrected quickly, the interference will result in leaks and potential explosions and environmental disaster. This corrosion is usually easily detected through various surveying methods such as close interval and/or direct current voltage gradient surveys. Even annual surveys should give some indications that would lead to further investigation to determine if interference exists.

Case History #3 shows the damage caused from a DC interference problem. This problem happened when a company installed a new FBE coated pipeline parallel to several other systems that had impressed cathodic protection, but did not properly bond the new pipeline into the CP system. This corrosion occurred in less than one year.

Shielding From Other Materials

Shielding can be caused from materials that are around a pipeline other than coatings. During the design phase of the pipeline it is critical not to use materials that will cause CP shielding. Some of these materials are solid, non-conductive rock shields, various plastic construction materials not removed from the pipe or ditch, high resistant sand or rock back fill, metal structures in close proximity, reinforced concrete structures and other metal structures that may pick up the CP current intended for the pipeline.

In Case History #4 a rock was removed from the top of an FBE coated pipeline at a corrosion indication from an ILI run. There was corrosion on the pipe under the rock that was shielding the FBE. Though there was blistering of the FBE in other places on the pipeline, there was no other corrosion located.

The criterion used for this pipeline was an “ON” -850 mV without consideration for IR drop except in areas that indicated a potential problem. The specific potentials for this site are not available. With adequate CP, fusion bonded epoxies (FBE) do not totally shield CP currents[xiv]; therefore corrosion is not a major problem. However, FBE maintains its electrical insulation properties in the presences of moisture and cathodic protection current.[xv]

Inadequate Cathodic Protection

This is the least likely cause of corrosion on cathodically protected and coated pipelines. With the use of ILI tools and ECDA, the true causes of external corrosion these systems are now being proven. If companies, government agencies, and contractors will spend more time training their employees on the proper evaluation techniques for determining the cause of external corrosion, the industry will find that inadequate CP is not the likely cause of corrosion.

CASE HISTORIES

Case History #1

Coal tar coated pipelines have performed well in some environments while performing poorly in others. In some cases, the poorly performing coal tar coating allows CP to be effective through cracks and pores in the coating, even when disbondment occurs.

In this case, the coal tar was deteriorated and disbonded enough that the CP current could be effective. There was corrosion from previous shielding or inadequate CP. See Figure #1.

The cathodic protection “ON” potentials at this site were in a range of -500 mV to -600 mV. Polarized potentials were in the range of -350 mV to -450 mV. Native potentials were in a -200 mV to 300 mV range.

There was no significant corrosion under the disbonded coal tar, with no active corrosion observed. The pH under the coal tar was approximately 10.

Case History #2

Coal tar coated pipeline coated in early 1950’s had a variety of corrosion problems discovered from an ILI run. Most of the corrosion found was “old” corrosion as seen in Case History #1. In some areas along this same pipeline, some of the corrosion was active under the thick disbonded coal tar.

Figure #2 shows the resulting corrosion was active in this area as indicated by the low pH (5) under the coal tar. These are the areas where recoating is recommended since this corrosion will not likely be controlled by CP. Typically, the conventional current will discharge from holidays in the coating on well coated pipelines.

Case History #3

When a new pipeline is installed in an area where impressed CP is being used on other systems, the potential for corrosion from stray currents exists. Companies must perform proper surveys to determine if these problems exist immediately after the new pipeline is installed.

Figure #3 shows the results of such an interference problem. The new FBE coated pipeline was not properly bonded into the existing impressed current CP systems. This corrosion developed in less than one year.

Case History #4

Shielding can occur from a variety of other materials and components around a pipeline. Some of these shields can be man-made or natural.

Figure #4 shows the results of a large rock setting on top of an FBE coated pipeline shielding the CP. Even though there were other areas that had blistering of the FBE, there was no corrosion because there was no shielding of the CP current by the FBE. The criterion used for this pipeline at this time was an “ON” -850 mV without consideration for IR (except when warranted).

Figure #5 shows the typical results when disbonded or blistered FBE is found. The pH is typically from 9 to 12 with little or no corrosion found. Some times the steel is discolored, but with no metal loss.

CONCLUSIONS

In today’s culture of coating and cathodically protecting pipelines, the real cause of external corrosion is seldom that of inadequate cathodic protection. Therefore, cathodic protection criteria is not the most important issue when considering NACE SP0169 and external corrosion control. These conditions are the same in all countries around the world as indicated in the variety of papers written about external corrosion on coated and cathodically protected pipelines.

Pipeline coatings that shield cathodic protection are the major cause of external corrosion on coated and cathodically protected pipelines. AC and DC interference is the most rapid and dramatic corrosion problem (especially at local holidays). However, proper monitoring and preventive methods are effective in controlling these problems. Preventing cathodic protection shielding from other materials besides coatings is also a very important issue when designing and installing a pipeline. Properly repairing holidays and damaged coatings with repair material that is compatible with CP and the existing coating is critical to reduce the chance for shielding from the repair coating and to limit the amount of cathodic protection required for the pipeline system.

If those responsible for corrosion control will properly evaluate the true reasons for external corrosion, we find that many conditions are present that cause external corrosion other than inadequate CP. Once we know the true cause of external corrosion, we can then find the most economical and reasonable solutions to prevent future external corrosion problems.

FIGURE #1

Disbonded Coal Tar coating that did not shield the CP current because the coating was deteriorated and cracked enough to allow current through the coating, therefore a high pH and minimal corrosion under the coating.

FIGURE #2

Disbonded Coal Tar coating which shielded CP currents.
Significant pitting in this area because of the CP shielding, not lack of CP.

FIGURE #3

Rare external corrosion on FBE coated pipeline caused from DC interference. Corrosion on FBE coated pipeline from shielding of the CP by a large rock on top of the pipe.

FIGURE #4

FIGURE #5

Typical results when evaluating disbonded or blistered FBE coating.
The pH of the water under the FBE at this site was 12 indicating that CP currents were not shielded.

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