

Paper No.  
**09043**



# COATINGS USED IN CONJUNCTION WITH CATHODIC PROTECTION – SHIELDING VS NON-SHIELDING PIPELINE COATINGS

BY

Richard Norsworthy  
Polyguard Products, Inc.  
Ennis, Texas 75120  
214-912-9072 or  
214-515-5000

## ABSTRACT

When using cathodic protection on coated pipelines, end users must consider the problems that exist if the coating disbonds (loses adhesion). Many in the pipeline industry assume cathodic protection will solve their external corrosion problems without truly understanding the relationship between the coating and cathodic protection. Cathodic protection (CP) current is very effective when it actually has a path to the pipe metal. Most external corrosion on pipelines is caused by disbonded coatings that shield CP, not lack of CP.

When disbondment or blistering occurs, most coating types divert current from its intended path, therefore, CP current can not adequately protect the external surfaces of a pipe. These are called “shielding” pipeline coatings. There are certain types of pipeline coatings that will allow the CP current to effectively protect the pipe if disbondment occurs and water penetrates between the coating and the pipe. These are called “non-shielding” pipeline coatings. This paper will discuss the differences in the two types of coating systems and how CP works with these coatings.

## INTRODUCTION

When using cathodic protection on coated pipelines, end users must consider the problems that exist if the coating disbonds (loses adhesion). Many in the pipeline industry assume cathodic protection will solve their external corrosion problems without truly understanding the relationship between the coating and cathodic protection. Cathodic protection (CP) current is very effective when it actually has a path to the pipe metal. Most external corrosion on pipelines is caused by disbonded coatings that shield CP, not lack of CP. Some failures are catastrophic, where as others have little or no effect on the coating performance<sup>1</sup> or the pipe.

Copyright

©2009 by NACE International. Requests for permission to publish this manuscript in any form, in part or in whole must be in writing to NACE International, Copyright Division, 1440 South creek Drive, Houston, Texas 777084. The material presented and the views expressed in this paper are solely those of the author(s) and are not necessarily endorsed by the Association. Printed in the U.S.A.

To adequately protect underground pipelines, a coating must conduct CP current when disbondment occurs.<sup>ii</sup> When disbondment or blistering occurs, most coating types divert current from its intended path, therefore, CP current can not adequately protect the external surfaces of a pipe. These are called “shielding” pipeline coatings. There are certain types of pipeline coatings that will allow the CP current to effectively protect the pipe if disbondment occurs and water penetrates between the coating and the pipe. These are called “non-shielding” pipeline coatings. This paper will discuss the differences in the two types of coating systems and how CP works with these coatings.

### **Cathodic protection:**

The electrochemical process of cathodic protection causes the environment around the cathode (pipe, tank, etc.) to become alkaline, especially at the surface of the metal being protected. The pH of typical pipeline surfaces with adequate CP would be in a range of 9 to 13. In this range steel is protected and corrosion is significantly reduced or eliminated.

Cathodic disbondment (CD) testing whether long term or short term gives some indication of how well the adhesion of the coating will withstand the electrochemical process of cathodic protection. Coatings have to be able to withstand the alkaline environment as well as hydrogen evolution and other potentially damaging electrochemical changes in the environment. Therefore, passing CD's is a requirement for pipeline coatings used in conjunction with CP.

Every coating system has finite life and eventually degrades, allowing oxygen, water, and chemicals to reach the substrate.<sup>iii</sup> Increasing cathodic protection (CP) is often considered as the best or only solution to prevent corrosion on a pipeline with poor or disbonded coatings. Increasing the CP may help to meet certain criteria and protect pipe exposed to the electrolyte, but it does not always protect the pipe under many types of disbonded coatings, therefore corrosion will continue unless these coatings are replaced. Increasing CP also creates many other problems including the possibility of causing further disbondment and coating deterioration, as well as potential interference and cost considerations.

### **What happens if coatings fail?**

Each coating manufacturer attempts to make coatings that will not fail. The problem is all pipeline coatings fail and disbond for various reasons. Most failures occur because of poor surface preparation, application technique, soil stress or selection of the wrong coating for the environment. However, all coatings experience disbondment and, therefore, the behavior of a disbonded coating is important in the overall performance of a coating system.<sup>iv</sup>

“Will the coating shield CP if the bond fails?”<sup>v</sup> Acidic and near neutral pH environments that develop under disbonded shielding pipeline coatings can lead to corrosion and possibly environmentally assisted cracking. One may realize, however, that as the coating deteriorates and as its permeability to O<sub>2</sub> increases, the corrosion rate deep in the

crevice (or in the blister) could become substantial as CP is shielded there.<sup>vi</sup> Generally, any changes in the properties of a coating are considered as a coating failure.<sup>vii</sup>

Soil stress and other mechanical damage can also create serious disbondment problems with pipeline coatings. Damage of the coating due to these stresses may lead to pipeline corrosion failure and costly repair.<sup>viii</sup> Certain types of coatings are more subjected to this problem than others.

All coatings have varying dielectric properties that reduce the tendency of the electrolyte to complete the electrical circuit between the adjacent anodic and cathodic sites on a substrate, thereby mitigating corrosion.<sup>ix</sup> The worst case scenario of coating failure is the one in which the coating no longer protects the pipeline, and, in addition, the coating prevents the CP from protecting the pipeline.<sup>x</sup> As a result of this failure to understand the influence of the coating, especially on the CP system, many premature pipeline failures have occurred.<sup>xi</sup>

Many pipelines have been installed with Fusion Bonded Epoxy (FBE) coating. When internal line inspection (ILI) tools (smart pigs) are run in FBE coated pipelines, corrosion is rarely found except at girth welds coated with a different coating that shields CP if the coating fails. FBE is a permeable coating and despite a high coating resistance, current could pass directly through the FBE barrier to the underlying steel, developing a high pH environment in the disbondment.<sup>xii</sup> ILI tools have shown significant corrosion under many types of non-FBE girth weld coatings after only a few years in service.

### **Determining true compatibility with CP;**

Field applied (girth welds and rehabilitation) coatings should be carefully selected to ensure they are truly compatible with CP should there be a coating failure or disbondment. Companies have performed expensive rehabilitations only to find their choice of coating material disbonded allowing corrosion to occur and requiring further expense.<sup>xiii</sup> Certain coatings allow CP current (if needed) to protect the pipe should the coating disbond, reducing or eliminating the chance for significant corrosion. These coatings are truly compatible with CP.

Field testing is the most effective way to determine if a coating is truly compatible with CP. A simple method is to test the pH of any liquid under disbonded coating. Since CP changes the pH of the electrolyte at the pipe surface to an alkaline pH, this is an excellent way to determine the effectiveness of the CP under disbonded coating.

There are also some laboratory tests that can be performed to establish the effectiveness of the coating to allow CP to protect the pipe under a disbondment. The process of testing whether a coating is truly compatible with CP involves the use of a properly designed test apparatus.<sup>xiv</sup> There have been many articles written about the testing to determine what happens under most disbonded coatings.<sup>xv, xvi, xvii</sup> They conclude that it is difficult to achieve protection under most disbonded coatings past the local holiday, much less under coatings that do not have holidays in the disbonded area.

Not all coating failures result in corrosion on the pipeline. Some coating failures have little or no effect on the corrosion rate of the pipe. FBE, as mentioned above, is one such coating. Rarely is external corrosion found on a pipeline coated with FBE if adequate cathodic protection is available. Therefore, in the presence of CP, it appears that the pipe will remain protected and blistering and coating disbondment of FBE coatings does not present an integrity threat to a pipeline.<sup>xviii</sup> Laboratory and field testing has also proven at least one geo-textile mesh backed tape coating has this characteristic when adequate CP is available.

No claim is made that these coating systems are going to allow this characteristic to work in all conditions, but field and laboratory results have proven this characteristic does exist and is an effective way to help mitigate corrosion under disbonded coating. FBE has been used for approximately forty years with numerous failures yet it has been very rare to find corrosion or Stress Corrosion Cracking (SCC). However, the electrical resistance is low enough to allow cathodic protection to prevent corrosion on the pipe with disbonded or blistering coating – FBE is non-shielding.<sup>xix</sup> When adequate CP is present, corrosion, including SCC, is significantly reduced or eliminated if water penetrates under the coating.<sup>xx</sup> When CP-compatible coatings degrade or ground water contacts the pipe, the surface is still protected from corrosion and SCC because the CP current can pass through the permeable coating.<sup>xxi</sup> There are cases when shielding is caused from other structures or interference from foreign DC or AC sources cause corrosion that cannot be controlled by the pipeline CP or coating systems.

The reference documents in the article include many case histories and information about pipeline coatings that shield CP when disbondment occurs allowing external corrosion to become a problem. These references also discuss coatings that allow enough CP to significantly reduce or eliminate corrosion on the structure even if the coating system adhesion fails and water penetrates between the coating and the pipe. Below are case histories of some coatings that are truly compatible with CP and some that were not.

## **CASE HISTORIES –**

### **Case History #1**

Though rare, corrosion has been found on FBE coated pipelines. A significant pit was found at the 12:00 o'clock position from an internal line inspection tool run in 1992. When the area was excavated a very large boulder (1 to 2 tons) was removed from the top of the pipe. There were several blisters in the FBE coating in this area. The one pit was directly under the boulder which had apparently shielded the CP from the pipe. No corrosion was found under any of the other blistered FBE in the area proving the typical non-shielding properties of FBE. See Photo #1.

The pipe was a 12” diameter coated with 22 mils of FBE and had been in service since the early 1980’s. The operating temperature was approximately 180° F. The “On”

potential was -1160 mVcse and the criterion used on this pipeline was an “ON” -850 mV. There was also a large waste management pond just above the pipeline and there were significant bacteria in the water around the pipe. A variety of coating systems had been used on the pipelines in this area, but these coatings (extruded polyethylene, solid film backed tapes and coal tars) all failed because of the heat, allowed water into the space between the solid film coatings which shielded the CP allowing corrosion to happen.

#### Case History #2

FBE coated 16” diameter pipe laid in 1985 and internally inspected in 1999. All indications from the internal inspection tool run in 1999 were for internal corrosion. This validates the use of the FBE coating since the overall coating condition is excellent. One area exposed for verification had some blistering, but no external corrosion.

#### Case History #3

FBE coated NPS 42 pipe was examined after eight years of service at ambient temperature. Several blisters were observed after excavation. Blisters were rated as such: Medium to large, with no holidays, with bright steel under the coating; Medium to large with darkened steel; Small with liquid under the coating.

The excavated pipe was left exposed to the atmosphere for sometime before the coating was evaluated. This may be the reason there was not water under the large blisters. De-ionized water was used to wash the surfaces under the larger blisters so an analysis could be made of the wash. The analysis of the water from the blisters with the darken metal showed about three times the amount of sodium, with some chloride and sulfate as the blisters with the bright steel. The pH of the water under the small blisters was > 13 indicating that CP was providing protection and non-shielding to CP.



Photo #1 - 12" diameter pipe with corrosion on FBE coated pipe. This pipe had a large boulder setting on top of the pipe shielding CP.



Photo # 2 – Checking pH under disbonded, non-shielding geo-textile mesh backed coating system. pH was approximately 10, proving non-shielding properties.

#### Case History #4

The geo-textile mesh backed coating mentioned above has rarely had a known failure. One pipe coated with this coating was excavated after three years of service life had minor wrinkling and water between the coating and pipe. The coating was applied in a severe soil stress area without proper tension, without outer wrap, without stripping of the weld seams, incomplete primer application and applied over disbonded coal tar allowing water to migrate along the weld seam under the mesh backed tape coating. There was no significant corrosion or metal loss. The pH of the water under the coating was 10, proving this coating is truly compatible with CP if there is disbondment and water penetration. See Photo #2.

#### Case History #5

A test area on a 30" natural gas pipeline was excavated and several coatings were applied for a test. The geo-textile mesh backed tape was chosen for this testing. The sunny side of the pipe was dry, but the shady side had condensation. The decision was made to coat the pipe with it partially wet to see the results when exposed. The site was excavated after three years of service. As expected, the coating did not bond to the wet surface, but was well bonded to the dry side of the pipe. The area that was wet had a pH of 11 under the pipeline coating, again proving this coating allows CP to work even if adhesion is lost and water penetrates. See Photo #3.



Photo #3 – Geo-textile mesh backed coating system applied to a partially wet pipe surface. No adhesion on wetted surfaces, but very good in other areas. After three years water under coating had a pH of 11, proving non-shielding.

#### Case History #6

Shrink sleeves were applied to a 10" pipe as the girth weld coating. The main body of the pipe was plant coated FBE. An ILI was run nine years later to inspect for possible problems. Corrosion was found only at the girth welds under shrink sleeves that had wrinkled from soil stress and possible poor application practices. Significant corrosion was found under some sleeves requiring exposing the pipe and replacing the coating.





Photo #4 - Shrink sleeve applied in 1997 and resulting corrosion found in 2006. Shrink sleeve shielded the CP. Pipe potentials met all NACE criteria.

#### Case History #7

Solid film backed tape coating was used on the girth welds on a 20 inch pipeline installed in 1980. ILI tool run in 1999 exposed many areas of significant corrosion under the tape coating on girth welds and other areas coated with the tape coating.

#### Case History #8

Six inch insulated pipeline installed in 1979, 24 years in service. PE tape anti-corrosion barrier, ~ 1" foam, PE tape outer jacket. Severe external corrosion at girth welds due to poorly applied field joint coatings. Corrosion was so extensive that the pipeline could not withstand the axial and bending stress during the excavation work. The pipe moved and the weld cracked. It is not believed that the line was leaking prior to the dig.

#### Case History #9

A 6" x 27 km pipeline was constructed in 1989. It was thermally insulated. The coating system consists of an FBE anti-corrosion barrier, 2" foam, and extruded PE outer jacket. The joint coatings were FBE, injection molded foam and shrink sleeve outer jacket. The pipeline was inspected in 2005. Out of 209 reported anomalies only three (3) were listed as external corrosion and all of the external corrosion was less than 30%. All three reported external anomalies were in the body of the pipe and not in the area of the girth weld coatings. The external indications were not exposed and may have been steel defects and not corrosion. After 16 years in service the pipeline has virtually no external

corrosion damage. Good specifications, application and inspection of protective coatings reduced repair costs.

#### Case History #10

A 3” x 4 km long thermally insulated pipeline was in-line inspected after about 15 to 20 years in service. In-line inspection shows corrosion many locations, mostly at the joints. The worst defects in the line were repaired. The corrosion will continue despite the application of CP. Most viable method to manage corrosion will be repeated in-line inspection and repair projects. This corrosion was preventable with better coating choice and application of joint coatings, as well as, use of injection molded foam methods.

#### Case History #11

Blisters on a high temperature (170°F) in Subkha regions of Saudi Arabia. After FBE removed, pipe had black color but no corrosion was observed.

### CONCLUSIONS

Coating selection, surface preparation and application are all critical to coating performance, but many times even if all these conditions are met, coating fail (disbond). As indicated by the above information, being CP compatible is a very important design factor for selecting a pipeline coating system. For a coating to be truly compatible with CP, the coating should allow the CP to provide protection to the pipe if disbondment occurs and water penetrates. The CP must be adequate to provide the needed current to significantly reduce or eliminate the corrosion under the disbonded coating.

There is a choice when selecting a coating system. Coatings that shield CP when there is a disbondment are the leading cause of external corrosion problems on pipelines. Improved training and certification of field coating applicators will help to ensure that coatings will be properly applied. Even with proper application some coatings can disbond through soil stress and other methods. Some coating manufacturers recognize the importance of these type coatings and strive to provide the pipeline industry with choices that are truly compatible with CP allowing current to protect the pipe should the coating adhesion fail.

**NACE International now offers a course titled “Coating Used in Conjunction with Cathodic Protection”. This course provides the students with an opportunity to understand how coatings and CP work together and the problems that can exist when using these two protection methods at the same time.**

---

<sup>i</sup> S. Papavinasam, M. Attard, and R. W. Revie – “External Polymeric Pipeline Coating Failure Modes” Materials Performance, October 2006, Page 28.

- 
- <sup>ii</sup> J. A. Beavers, N. G. Thompson – “Corrosion Beneath Disbonded Pipeline Coatings” – Materials Performance, April 1997, page 19.
- <sup>iii</sup> “Coatings Used in Conjunction with Cathodic Protection” – NACE International Technical Committee Report Item No. 24207, page 2.
- <sup>iv</sup> J. A. Beavers, N. G. Thompson – “Corrosion Beneath Disbonded Pipeline Coatings” – Materials Performance, April 1997, page 13.
- <sup>v</sup> D.P. Moore, “Cathodic Shielding Can be a Major Problem After A Coating Fails”, Materials Performance 39, 4, 2000, pg. 44.
- <sup>vi</sup> F. M. Song, D. W. Kirk, D. E. Cormack and D. Wong – “Barrier Properties of Two Field Pipeline Coatings” Material Performance, April 2005, Page 26.
- <sup>vii</sup> S. Papavinasam, M. Attard, and R. W. Revie – “External Polymeric Pipeline Coating Failure Modes” Materials Performance, October 2006, Page 28.
- <sup>viii</sup> B. C. Yen and G. D. Tofani; “Soil Stress Assessment can Prevent Corrosion, Reduce Pipeline Coating Damage”; Oil and Gas Journal; August 26, 1985; page 63.
- <sup>ix</sup> “Coatings Used in Conjunction with Cathodic Protection” – NACE International Technical Committee Report Item No. 24207, page 2.
- <sup>x</sup> S. Papavinasam, M. Attard, and R. W. Revie – “External Polymeric Pipeline Coating Failure Modes” Materials Performance, October 2006, Page 28.
- <sup>xi</sup> G. Mills – “The Pipe Coating as an Engineered Part of the Cathodic Protection System”; Materials Performance, December 1988, page 13.
- <sup>xii</sup> J. Been, R. Given, K. Ikeda-Cameron and R. Worthingham; “Investigating Coating Performance”; Pipeline and Gas Technology, April 2007, page 36.
- <sup>xiii</sup> R. Norsworthy – “Establishing Compatibility” – World Pipelines, February 2007
- <sup>xiv</sup> R. Norsworthy – “Fail Safe Tape System Used in Conjunction with Cathodic Protection” – Materials Performance, June 2004, Page 35.
- <sup>xv</sup> F. King, T. Jack, M. Kolar and R. Worthingham, - “A Permeable Coating Model for Predicting the Environment at the Pipe Surface Under CP-Compatible Coatings”, CORROSION 2004, Paper 04158, page 1.
- <sup>xvi</sup> J. A. Beavers, N. G. Thompson – “Corrosion Beneath Disbonded Pipeline Coatings” – Materials Performance, April 1997, page 13.
- <sup>xvii</sup> G. R. Ruschau and Y. Chen – “Determining the CP Shielding Behavior of Pipeline Coatings in the Laboratory”; CORROSION 2006; Paper # 06043
- <sup>xviii</sup> J. Been, R. Given, K. Ikeda-Cameron and R. Worthingham; “Investigating Coating Performance”; Pipeline and Gas Technology, April 2007, page 41.
- <sup>xix</sup> J. Alan Kehr – “Fusion Bonded Epoxy (FBE) – A Foundation for Pipeline Corrosion Protection”; NACE Press, page 471.
- <sup>xx</sup> R. Norsworthy – “Is Your Pipeline Coating “Fail Safe?” – Pipeline and Gas Journal, October 2006, page 62, Volume No. 233 Number 10.
- <sup>xxi</sup> F. King, T. Jack, M. Kolar and R. Worthingham, - “A Permeable Coating Model for Predicting the Environment at the Pipe Surface Under CP-Compatible Coatings”, CORROSION 2004, Paper 04158, page 1.