Dual powder FBE system – a new approach in multi-layer systems for underground pipelines

K VARUGHESE and **J BETHEA**
Herberts-O'Brien Inc., USA

Abstract

Pipe coatings need at least corrosion protection and mechanical properties as minimum requirements. Two types of materials which are used worldwide as pipe coatings are thermoplastics and thermosetts. Both have strengths and weaknesses when considered for pipeline protection. Thermosetts (FBE) have excellent corrosion protection properties while thermoplastics are well known for damage resistance. Though it is ideal to have the maximum values of all required properties in a single system, due to the opposing nature of the properties, it is impossible. Therefore, the industry has taken a new approach to achieve this through multi-layer systems. In a conventional multi-layer (3 layer) system, the corrosion protection FBE is tied to the mechanical protection plastic system through an adhesive middle layer. Dual powder system is the latest in the multi-layer systems with an FBE corrosion protection base coat and a plasticized FBE, mechanical protection top layer. In this system the top layer has all the advantages of plastic while maintaining the FBE character for compatibility with the CP system. Since the technology utilizes chemical bonding with thermosett curing radicals, the middle layer (tie layer) is eliminated , providing a single film though it is a multi-layer system.

In this paper the corrosion fundamentals and the basics of corrosion prevention by protective coating and cathodic protection (CP) are explained. The importance of considering coating as a part of the CP system and the most critical properties which are needed to work in unity with CP are highlighted. The significance of field and shop girth weld, spools and fittings in a pipeline is discussed along with the challenges in applying the multi-layer system on them. The application of Dual Powder system on all sections of a pipeline: line pipe, girth welds, spools and fittings are discussed. The repair procedure is also explained.

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INTRODUCTION

Coating is the primary line of defense against underground pipeline corrosion. Over the years several types of pipe coating systems were tried in the fight against corrosion with mixed results. Asphalt, extruded and sintered Polyethylene, Polyethylene tapes and Fusion Bonded Epoxy (FBE) are the major systems which are widely used worldwide and they all have several years of field performance history. FBE is the latest among them. Even this system has over thirty years of service history in various field conditions.

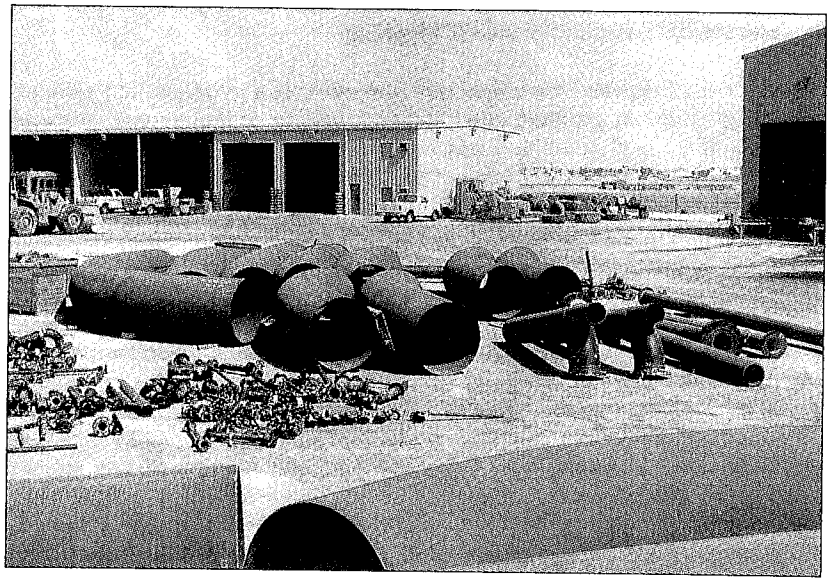
Although all these systems have excellent properties and some of them have good track record in protecting the pipeline, they all fall short in some areas. Therefore, for quite some time, the pipeline industry had been focusing its attention in developing better coating systems. The latest systems commonly known as "Multi-Layer" systems, are the result of this effort. Before attempting to discuss the new multi-layer systems, a review of the requirements of a good coating is worthwhile.

Many authors [1,2] had previously tried to identify the properties needed for underground pipeline coatings which can be grouped into corrosion protection and mechanical properties. Lower oxygen and water permeability coefficients, excellent wetting, cathodic disbondment resistance, adhesion and cohesion are some of the required corrosion protection properties. The import mechanical properties are flexibility, impact resistance and abrasion resistance. Other requirements such as compatibility with cathodic protection system[3] and girth weld systems[4] have been recently addressed by some authors. However, the importance of being able to repair the damages and getting the applied film tested fast and relatively inexpensively has not been addressed adequately. Another ignored area is the coatings for fittings and shop girth welds. The fact that the pipeline is not a straight line and that it contains multi-shaped fittings, spools and girth welds on line pipe as well as on fittings (photograph #1) is being frequently forgotten. The importance of recognizing the pipeline as a whole unit instead of treating it in separate sections as line pipe, spools and fitting and girth welds has not been fully acknowledged. It is quite accurate to state that a coating system which is not capable of application to all sections of the pipeline is not a perfect system.

Protective coating and cathodic protection are the two parts of the corrosion control system for underground pipelines. Together they provide an efficient method to protect the pipeline. The efficiency of this system, however, depends on the ability of the coating to work as a part of the CP system. Considerable effort had been devoted by many to understand the role of pipe coating in mitigating corrosion and the critical properties of the protective coating which influence the success of the CP system[2,5].

To understand the importance of certain properties and how they influence the CP coating system, a review of the basic corrosion process and the corrosion control mechanisms are desirable.

Photograph #1 - Spools and Fittings Stored for Coating Application.



Corrosion Fundamentals

The first step in the corrosion process is the conversion of metallic iron into ferrous ions which is given by the following equation.

$Fe^{\circ} \rightarrow Fe^{++} + 2\bar{e}$ — eqn (1)

This is a natural and spontaneous process and the rate of this reaction is dependent on the concentration of Fe^{++} and the electrons ($\bar{e}$) present. Since the reactants such as hydroxyl ions (OH^{-}) (product of oxygen and water) can remove the Fe^{++} by converting it into corrosion product, $Fe(OH)_2$, the concentration of Fe^{++} can decrease. In such situation more metallic iron will convert into Fe^{++} to take the place of the Fe^{++}. This will influence the corrosion rate. Therefore, corrosion can be effectively controlled by providing a barrier against oxygen and water or any other reactants. This is the principle used in corrosion prevention by protective coating.

The corrosion reactions involving hydroxyl ion (OH^{-}) can be represented as follows:

$2H_2 + O_2 + 4\bar{e} \rightarrow 4\,OH^{-} \rightarrow$ eqn (2)

$2\,Fe^{++} + 4\,(OH^{-}) \rightarrow 2\,Fe(OH)_2 \rightarrow$ eqn (3)

From eqn (2) it can be seen that electrons are needed for O_2 and H_2O to be converted into OH^{-}. These electrons are coming from the first process (eqn. 1) if other sources for electrons are not available. The removal of these electrons can accelerate the corrosion

process. Conversely, if the pipe surface can be provided with excess electrons from an external source, the corrosion process can be slowed. This is the principle used in the corrosion prevention by Cathodic Protection (CP) system.

Both coating and CP systems have unique corrosion prevention properties, and when used in combination, provides an excellent, cost efficient corrosion control system. However, certain properties of the coating and their relationship to one another become highly critical when used in combination with CP. Some of these properties, although otherwise highly desirable, may have to be sacrificed to some extent for the success of the CP coating combination system. A detailed study on this can be found elsewhere[6].

Multi-Layer Systems:

Although many properties are desirable for pipeline coatings, some of them are considered highly essential. These essential properties can be grouped into two: corrosion protection properties and mechanical properties. The first group is essential to protect the pipeline from corrosion. The latter, mechanical properties, is also equally needed to protect the coating from construction related damages. Ideally, the coating should have the highest values of both mechanical and corrosion protection properties.

Considerable effort has been expended by the coating industry to develop a coating with highest values of both properties but with no success. The difficulty in combining the best values of both mechanical and corrosion protection properties in a single system has led the industry towards multi-layer systems. The Three-Layer Polyethylene and Polypropylene, two layer Duval system and Nap-Gard Dual Powder Gold are the multi-layer systems developed to achieve this objective.

The thermosett systems, especially FBE's, are well known for their corrosion protection properties while the thermoplastic systems are credited for their mechanical properties. All three multi-layer systems mentioned attempt to combine the best of both properties by utilizing thermosett FBE's strength of corrosion protection and the plastics' mechanical properties.

Detailed system descriptions and application procedures of all three multi-layer systems can be found elsewhere[7, 8, 9] which is beyond the scope of this paper. However, a brief discussion will help to understand the differences between them.

The three layer polyethylene system consists of a liquid epoxy (3 to 5 mils; 75 to 125 μm) or FBE (5 to 12 mils; 125 to 300 μm) primer and a polyethylene top coat. In three layer polypropylene the top is polypropylene. In the three layer systems, the corrosion protection epoxy (FBE) is connected to the mechanical protection thermoplastic top coat through a thermoplastic adhesive middle layer.

The Duval system consists of two layers: FBE primer and polypropylene top coat. The FBE base coat is 20 mils (500 μm) average. This is bonded to the polypropylene topcoat also 20 mils (500 μm) average. In this system the adhesive middle layer is eliminated by introducing a chemically curing material into the polypropylene system.

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Both three layer and Duval system utilize an extrusion process to apply the thermoplastic systems to the FBE primer. The only multi-layer system which is different from others in combining corrosion protection layer to the mechanical protection layer is the Nap-Gard DPS Gold system.

Nap-Gard Dual Powder System (Nap-Gard DPS Gold).

Nap-Gard DPS Gold system consists of Nap-Gard Mark X FBE (either 7-2500 or 7-2501) 8 - 12 mils (200 to 300 μm) base coat for corrosion protection and 16 - 20 mils (400 - 500 μm) of plasticized FBE top coat (Nap-Gard 7-2504) for improved water resistance and mechanical protection. This system utilizes the fusion bond technology to combine the corrosion protection FBE layer to the plasticized FBE mechanical protection layer.

Application Methods:

(a) Line Pipe:

Both layers are spray applied using electrostatic spray system. In the same booth, the first few guns (the lead guns) will spray the base coat and the rest of the guns will spray the top coat.

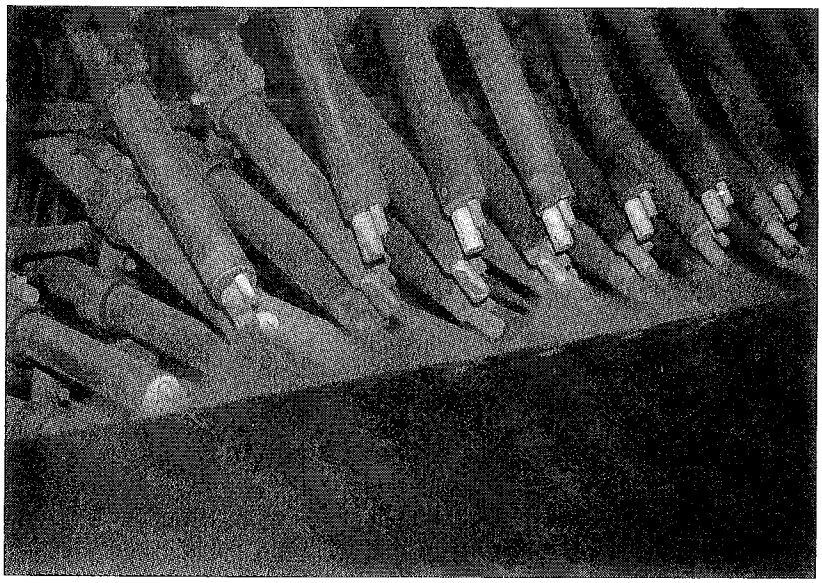
The surface preparation is the same for FBE application; usually a cleanliness of Swedish Standard SA 2½ or better is needed. An anchor profile of 1.5 mils to 4 mils (37.5 μm - 100 μm) is recommended. Phosphoric acid wash followed by deionised water wash is recommended if contaminants are present on the pipe surface. The pipe surface is heated to 450 - 475 °F (232 - 245°C). Base coat FBE is then sprayed onto the hot surface followed by the plasiticized FBE top coat (Photograph #2). The coated surface is then water quenched after allowing time for cure. The coated joints are then holiday tested and are repaired if any damages are identified. The joints are then shipped out after completing other on line quality control tests which are normally done for FBE systems. Photograph #3 shows on line thickness test.

(b) Girth Weld Coating Application:

Nap-Gard DPS Gold can be applied on girth welds both in the field and shop. Application is similar to FBE application. But the application unit has two separate fluid beds, one for base coat and the other for top coat.

First , a required quantity of the base coat is applied by spray method. Then immediately, using a control system, the fluidized top coat material is introduced into the spray system.

Photograph #2 - Guns spray applying Red and Gold Coating of Nap-Gard DPS.



Photograph #3 - On line film thickness testing of Nap-Gard DPS.



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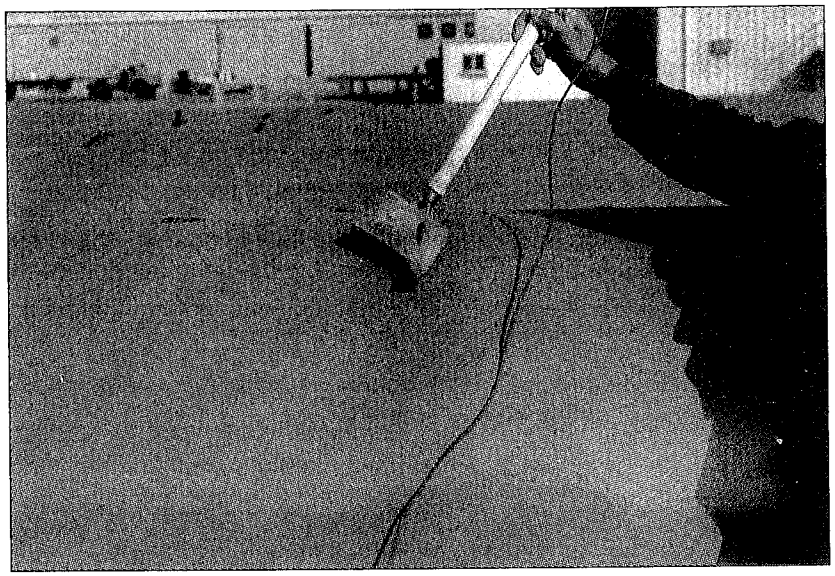
(c) Spools and Fittings:

Nap-Gard DPS Gold can be applied on all fittings and spools of various sizes and wall thickness. As a rule of thumb, Nap-Gard Gold system can be applied onto any item that FBE can be applied.

(d) Repairs:

Damages can be repaired easily in the shop and in the field using a fast curing two part liquid system. The chemical resistance of this repair material is tested under the same test condition as the Nap-Gard DPS Gold and found to have equal test performance. Photograph #4 shows a repaired area being tested for electrical insulation.

Photograph #4 - Repaired Area being tested.



(e) Tests for Applied Film Characteristics:

Nap-Gard DPS coating can be tested for the following:

1. Cure - DSC method.

The coating can be tested for cure using Differential Scanning Calorimeter. Test methods are similar to those used for FBE systems. Results are available within one hour.

2. Water Soak:

Boiling water soak test. Usually a 24 hour test is conducted.

3. Bend Test:

Bend straps can be obtained from the coated pipe and flexibility tests can be performed as per customer's specification. Results are available immediately.

4. Cathodic Disbondment Test:

Samples can be extracted from coated pipe and CD tests can be performed as per customer's specification. Usually the results obtained in a short test duration (such as a 24 hour test) will indicate the quality of the applied coating.

5. Foaming Tests:

Samples can be obtained and tested for cross sectional and interfacial porosity. Test method is the same as that used for FBE system.

6. Other tests:

Adhesion, Abrasion Resistance and Impact Resistance can be performed easily with Nap-Gard DPS samples. Test methods are similar to those of FBE.

Conclusions:

Through multi-layer systems, the coating industry has achieved a great success in developing better systems for underground pipelines, specifically by providing excellent corrosion protection and excellent impact resistance in one system.

In all multi-layer systems, the strength of FBE in preventing corrosion is utilized by applying it as the prime coat against the metal surface. The excellent impact resistance property of the plastic is exploited by applying it as the top coat to prevent mechanical damages. Although a single layer system is preferable, multi-layer systems are equally acceptable if various layers hold together at least until the stipulated design life of the pipeline.

It is important to recognize that the success of the system depends on the ability of the base coat and the top coat to behave like a single unit. In the case of the three layer systems, the unity of the thermosett FBE to the thermoplastic Polyolefins is achieved through a connecting thermoplastic adhesive layer. Obviously one of its weaknesses lies here. For

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2. The plasticized FBE topcoat provides excellent water resistance (characteristics of the plastic system) while maintaining the superior oxygen resistance of the FBE.

3. Nap-Gard DPS is designed to maximize the impact resistance while maintaining its ability to be a part of the CP system without any possibility for cathodic shielding.

4. The technology used to connect the corrosion protection and mechanical protection layers is through chemical bonds through generically similar curing radicals for both layers.

REFERENCES:

(1.) J. Banach, "TransCanada PipeLines Recent Experiences with Epoxy and Urethane Pipeline Coatings". TransCanada Pipelines, Publi.

(2.) Kuruvila Varughese and S.P. Jacob, "Critical properties of Protective Coatings which Affect Corrosion Prevention of Underground Pipeline", Proceed: SSPC 1996 International Conference. Charlotte, N.C. Nov. 17 - 21, 1996.

(3.) John A. Weavers and Neil G. Thompson, " Corrosion Beneath Disbonded Pipeline Coatings", Materials Performance, April 1997.

(4) Dennis Neal, "Comparison of Performance of Field Applied Girth Weld Coatings", Materials Performance, Jan. 1997.

(5.) G. D. Mills, "The Role of Pipeline Coatings in Mitigating Corrosion", proceed. International Conference in Organic Coating Science and Technology, Athens, Greece, July 1986.

(6) Kuruvila Varughese, "Understanding Mechanical Properties Critical to Project Economics". Oil and Gas Journal, Sept. 16, 1996.

(7) Mike Alexander, "High Temperature Performance of Three Layer Epoxy/Polyethylene Coatings", Material Performance, June 1992, pages 41-44.

(8) G. Connelly et al; "Three Layer Pipe Coatings for Elevated Temperatures" Pipeline Industry, March 1990, pages 53-58.

(9) J. An Nunn and Richard Nortsworthy, "Two Layer Coating Effective With High Temperature Lines". Pipeline Industry, March 11, 1993, pages 61-63.

(10) Kuruvila Varughese, "Mechanical Properties Critical to Pipeline Project Economics", Oil and Gas Journal, Sept. 9, 1996n and Sept. 16, 1996.

instance, if the adhesive layer loses its adhesion to the FBE, layer separation is possible exposing the pipeline to cathodic shielding. The other weakness is the possibility for air entrapment between the layers during the application (extrusion) of the middle and top layers. Bridging of the polyolefins at the weld area is also a serious matter to be reckoned with during the 3 layer system application. However, these problems are minimized by improved application techniques developed by the coating industry in recent years.

Nap-Gard DPS has successfully addressed above concerns. In this system, the corrosion protection FBE bottom layer (Nap-Gard 7-2500 or 7-2501) and the mechanical protection plasticized FBE top layer (Nap-Gard 7-2504) are chemically crosslinked eliminating the adhesive layer. The curing radicals for both layers are generically the same. This allows intimate mixing between the layers eliminating the possibility for layer separation.

Nap-Gard DPS multi-layer system can be applied to all sections of the pipelines: straight joints, spools and fittings, shop and field girth welds which make it unique among the multi-layer systems. Application of the system is relatively easy and does not need sophisticated equipment. Since the FBE technology is well established throughout the world, this system can be expected to have minimum operator errors during application. This is critically important when dealing with field girth weld coating application.

Two other important requirements of the coating are easy reparability and testability. If the system requires extended time and expensive equipment to test the qualities of the applied film, increases in cost and construction delays are inevitable. Ideally, the applied coating's quality test results should be available within hours to enable the plant to adjust the application parameters if needed. This can avoid the uncertainties in the quality of the applied film and having to deal with a yard full of rejected pipe and fittings of weeks of production if the results obtained (after weeks) are unacceptable.

Besides the easy application and testing advantages, Nap-Gard DPS Gold system offers a different concept in multi-layer philosophy; it recognizes the importance of coating and CP compatibility. While developing this system, this property had been given the most importance. Although it is desirable to have the maximum values of both mechanical properties and corrosion protection properties, this system emphasizes the point that the most important corrosion protection properties should not be compromised to maximize the mechanical properties. It had been recently reported[3] that the FBE allows the CP current to pass through even at disbonded conditions and protect the pipeline while plastic tape systems shield the CP current enhancing the stress corrosion cracking (SCC) in underground gas pipelines. Although Nap-Gard DPS Gold utilizes plastics' superior mechanical property for the top layer, it still maintains the FBE character by using a plasticized elastomer instead of a total plastic system.

The important characteristics of the Nap-Gard DPS Gold can be summarized as follows:

1. Nap-Gard DPS Gold utilizes an elasticized FBE topcoat instead of a total plastic system to provide compatibility with the CP system. The topcoat is similar to FBE while providing the mechanical advantages of a plastic top coat.