Joint Industry Project

Field Applied Pipeline Coatings

The stated purpose of this project, which was conducted by Charter Coating Service, Ltd., of Calgary, Alberta, Canada, was to evaluate how field applied joint coating systems performed under three levels of surface preparation quality *(abrasive blast, power tool, and hand tool).* The Background on page 1 states:

> ***"The main site of external corrosion on pipelines is the joint area which is coated in the field."***

In field application, job site conditions can be quite variable, and installation methods are sometimes done by untrained and/or unsupervised personnel.

Eleven manufacturers of field applied coatings were invited to submit a product for testing. The types of coatings were grouped as follows:\

- Liquid coatings, 100% solids
- Cold Applied Tapes (1)
- Torch Applied Tape
- Heat Shrinkable Sleeves

(1) Polyguard RD-6 was categorized by the laboratory as a Cold Applied Tape for purposes of this test. For a summary of the differences between Polyguard RD-6 and "Tapes", click here: www.polyguardproducts.com/products/pipeline/RD6/RD6_Not-A-Tape.htm

The most important finding of this test for Polyguard RD-6 is a demonstration that, even with less than the best surface preparation, RD-6 experienced minimal cathodic disbondment. Click here: www.polyguardproducts.com/products/pipeline/RD6/RD6_surface_preparation.htm

Surface Preparation Method	RD-6 Cathodic Disbondment *(Radius in mm @ 21°C/ 70°F)*
Abrasive Blast Cleaning	**0 mm**
Power Tool Cleaning	**7 mm**
Hand Tool Cleaning	**8 mm**

A secondary RD-6 advantage was also demonstrated by this test, as shown in the measure of total application time to backfill. RD-6 had an elapsed time of one hour total.
www.polyguardproducts.com/products/pipeline/RD6/RD6_Fast_Installation.htm

In accordance with an initial agreement, only the Polyguard RD-6 corrosion coating is identified by name in the condensed report which follows. The other coatings are identified only generically.

FIELD APPLIED PIPELINE COATINGS - SUMMARY OF TEST RESULTS

Coating No./ Coating Name	Cathodic Disbondment (radius in mm)						Impact Resistance (in-lbs)			Hot Water Soak (adhesion rating, 1=best, 5=worst)		
	21°C / 70°F			Hot[1] (°C)								
	Blast	Power tool	Hand tool	Blast	(°C)	Power Tool	21°C 70°F	0°C 32°F	-30°C -22°F	Blast	Power tool	Hand tool
LIQUIDS												
1/ Liquid Epoxy 100% Solids	4	27	37	33	**90**	27	48	43	40	2	5	5
2/ Liquid Epoxy 100% Solids	6	18	28	22	**65**	15	48	79	58	1	2	5
3/ Liquid Epoxy 100% Solids	3	8	19	23	**90**	Total	35	38	20	2	3	5
4/ Liquid Epoxy 100% Solids	5	38	Total	45	**90**	Total	27	18	16	4	5	5

Coating Manufacturers	
Coating No., Manufacturer	
1	Liquid Epoxy
2	Liquid Epoxy
3	Liquid Epoxy
4	Liquid Epoxy
5	Tape Cold Applied
6	Tape Cold Applied
7	**Polyguard Products**
8	Tape Torch Applied
9	Shrink Sleeve
10	Shrink Sleeve
11	Shrink Sleeve

Coating No./ Coating Name	Cathodic Disbondment (radius in mm)						Impact Resistance (in-lbs)			Shear Resistance (hrs. to fail)			Peel Rate at 2 kg weight (mm/min)				
	21°C / 70°F			Hot[1] (°C)													
	Blast	Power tool	Hand tool	Blast	(°C)	Power Tool	21°C 70°F	0°C 32°F	-30°C -22°F	21°C 70°F	Hot[1] (°C)	(°C)	21°C 70°F	Hot[1] (°C)	(°C)	YJI	FBE
TAPES (Cold Applied)																	
5/ Tape with Primer	5	10	14	Mastic Flow	**60**		123	137	158	0.1	instant	**60**	2.9	360	**60**	3.1	2.1
6/ Tape with Primer	11	14	21	Mastic Flow	**75**		171	166	139	2.7	instant	**75**	2.1	instant	**75**	5.9	4.5
7/ Polyguard RD-6 Tape with Primer	**0**	**7**	**8**	**Mastic Flow**	**65**		**92**	**130**	**134**	**22.1**	**instant**	**66**	**<1**	**64**	**66**	**<1**	**<1**
TAPES (Hot Applied)																	
8/ Tape with Primer	15	6	16	33	**43**	34	48	43	40	>50	0.4	**43**	<1	30	**43**	<1	<1
SHRINK SLEEVES																	
9/ Sleeve with Primer	0	8	12	32	**65**	60%[2]	>180	>180	116	>50	2.3	**65**	<1	53	**65**	<1	<1
10/ Sleeve with Primer	3	40%[2]	33	18	**80**	Total	>180	>180	>180	>50	>50	**80**	<1	11	**80**	<1	<1
11/ Sleeve	8	11	18	16	**80**	85%[2]	124	143	81	36.25	instant	**80**	2.2	87	**80**	2.7	2.4

[1] "Hot temperatures are shown in **shaded areas** for each test.

[2] Proportion of test area disbonded, these areas were extensive.

FIELD APPLIED PIPELINE COATINGS - EXECUTIVE SUMMARY

A joint industry project was conducted by Charter Coating Service to examine the performance of a series of external pipeline coatings that can be applied under field conditions. The eleven participants in this project included both end user companies and coating suppliers. Eleven pipeline coatings were selected including: four liquid coatings; three cold applied tapes; one hot applied tape; and three shrink sleeves. Coatings were examined for application characteristics and for performance in a number of tests that simulate stresses imposed on pipeline coatings in service. The coatings were examined over different substrates including different standards of steel cleanliness and different main line coatings.

Application Characteristics:
All the coatings were applied with simple equipment that could be readily transported and used in the field. A notable difference between the coatings is the requirement for preheat of the pipe in the application of the shrink sleeves. Pre-heating is not typically possible on pipelines that are in service and so this requirement restricts the use of shrink sleeves in rehabilitation work.

The liquid coatings were the fastest to apply but required the longest time to set-up to a point where the line could be backfilled. This set-up time can be reduced by preheat of the pipe. The liquid coatings were the easiest to examine for quality of application.

Application of the cold applied tapes was faster and easier using a wrapster. The hot applied tape required careful use of a torch but was more simple to apply than the shrink sleeves. The shrink sleeves required the most skill to apply well.

Performance Characteristics:
The coatings tested and their performance are shown in the table on the following page. The coatings were examined for resistance to: cathodic disbondment; impact damage; adhesive failure of liquid applied coatings (hot water soak, pull-off adhesion); and soil stress damage of tapes and sleeves (shear and peel resistance). Tests were conducted at varying temperatures to simulate the effects of application and service under different ambient and pipeline service conditions. Pull-off adhesion data has not been included in the Table because the preponderance of failures were between the coatings and the pull-off load fixtures. Failures of this type do not give true adhesion value and can be misleading.

The following notes summarize the main differences noted in the performance of the coatings in this study.

- Performance was improved by better substrate preparation in the order: abrasive blasted better than power tool cleaned better than hand tool cleaned.
- The coatings that had the least tolerance for poorer surface preparation were those that included a two-component epoxy (the liquid coatings plus). These coatings would not typically be suited for application where the substrate can only be power tool cleaned.
- Higher temperatures worsened performance characteristics of all coatings. Performance in these tests indicates that most of the coatings would not be expected to give long term protection to pipelines running continuously at or near their maximum rated temperature. In selecting a coating for high temperature service it is important to examine the performance characteristics of the candidate coatings at the service temperature.
- The tapes and sleeves had higher impact resistance than the liquid coatings which would be expected since tapes and sleeves have a deformable outer wrap. Most coatings had lower resistance to impact under cold conditions.
- Adhesion of the test products to main line coatings varied. Coatings selection should include consideration of the compatibility of the candidate coatings with the existing coatings on the pipeline.

BACKGROUND

The failure of pipelines by external corrosion has caused both financial and environmental consequences and is also a safety hazard. Corrosion protection of pipelines is accomplished by a combination of cathodic protection and protective coatings. The coatings provide a barrier to the environment and the cathodic protection protects holiday or damage sites in the he coating.

The main site of external corrosion on pipelines is the joint area which is coated in the field. The steel at the junction between different pipe sections is more susceptible to corrosion because of the heat affected zone near the weld or because of the complexity of the joint system. Nevertheless, the joint area has historically received the least amount of attention when it comes to coating application. Corrosion can occur at the joint area despite the cathodic protection because the pipe may be shielded from flow of current between the coating failure and the anode. Cathodic shielding, as it is called, is most commonly attributed to the electrical insulating properties of disbonded coating.

A problem often associated with external corrosion is stress corrosion cracking (SCC). A December 1996 report by the National Energy Board (NEB) of Canada has reviewed the SCC on Canada's pipelines. The NEB report recommends a comprehensive approach to the SCC problem including the implementation by each pipeline company of an SCC management program. The report notes that most of the 22 SCC related pipeline failures occurred on pipelines that were coated with polyethylene tape, a common joint coating.

Interviews with a number of companies identified a desire for a test program to evaluate field applied external pipeline coatings. This study was designed to bring in a number of industry participants, both end users and coating suppliers, in a cooperative venture. Based on a test plan developed by Charter Coating, a number of interested companies met to discuss the details of the project. Further to this meeting a final test plan was developed. Companies that elected to participate in this project all contributed the same amount to the project and were considered equal participants in all respects.

The test plan that was developed for this project examines characteristics of the coatings that have a bearing on their long term performance in service. These characteristics include both performance and application characteristics since poor performance is often a result of improper application procedures. The performance tests were selected to simulate stresses encountered on buried pipelines. Tests were conducted at both 21°C/70°F to represent cold and ambient running lines and at the maximum rated temperature of the selected coating systems to determine changes in performance as a result of temperature and to evaluate the acceptability of the suppliers temperature ratings on buried lines.

The joint industry project that was developed included one coating per participant. Coatings were selected by the participants as detailed in the Coating Selection section of this report. All tests and test conditions were specified at the introductory meeting. Products and product information were supplied free of charge by the coating suppliers. This study was limited to application and testing of the selected coating systems.

TEST PROGRAM OBJECTIVES

- Select and source a representative range of field applied external pipeline coatings.
- Identify substrates commonly encountered in pipeline joint and rehabilitation coating.
- Evaluate the application characteristics of the selected coating systems.
- Record the different temperature requirements for application of the coatings.
- Compare performance of coatings applied to different surface preparations of steel pipe.
- Determine performance of the coatings at both 21°C/70°F and at the maximum rated temperatures for the coatings.
- Measure impact resistance of the coatings at varying temperatures.
- Examine and compare adhesion of the coatings to the different substrates.
- Evaluate shear resistance of tape and sleeve coatings.

COATING SELECTION

Coating selection was based on discussion between the participants that were present at the introductory meeting so as to result in the desired mix of coating systems. Each participant selected one coating for the study. The final decision as to the coatings used was at the discretion of the participant that sponsored the selected product. The coatings selected represent a broad range of tried and tested or recently introduced products from a number of generic coating types.

SUMMARY OF TEST PROGRAM

Application Characteristics

The different generic types of coating were compared to determine the strengths of each of the systems. Application characteristics of the coating systems were evaluated for:

- ease of application
- equipment requirements
- required temperatures
- speed of application
- speed of set-up (time to backfill)
- safety aspects of the applications
- ease of inspection (can defects be easily detected?)
- tendency of tent over welds
- likelihood of channelling within the coating

The components within each coating system are noted together with any preheating that was used. All coatings were applied either by or in the presence of representatives of the coating suppliers.

The coatings were applied to a variety of substrates. These substrates included prepared pipe and main line coatings to simulate the environments at joints, tie-ins, risors and repair areas. Surface preparation methods included hand tool, power tool, and abrasive blasting.

Details of application characteristics are in the Application Section of this report.

Performance Characteristics

The performance tests in this project are shown in the following table. Details of the performance of the coatings are included in the different test sections of this report.

TEST	TEST PROCEDURE	SUBSTRATE TYPE	TEST CONDITIONS	
			TEMPERATURE	OTHER
Cathodic Disbondment	ASTM G8-90	Abrasive blasted - SP6[1] Power tool cleaned - SP3 Wire brushed - SP2	70°F/21°C	30 days -1.5V
		Abrasive blasted Power tool cleaned	Maximum service rating[2]	
Peel Resistance (Only tape and sleeve products)	CSA Z245.21-M92 Hanging Weight	Abrasive blasted FBE Polyethylene system Tar and fiberglass wrap	70°F/21°C	0.3,2.0 and 15.3 kg per inch width
		Power tool cleaned	Maximum service rating[2]	
Pull-off adhesion (Liquid products)	ASTM D4541-89	All six substrate types	70°F/21°C	--
Impact resistance	ASTM G14-88	Power tool cleaned	70°F/21°C	--
			70°F/21°C	
			70°F/21°C	
Shear resistance (Only tape and sleeve products)	Aramco 09-AMSS-96 "Alyeska Shear Test"	Power tool cleaned	70°F/21°C	50 hours
			Maximum service rating[2]	
Hot water soak (Only liquid products)	CSA Z245.20-M92	Abrasive blasted Power tool cleaned Wire brushed	203°F/95°C	24 hours

[1] 2.0-3.0 mil profile
[2] Manufacturer's maximum continuous temperature rating

1 APPLICATION CHARACTERISTICS

INTRODUCTION

Improper application of field applied pipeline coatings has been the source of many coating failures. Problems in the application may be attributed to one or more of the following factors:

- Application specifications either don't exist or have poor detail
- Quality control of the application work is limited and often performed by individuals with minimal knowledge of the coating system
- Training of the field applicators is insufficient

In planning a particular project, it is important to understand that there may be restrictions on the equipment and personnel that can be used to apply the coatings. In this study coatings were selected that were relatively easy to apply and required quite simple equipment since these products can be used more widely than complex systems. For example we did not examine fusion bond epoxy(FBE) or plural component spray applied coatings even though these systems are used for field application to new pipelines.

The application of all the coatings was observed by Charter Coating and was conducted either by or in the presence of representatives of the coating suppliers. This allowed for continuity of analysis of the application characteristics while ensuring that the suppliers standard application procedures were being properly adhered to. All applications were conducted at 2 °C/70°F with an initial pipe temperature of 18-19°C/64-66°F.

All coatings were applied to six substrates. These were:

Abrasive blasted steel (SSPC-SP6, commercial blast to 2.0-3.0 mil profile)
Power tool cleaned steel (SSPC-SP3)
Hand tool cleaned steel (SSPC-SP2)
Polyethylene coated pipe (YJI)
Fusion bond epoxy (FBE) coated pipe
Tar and wrap coated pipe

The objective of this work was to identify application characteristics and equipment requirements that might impact on the desirability of the coatings for specific projects.

COATINGS IN STUDY

The generic components of the coatings are shown in the following table. All tapes were applied with a 50% overlap resulting in a double layer of tape over the surface of the pipe (see Figure 2 in Photographic Section). The average film thickness shown in the table is the film thickness measured over the power tool cleaned steel substrate.

Coating Type	Coating Name	Base	Hardener	Mix Ratio[2]	Av. DFT (mils)
Liquid Coatings	No. 1	Epoxy resin	Amine	1:1	55
	No. 2	Epoxy resin	Amine	3:1	39
	No. 3	Epoxy resin	Amine	3:1	23
	No. 4	Epoxy resin	Amine	3:1	23
Coating Type	Coating Name	Primer	Adhesive	Backing	Av.DFT (mils)
Cold Applied Tapes	No. 5	Primer Bitumen based	Bitumen based, fabric reinforced	PVC	110
	No. 6	Primer Bitumen based	Bitumen based	PVC	100
	Polyguard RD-6 No. 7	**Polyguard #600** Bitumen based	Bitumen based	Woven geotextile	95
Hot Applied Tape	No. 8	Bitumen based	Coal tar, reinforced	Thin plastic film	105
Shrink Sleeves	No. 9	2-component[1] epoxy	Copolymer hot melt	Expanded polyethylene	105
	No. 10	2-component[1] epoxy	Copolymer hot melt	Expanded polyethylene	60
	No. 11	None	Mastic	Expanded polyethylene	70

[1] All 2-component epoxies were 100% solids products
[2] Mix ratios are by volume

SUMMARY OF APPLICATION PARAMETERS

Coating	Equipment Requirements	Time to Apply[1]	Time to Backfill[2]	TEMPERATURES USED				Final Film Thickness Range (Avg.) mils[3]	Holidays
				Preheat of Product	Preheat of Pipe	Heat Applied to Primer	Post Heat		
No. 1	stirrer (power stirrer preferred and an applicator (brush, roller, or trowel),	30 min	5 hrs	None	None	None	None	12-77(55)	None
No. 2		30 min	5½ hrs	25°C/77°F	None	None	None	15-75(39)	5 pinholes
No. 3		30 min	3½ hrs	25°C/77°F	32°C/90°F	None	None	13-66(23)	2 pinholes
No. 4		30 min[4]	4½ hrs	None	None	None	None	16-80(23)	6 pinholes
No. 5	stirrer, brush, and wrapster (wrapster optional)	45 min	¾ hrs	None	None	None	None	(110)	None
No. 6		90 min	1½ hrs	None	None	None	None	(100)	None
Polyguard RD-6 No. 7		**60 min**	**1 hr**	**None**	**None**	**None**	**None**	**(95)**	**None**
No. 8	stirrer, applicator, and torch	40 min	¾ hr	Propane torch	None	None	None	(105)	None
No. 9	stirrer, applicator, and torch	50 min	2.¾ hrs	None	45°C/113°F	90°C/194°F	Heat from propane torch to shrink sleeve	(105)	None
No. 10		90 min	2½ hrs	None	70°C/158°F	None		(60)	None
No. 11	torch	50 min	1¾ hrs	None	100°C/212°F	None		(70)	None

[1] Time to apply was recorded during application of each coating to 11 foot of 4" diameter power tooled pipe and includes mixing time and, where appropriate, time to set-up of primer
[2] Time to backfill includes time to apply plus time required for the coating to develop properties that will withstand backfilling
[3] Only an average film thickness is given for the tapes and sleeves because there was little variation for each product
[4] Due to dripping of the coating the applicator continued to go back to the pipe to brush out the drips, thereby extending the time to apply