Pipeline Coating Performance

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ABSTRACT

Even though pipeline coatings are referred to as the first line of defense against external corrosion, coatings have not always been given the consideration deserved when constructing a gathering or transmission line. This paper presents a CSA Z662 compatible methodology for coating selection and application. Coating selection is an important first step for owner companies, or their engineering companies, in achieving the desired pipeline coating performance. Owner and/or their engineering companies must then be responsible for dictating the performance criteria of the selected coating that is used to qualify coating application facilities. Acceptance of a robust Inspection and Test Plan (ITP) to ensure repeatable process control during application is another step that is critical to achieve the desired performance of the coating specified. The paper ends with a description of additional programs to be implemented when there is variability in the application process to determine if and where coating performance may not be as optimal as desired.

Key words: FBE=Fusion Bond Epoxy, Cathodic Disbondment, Adhesion, Qualification and ITP=Inspection & Test Plan

INTRODUCTION

Within CSA Z662-11, Oil and Gas Pipeline Systems, Section 9.2 states that the owner or operating company, whichever is applicable, shall be responsible for performing and documenting coating system evaluations and selections. This coating selection process must consider parameters such as, but not limited to: installation and operating conditions, maximum operating temperature, soil conditions, stresses, backfill, minimum flexibility temperatures and repair-ability[1]. The acceptance criteria as a minimum shall be as per the standard or more stringent as specified by the owner or engineering company.

It is important that the applicator demonstrates that they are capable of applying the coating as per the specification. Qualification periods might be for each project or a reasonable period prior to coating commencement. The ITP's testing parameters and pass/fail criteria of the coating applied are to be determined by the owner or engineering company with consideration given to operating conditions and long term pipeline integrity.

The owner or engineering company can request additional testing or application parameters through the ITP to meet their desired performance criteria; such as higher preheat temperature prior to coating application, different acid percentage or blast anchor profile pattern depth. The pipe coating applicator must maintain process control by adhering to the approved ITP and maintaining pertinent application equipment. The ITP must speak to re-qualification should there be changes in process which may be either material or equipment. However, the re-qualification may not be practical if changes are made during production and therefore a program must be implemented to obtain coated pipe samples from the right-of-way to determine if and where there may be areas of pipe that may not meet the expected performance results for the operating conditions.

The following is a review of an actual recent pipeline coating program after the coating was selected and after a coating applicator had been selected from a group of qualifying applicators. FBE was the only coating that was considered and tested for pipeline coating application. The maximum design temperature was 65°C. The paper concentrates on the problems identified as a result of the ITP and describes steps taken to identify and follow batches of coated pipe that did not meet desired coating performance criteria.

EXPERIMENTAL PROCEDURE

The ITP established a number of tests to be completed on coated samples from each batch. Those tests were:

- Cathodic Disbondment testing is conducted at 20°C or for 65°C in a circulating oven. The electrolyte solution is 3% NaCl in distilled water and filled to 300 ml in 75 mm ± 3 ID cylinder. The applied voltage across the electrolyte is closely maintained at -1.5V with an induced break in the coating of 3.2 mm diameter. The 28 day 65°C test has the solution maintained once per week by the addition of distilled water[2].

- Adhesion testing is a qualitative examination of water absorption of FBE under tap water at 75°C for a set duration. After cooling to room temperature and within one hour of removal from warm water the FBE coating shall be evaluated as per CSA Z245.20 clause 12.14.3 (f)[3].

The FBE coating specification was 400 microns nominal thickness. Samples were obtained from multiple applicators applying 2 FBE coating formulations.

RESULTS

There were two pre-approved FBE manufacturers' coating formulations that the owner specified and both materials were tested as part of the applicator qualification. The properties of the tests selected and acceptance criteria established in Table 1 were applicable when considering the maximum design temperature of 65°C (cathodic disbondment), muskeg soil conditions (adhesion) and winter construction (-30°C impact and flexibility). The applicator qualification testing could was per the criteria generated by an engineering company as detailed in Table 1. Although two product manufacturers were accepted, the test results for cathodic disbondment testing at 65°C for 28 days were noticeably different. The qualification table from Applicator A was submitted and approved prior to production coating.

Test Properties	***Acceptance Criteria***	**Product 1**	**Product 2**
Cure - ΔTg	*ΔTg ≤ 5°C & Cure ≥ 95%*	3.28°C & 99.2%	1.66°C & 99.8%
24 hr CDT @ 65°C	*11.5mm radius maximum*	2.4 mm	1.88 mm
28 day CDT @ 65°C	*15 mm radius maximum*	6.6 mm avg.	13.1 mm avg.
28 day CDT @ 20°C	*15 mm radius maximum*	5.5 mm avg.	4.6 mm avg.
24 hr adhesion @ 75°C	*Rating 1-3*	Rating 1	Rating 1
28 day adhesion @ 75°C	*Rating 1-3*	Rating 1	Rating 1
Cross Section Porosity	*Rating 1-4*	Rating 2	Rating 1
Interface Section Porosity	*Rating 1-4*	Rating 4	Rating 2
1.5 J Impact @ -30°C	*No Holidays*	0 Holidays	0 Holidays
2.5° Flexibility @ -30°C	*No Cracking*	2.57°, no cracks	2.52°, no cracks
Interface Contamination	*30% maximum*	10%	25%

Table 1: Testing Table of Qualified FBE from Applicator A

Focusing on the 28 day CDT at 65°C tests and the acceptance criterion of less than a 15 mm diameter disbondment, initially Applicator A applied FBE 1 with great success as shown in Table 2:

Test Properties	**Acceptance Criteria**	**Product 1**
28 day CDT @ 65°C	15 mm radius maximum	3.6 mm
		5.4 mm
		5.1 mm

Table 2: Initial Results of Tested Coating Product 1

During production coating the applicator made a FBE manufacturer change and revised the electrostatic application system. Therefore with two (2) changes to the application process the owner requested testing of Product 2 and the following results were obtained as shown in Table 3 for the 28 day CDT at 65°C test. Even though the product qualified months earlier the performance of Product 2 did not perform well and did not meet the acceptance criteria.

Test Properties	Acceptance Criteria	Product 2
28 day CDT @ 65°C	15 mm radius maximum	22.8 mm
		22.9 mm
		22.8 mm

Table 3: Results of Tested Coating after Switch to FBE Product 2

Although the coating specification stated qualification period was valid within 2 years prior to commencement of production coating, the process had changed and the owner requested additional testing of the applied pipeline coating as a result of the change to the material being applied and the change in the application process. The variability of the coating performance is shown in Figure 1 (Applicator A - Product 2); where the results show the applied coating continually did not meet the cathodic disbondment test acceptance criteria of 15mm. The orange line shows results from Applicator B (Product 2) which exhibits good repeatability and continually met the criterion. Applicator A struggled with reproducibility while Applicator B was able to consistently meet the acceptance criterion even with stripped and recoated pipe. Of note is that the results from the daily production tests for both applicators had similar results that met the daily coating test criteria; it was the additional 28 day CD tests that indicated that coating performance did not meet the desired performance criterion. The time period of testing spanned a 5 month production time frame.

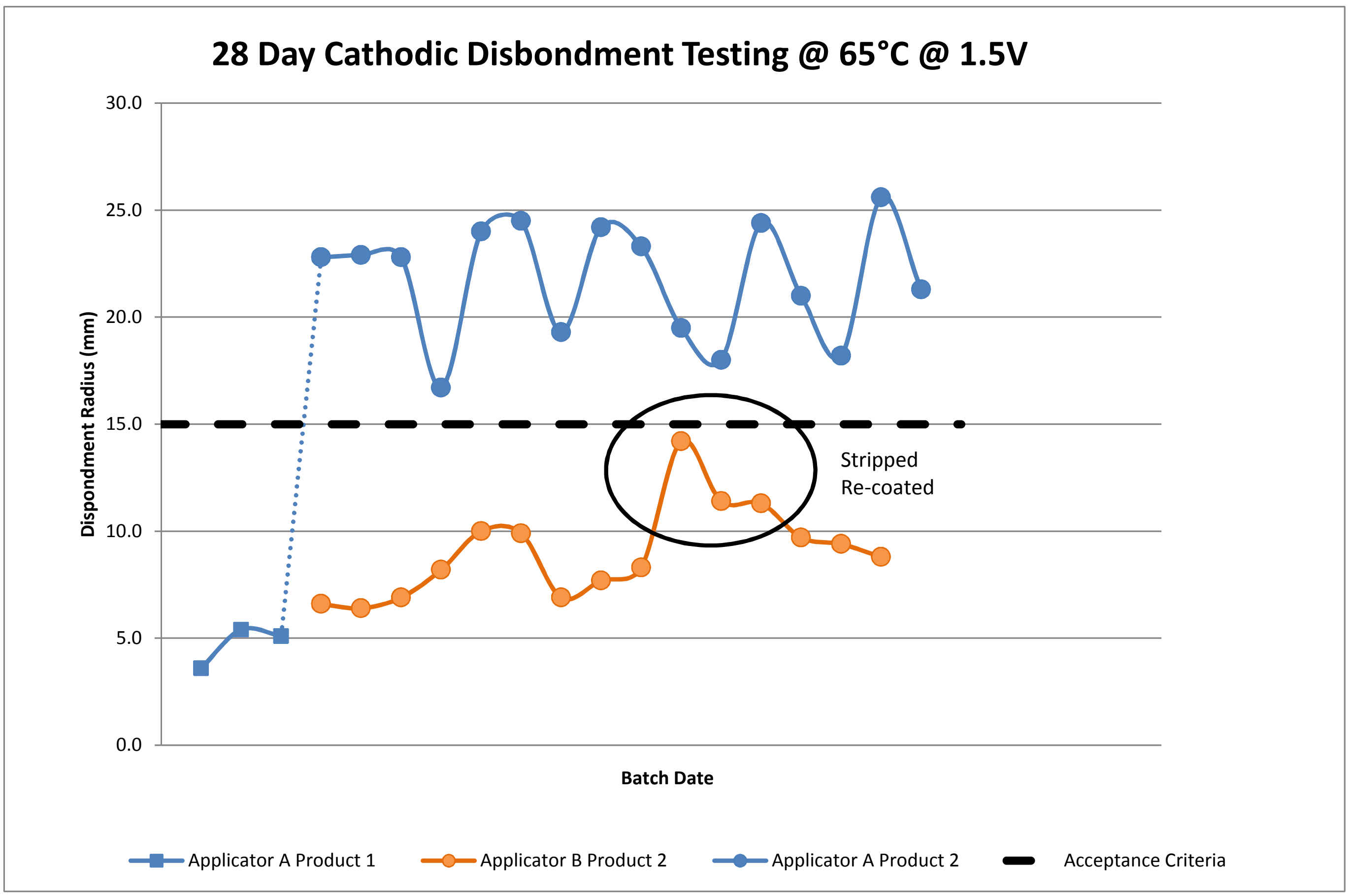

Figure 1: Results of 28 Day Cathodic Disbondment Tests

Although commercially they were not obligated to do so; Applicator A agreed to revert back to applying Product 1 as a result of the decrease in coating performance. In addition Applicator A also agreed to continue additional testing to monitor coating performance throughout the remaining application process.

Figure 2 displays that the coating performance of Product 1 after many weeks of stable application is comparable to that of Product 2 applied by Applicator B.

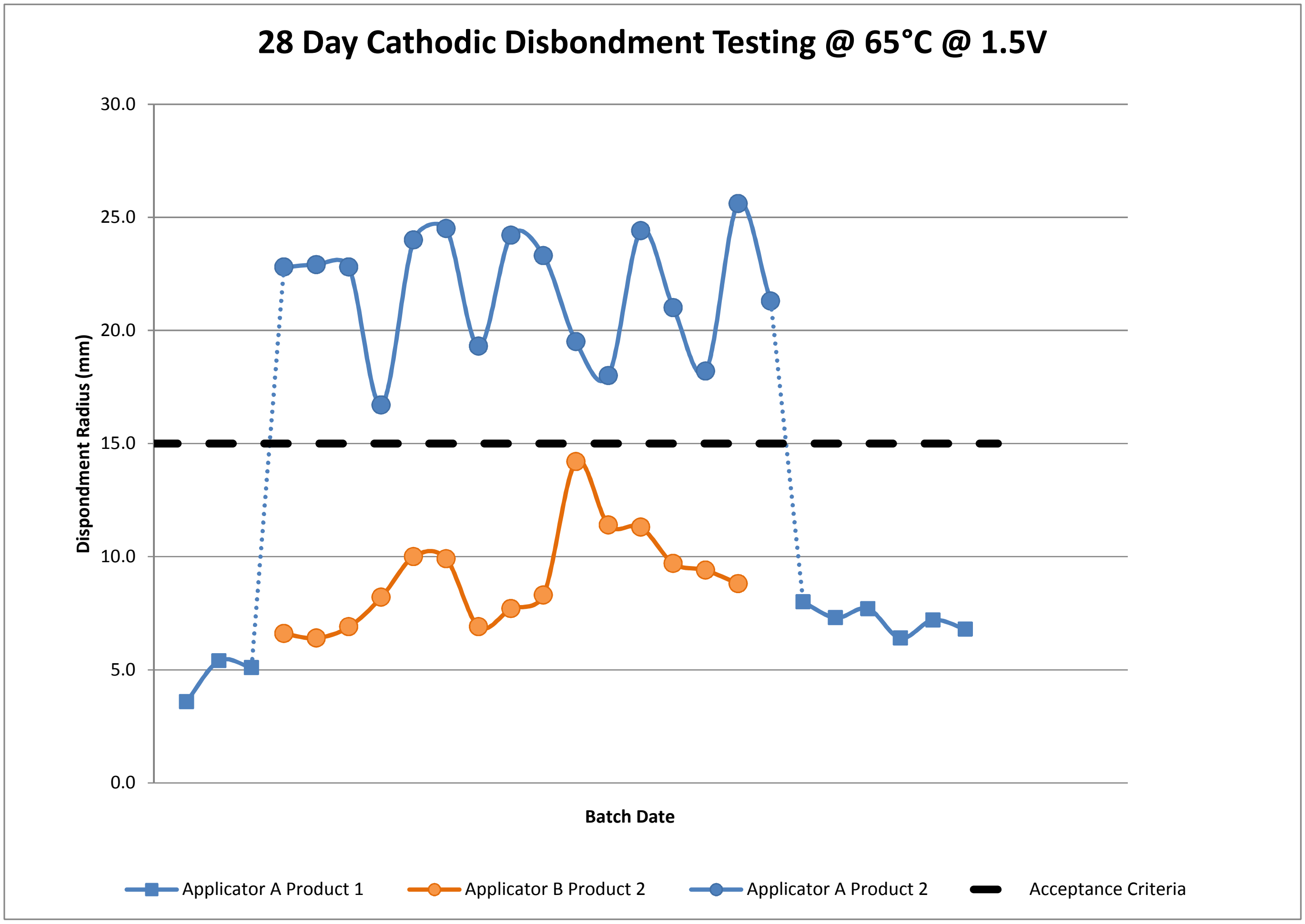

Figure 2: Results of 28 Day Cathodic Disbondment Tests after reversion to Product 1

Although the remainder of the coating application continued to meet the owner's desired performance criteria there was a portion of coated pipe whose performance may have not be as optimal as expected. In an attempt to understand if and where future coating performance issues may occur, a program was implemented to periodically (one sample every ~10km) obtain Applicator A - Product 2 coated pipe samples from the field and conduct additional longer term tests as shown in Table 4.

Test Properties	Acceptance Criteria	Applicator A Product 2			
		Location 1	Location 2	Location 3	Location 4
28 day CDT @ 65°C	15 mm radius maximum	20.2 mm	23.8 mm	20.1 mm	24.8 mm
		21.4 mm	23.5 mm	22.4 mm	10.2 mm
		24.5 mm	25.2 mm	23.1 mm	25.5 mm
28 day CDT @ 20°C	15 mm radius maximum	9.8 mm	10.4 mm	5.9 mm	11.4 mm
		5.7 mm	10.8 mm	10.5 mm	6.2 mm
		8.7 mm	6.1 mm	10.2 mm	7.3 mm
28 day adhesion @75°C	Rating 1-3	Rating 1	Rating 1	Rating 1	Rating 1

Table 4: Results of Tested Coating from Field Samples Product 2 from Applicator A

These test results in Table 4 were then compared to control samples that were donated by three (3) other applicators. The control samples of random selection yielded results which met performance expectations while the Field Product 2 by Applicator A did not always meet criteria as shown in Table 5.

Test Properties	Acceptance Criteria	Applicator A	Applicator A	Applicator X	Applicator Y	Applicator Z
		RoW Product 1	RoW Product 2	Control Sample	Control Sample	Control Sample
28 day CDT @ 65°C	15 mm radius maximum	11.1 mm	21.6 mm	No data	15.0 mm	10.5 mm
		10.0 mm	14.2 mm			7.5 mm
		10.0 mm	12.8 mm			9.8 mm
28 day CDT @ 20°C	15 mm radius maximum	No data	No data	10.3 mm	2.2 mm	5.9 mm
				8.3 mm		4.8 mm
				8.9 mm		3.1 mm
28 day adhesion @75°C	Rating 1-3	Rating 1	Rating 2	Rating 2	Rating 2	Rating 1

Table 5: Results of Tested Coating from Field Samples

CONCLUSIONS

The initial qualification test results from Applicator A were acceptable but with changes to both coating material and the application process; additional testing was requested to ensure the changes would not affect coating performance. Once evident, the changes resulted in less than desirable expectations. When Applicator A reverted to the original material and application process the coating performance returned to meeting the expected coating criteria. It is therefore essential that the owner company is engaged in both the selection of coatings and approving an ITP that is robust and will result in applied coating that meets the desired performance criteria. This can include stipulating additional test requirements and / or re-qualification should any changes to either material or process occur. Although it may not always be practical to re-qualify during production; other programs can be implemented to assess coating performance post application.

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REFERENCES

1. CSA & Z662-11 Oil and Gas Pipeline Systems Section 9
2. CSA Z245.20-10 Plant-Applied External Fusion Bond Epoxy Coating for Steel Pipe Clause 12.8
3. CSA Z245.21-10 Plant-Applied External Fusion Bond Epoxy Coating for Steel Pipe Clause 12.14