

Field and Laboratory Studies on the Effect of UV Degradation and UV Protector Paints on Stockpiles of FBE Coated Pipeline

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ABSTRACT

Field and laboratory studies were carried out to investigate the effect of UV degradation on stockpiles of FBE Coated Pipeline. In addition, three commercially available UV protector paints were examined as potential protection of the underlying FBE system 1A pipeline coating from UV degradation. This study was done under actual field exposure for two years and using laboratory tests simulating weathering conditions using a Q-SUN Xenon Arc Test Chamber to simulate the damage caused by full-spectrum sunlight and rain. Coating flexibility by laboratory testing, and Photooxidation Index (POI), Carbonyl Index (CI) and changes in the polymer chemical structure by Attenuated Total Reflection – Fourier Transform Infrared (ATR-FTIR) were examined at different time intervals. The results indicated that although the tested UV protector coatings were effective in preventing the underlying FBE coating from chemical/oxidative degradation and chalking, maintaining the color of FBE gloss; the underlying FBE coating exhibited a reduction in flexibility after nine months of field exposure and 250 hours of accelerated laboratory test conditions. No further decrease in the FBE coating integrity was noted with increasing exposure/testing time.

Key words: FBE Coating System 1A, Stockpiles, UV Degradation, UV Protector Paints, Field Exposure, Q-SUN Xenon Arc Test Chamber, Flexibility, ATR-FTIR.

INTRODUCTION

Fusion bonded epoxy (FBE) is the primary coating used in North America for new pipeline construction and is strongly featured in the Middle East¹. Pre-coated FBE pipe is routinely stockpiled and stored in large quantities at several locations close to pipeline right-of-ways. Once stockpiled, most of the pipes

remain un-used until an inspection and remediation program is initiated². Integrity projects purchase FBE coated pipe in advance and stockpile it until it is required. In addition, project delays and left-over pipe from completed projects can cause stockpiling for future use for undetermined periods of time. Under ultraviolet (UV) exposure in the presence of air, photooxidative degradation of FBE coatings occurs due to photometrical reactions arising from UV absorption. The main absorbers of UV radiation responsible for initiating photochemical reactions are carbonyl groups present on the polymer backbone³. The absorbed UV energy can break existing chemical bonds, form free radicals and produce new carbonyl groups in the main chain by reacting with oxygen. Therefore, the rate of carbonyl growth which correlates well with the rate of crosslink scission can be a relative measure of the photooxidation rate for a given FBE coating system⁴. Once photooxidation degradation begins, a rapid breakdown of the coating will follow as chemical degradation can transform into substantial changes in the physical, mechanical and corrosion protection properties, ultimately leading to failure of the coating. The extent and degree of polymer degradation (visibly observable as chalking) depend on the intensity and duration of the UV exposure. Generally, the top of a stockpiled FBE coated pipe (12 o'clock position) suffers the most coating breakdown, less on the sides (3 or 9 o'clock positions) and little to none on the bottom (6 o'clock position)². Other elements in outdoor environments such as moisture and wind can also contribute to the degradation of stockpiled FBE coating. The outer layer of chalked FBE, which protects against further degradation, can be removed by rain and wind leading to alternate chalking causing a noticeable reduction in the coating thickness. Shorter wavelength UV rays have more destructive power than the longer wavelengths, but they cannot penetrate inside the coating and therefore cause most damage to the surface layer of coatings⁵. It is reported that UV light with a wavelength range of 290 nm to 400 nm has particular impacts on aesthetic changes, chemical breakdown and deterioration of mechanical properties^{3,6}. Coating formulations can also affect the susceptibility of FBE coatings to UV degradation. To reduce or eliminate the effects of UV degradation, protective materials are usually applied preferentially to FBE coated pipe stored in the outer layers of the stockpiles. Whitewash UV protector paint has been proven to preserve and retain the original dry film thickness and conserve many of the initial physical characteristics of the underlying FBE coating except for the flexibility². However, in the previous studies, the investigation of chemical changes in the polymer structure of stockpiled FBE coatings under UV exposure has not been conducted. In addition, few details were reported regarding the correlation between the real-world weathering conditions and accelerated weathering conditions in laboratory settings, this correlation would be helpful for future coating and protective material selection and evaluation for stockpiling.

In this study, field and simulated laboratory tests were developed to investigate the effect of UV degradation on stockpiles of FBE coated pipe in terms of the coating's mechanical (flexibility) and chemical properties and the correlation of the real-world conditions with the simulated laboratory conditions. The study also investigated the protection effect of three different commercially available UV protector paints on the underlying FBE system 1A pipeline coating under UV exposure.

EXPERIMENTAL PROCEDURE

A section of a new production pipe coated with FBE system was cut into test samples with dimensions of 1" x 8" x 0.25 (pipe wall thickness). The samples were either left as unprotected FBE (control) or coated FBE with one of the three selected commercially available UV protector paints labelled in this study as 1C, 2O and 3R. The samples were divided into two sets, one set was used in the laboratory study, and a duplicate set was exposed to an actual field condition for two years. Multiple samples were used for each set to test duration to provide at least three samples per test duration. The uncoated sides of test samples were protected with a polyethylene tape to prevent corrosion and the tape was removed after laboratory weathering/aging or field exposure. The coating on the samples was evaluated after periodic intervals for color, dry film thickness (DFT) and flexibility. ATR-FTIR analysis was also used to calculate POI (photooxidation index) and CI (carbonyl index) of the top FBE layer.

Coating Systems Used and DFT Measurements: The FBE system and the type of the UV Protective paints are given in Table 1. A Positector 6000 thickness gauge was used to measure the dry film thickness (DFT) of the test samples before testing and after different test durations.

Table 1: Coating Systems and Pre-Test Dry Film Thickness

Labelling System	Coating and Paints Identification	Dry Film Thickness	
		Min – Max Mils / mm	Average mils / mm
FBE 1A	FBE System 1A as per CSAZ245.20 Identification ⁷	15.2 – 20.6 / 0.386 – 0.523	17.5 / 0.445
FBE + Paint 1C	Polyurethane / Acrylic	18.0 – 24.0 / 0.457 – 0.610	21.7 / 0.551
FBE+ Paint 2O	Acrylic Latex	16.4 – 22.5 / 0.417 – 0.572	19.6 / 0.497
FBE+ Paint 3R	Acrylic Latex	19.6 – 25.2 / 0.447 – 0.640	20.3 / 0.515

Flexibility: Flexibility: Test was conducted at -30 °C (-22 °F) to determine if the coating can pass the acceptance criteria of no cracking or holidays at 2.5 °/PD as per CSA Z245.20-14, Section 12.11 for FBE System1A. Failed samples were further tested to determine the bending angle per pipe diameter (°/PD) without cracking. The equivalent Flexure Strain of the coating was also calculated as per NACE TM0304⁸. The two equations used in this study are given below:

- ❖ $D = 57.5 * t / R + 1/2 t$ as per CSA Z245.20-14, Section 12.11⁷
Where: D = the required angle of strain (deflection) per pipe diameter (°/PD)
R = mandrel radius (mm), t = the sample thickness (mm)
- ❖ Flexure Strain of Coating = $(t/2 + c) / (R + t/2)$ as per NACE TM0304⁸
Where: t = steel panel thickness (mm), c = coating system thickness (mm),
R = mandrel radius (mm)

ATR-FTIR: A Perkin-Elmer Spectrum 100 FTIR with ATR accessory was used to record the infrared (IR) spectra of coating chips collected from the plain and protected FBE system 1A. The ATR crystal was a ZnSe/diamond prism. The top surface of the FBE was slightly scraped using a utility knife to remove the contaminants. For the FBE top coated with UV protector paints, the top surface of the underlying FBE coating was obtained by carefully removing the topcoat of UV protector while under a microscope. After collection of the background spectrum, each coating sample with the surface to be tested downward, was placed onto the ATR top plate, the pressure plate was placed over the sample, the pressure arm was swung round until it was above the pressure plate, and the pressure pin was screwed down to apply an appropriate pressure to the sample. The sample was scanned over a range of 4000 cm⁻¹ to 600 cm⁻¹, using scan number 20 and scan resolution 2 cm⁻¹. The collected spectrum was then analyzed, and the POI (photooxidation index) and CI (carbonyl index) were calculated by comparing the peak areas representing oxidation (-NH and -OH at about 3400 cm⁻¹, or -C=O at 1730 cm⁻¹), to the alkyl area of the spectrum (-CH₃, -CH₂-, -CH=) at 2800 cm⁻¹.

Laboratory Study

An accelerated weathering test was undertaken using a xenon arc light source with daylight filters to simulate sunlight, and a controlled temperature/humidity/water spray to simulate various weather conditions. The study was expanded to include a laboratory ageing test using no UV light exposure but only the temperature and humidity cycles of the earlier simulated weathering test. This was done to