Chevron's Use of EonCoat® To Prevent Corrosion On Steel

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Abstract: The paper will discuss how Chevron U.S.A. has been successful in using EonCoat® to prevent atmospheric corrosion and using a high temperature version of the coating to prevent corrosion under insulation (CUI). Chevron's Benjamin Chaloner-Gill, Ph.D., Senior Advisor, Materials and Corrosion, R&D, is the senior author of the paper and will deliver the lecture at EUROCORR 2018. The resulting alloy forms a magnesium iron phosphate alloy layer to prevent atmospheric oxygen and moisture from reaching the substrate.

Third party laboratory testing (carried out at Charter Coating Service (2000) Ltd.) and field-test results will be presented to the audience. Commercial use case history will be shared with the presentation of a case study involving Chevron's use of the technology at their refinery in Pascagoula, Mississippi, USA.

Usage detail will be revealed, including surface preparation (ISO Sa 2), and the coating's unique characteristic that allow for the coating to be applied over a flash rusted surface.

Keywords: Chevron; corrosion protection; refinery best practice; CUI; corrosion under insulation

Introduction

In a recent paper delivered to the Society of Petroleum Engineers in Aberdeen, Scotland on 18 June 2018 (SPE – 190893 – MS), the chemistry of EonCoat was fully explained. In short, when EonCoat chemically reacts with carbon steel, a protective passivated layer over the iron is produced. This protective layer has two important attributes that are very attractive – (1) it is insoluble and (2) it is chemically bonded to the substrate. By understanding the chemistry of EonCoat and these features, this non-traditional (i.e., inorganic) coating system can be utilized in the protective coating realm.

Chemistry of EonCoat

EonCoat is a two-component waterborne spray system. Part A is based on potassium monophosphate, KH_2PO_4, and Part B contains magnesium hydroxide, $Mg(OH)_2$. Minor amounts of proprietary components are added to the formulation to control the rate of the reaction, rheology of the system, stability (shelf life) of the product and some other properties. After spraying, the coating sets in minutes by acid-base reaction:

$$KH_2PO_4 + Mg(OH)_2 + 4\ H_2O \rightarrow MgKPO_4 \cdot 6\ H_2O \qquad (1)$$

The product that forms in reaction (1) is a solid material with appearance and mechanical properties that resemble those of traditional ceramics.

As EonCoat is spray-applied onto carbon steel, the acid in EonCoat converts the top layer of steel into iron phosphate and/or iron magnesium phosphate so that the steel can no longer corrode. Passivation layer formation reaction tentatively can be represented by the following equations:

$$Fe + 2\ H_3PO_4 \rightarrow Fe(H_2PO_4)_2 + H_2 \qquad (2)$$
$$Fe + 2\ KH_2PO_4 + 2\ H_2O \rightarrow Fe(H_2PO_4)_2 + 2\ KOH + H_2 \qquad (3)$$
$$Fe + Fe(H_2PO_4)_2 \rightarrow 2\ FeHPO_4 + H_2 \qquad (4)$$
$$Fe + 2\ FeHPO_4 \rightarrow Fe_3(PO_4)_2 + H_2 \qquad (5)$$

Since the above reactions occur in the presence of a metal oxide/hydroxide that is a major component of Part B, the following reactions can occur at the same time:

$$2\ Fe(H_2PO_4)_2 + Mg(OH)_2 \rightarrow 2\ FeMg_{0.5}(PO_4) + 2\ H_3PO_4 + 2\ H_2O \qquad (6)$$

The second mechanism for corrosion protection is the cementitious layer. This results from the reaction (1) between the acid/acidic salt and the metal oxide. This cementitious layer which is based on a binder, $MgKPO_4 \cdot 6\ H_2O$ which is a spatially soluble metal phosphate with solubility product constant $KSP = 2.1 \cdot 10^{-12.}$ The cementitious layer works as a phosphate reservoir providing phosphate ions to the steel surface for the whole lifetime of the coating.

In essence, EonCoat works by passivating the surface of the substrate so it can no longer react with corrosive substances such as oxygen and moisture. Unlike paint, EonCoat chemically bonds to the surface of the steel. And unlike paint, it is not a barrier coating.

Testing of The Technology

To fully understand this coating system, a thorough investigation has been undertaken. Testing has been conducted both in the field and at a third-party laboratory over a three-year period. Through this testing, we have learned how to use EonCoat as a coating system in two different regimes. The two regimes that have been tested are atmospheric corrosion below 100 ^{o}C and corrosion under insulation (CUI) both at low temperature (less than 100 ^{o}C) and at higher temperatures (up to 350 ^{o}C). Given our understanding of how EonCoat works, this coating system has been utilized as a protective coating at our facilities, in both applications.

To gain a full understanding of EonCoat as a protective coating system, atmospheric corrosion testing has been conducted in the following environments: salt fog testing (ASTM B117), cyclic corrosion testing (ASTM 5894), and CUI testing (NACE 2014, Paper 4193). Furthermore, testing also included various surface preparations Sa 2 ½ | SSPC SP 10, Sa 2 | SSPC SP6, SSPC SP 7 and SSPC SP 5. A third variable was also included in the surface preparation experimental matrix, soluble salts. While this test matrix could be a paper in itself, the results of the testing will be simplified for brevity.

The long-term laboratory test results revealed that the preferred surface preparation is Sa 2 | SSPC SP 6. The laboratory test results were consistent with field-testing. Field testing consisted of coating very large panels (5 feet x 7 feet) with EonCoat with the various surface preparations. Panels were placed at two different geographic locations in the United States – Pascagoula, Mississippi and Richmond, California. While these two locations differ greatly in both temperature and humidity, the performance results were the same. Salt levels made no difference in performance. Whether the steel was contaminated with salt or the steel was clean, no performance difference was observed.

Both of these conclusions have major implications in understanding the cost of EonCoat application. Additionally, as was detailed at the SPE conference, Florida International University's Department of Mechanical and Materials Engineering conducted extensive cyclic polarization studies (Reference – Unpublished data?) that reached the same conclusion. Internal EonCoat test data, reviewed by Chevron, also resulted in the same findings. EonCoat can be applied on a flash rusted or rusted surface. These results, a simplified surface preparation and being able to coat over a rusted surface, will lower the overall cost of application when compared with a standard three coat system. EonCoat projects this coating system to last 30+ years in atmospheric service. With a lower total cost of application and a simpler surface preparation prior to coating, EonCoat provides an attractive solution that facility operators are seeking.

Current coating products in the market place for CUI provide a very wide temperature range. CUI occurs due to damage to the coating system. If the coating is damaged and insulated, then CUI becomes a very costly inspection and maintenance problem. When damage to the coating system occurs, the damage is not intentional. But it leaves behind an asset integrity problem. What if the tables were turned? What if mechanical integrity is built into the protection layer? What if this layer is not susceptible to mechanical damage? If so, the solution would provide a large number of benefits. First and foremost, the failure mode has changed. It would no longer be the coating failure leading to a corrosion and inspection problem. This is the second attribute of EonCoat, the mechanical integrity of the protective layer, which changes the game for CUI.

To test the mechanical integrity of EonCoat, panels were intentionally damaged. Damage was inflicted in a number of different ways – (i) Impact damage with a ball being dropped on the panel, (ii) The panel was dropped from a height of 3-4 meters onto the cement, (iii) A saw blade was used to make a cut like mark in the protective layer (but not cut through the steel itself), (iv) Various hardness tests (designed to inflict mechanical damage) were done on the panel, and (v) A mechanical polisher was used in some areas. In the most extreme case, one of the panels was bent at a 90^{o} angle. This bend did bring new steel to the surface. Figure 1 shows the panels after damage and before B117 exposure.

Figure 1 – EonCoat panels with intentional mechanical damage.

Then the panels were subjected to ASTM B117 conditions; the figures show the duration time for the panels. In the pictures below, we show the panels before B117 testing and then after 335 hours (Figure 2) and after 1,870 hours (Figure 3). In all cases, there is not rust in the areas where the panels were intentionally damaged, aside from the 90^{o} bend in the panel. Again, the panels show no sign of rust. Organic coating would have failed to control the corrosion in these conditions.

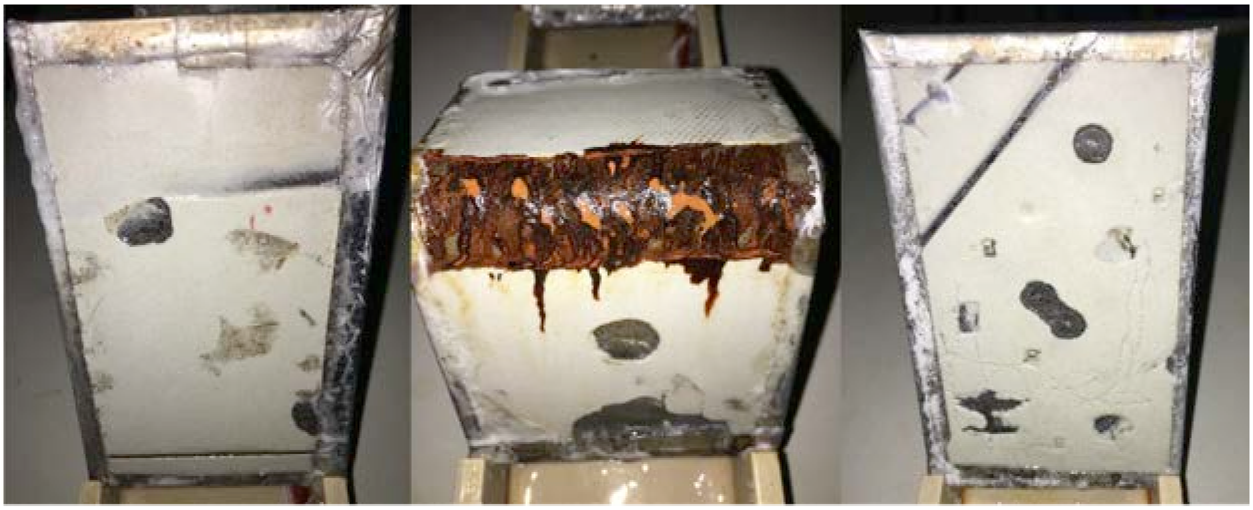

Figure 2 – EonCoat panels with intentional damage after 335 hours of B117 exposure.

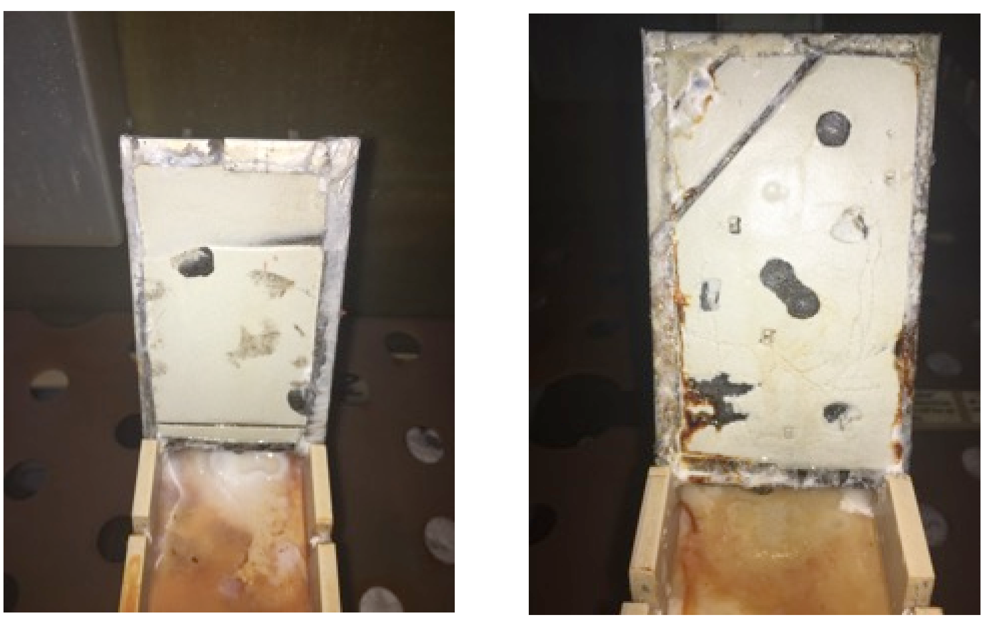

Figure 3 – EonCoat panels with intentional damage after 1,870 hours of B117 exposure.

Where new steel is exposed, that section of the panel rusted, as expected. But notice on the portion of the panel that was bent – at the edge of the EonCoat, there is no rust along the entire line. Meaning, when the EonCoat forms a chemical bond with the surface of the steel, the protective layer is formed. When this occurs, the mechanical integrity is maintained. (It should be noted that in the field, if a section of tank or pipe incurred mechanical damage as severe as a 90^o bend, that steel would be taken out of service as it would be permanently deformed.)

Field-testing of EonCoat in CUI conditions continues. Figure 4 (below) shows cross-cut adhesion into the coating. The cross-cut adhesion was performed in February 2018 and then re-examined in June 2018, 4 months later. The picture in Figure 4 shows the cross-cut and subsequent removal of adjacent phosphate ceramic. This picture was taken in June 2018 after the pipe had been placed back in service. The pipe service, insulated with blankets, is running at temperatures ranging from 120 to 138 ^{o}C.

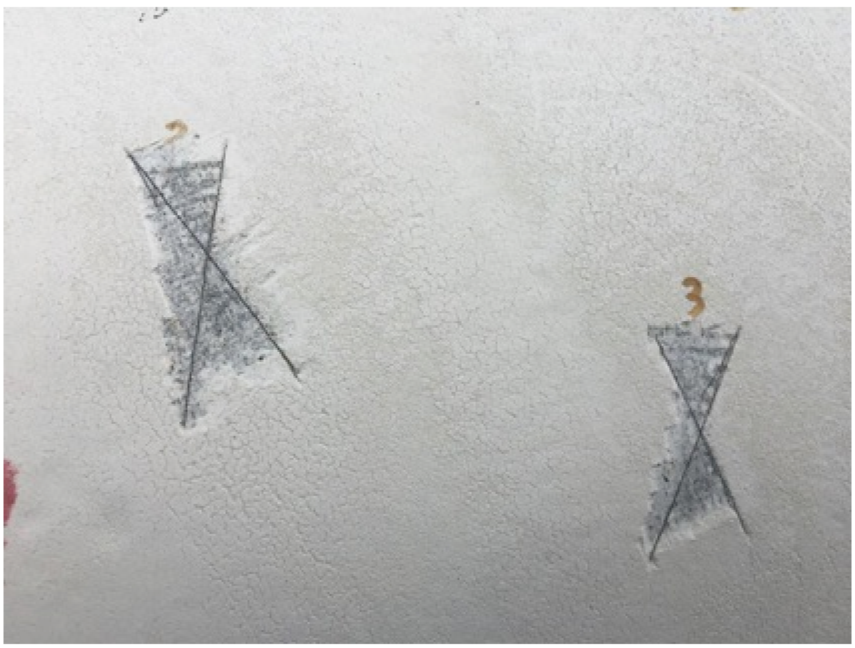

Figure 4 – Cross-cut adhesion of EonCoat – June 2018 after 4 months of being insulated and in service.

Like the intentionally damaged panels above, again, the EonCoat shows no rust. Organic coatings would have begun to show corrosion.

Conclusion

Through years of extensive lab and field tests, EonCoat is proving to be an effective anti-corrosion coating technology. In 2018, EonCoat was incorporated into the Chevron Engineering Standards.