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Performance Evaluation of Epoxy Anticorrosive Coatings and Polyurethane Protective Tape by Salt Spray Fog Test

Marcos Moraes[a], Sérgio Abud Filho[b], Artur Graeff[c], Emerson Monteiro[d], Hector Medeiros[e], Edmilson Cavalcanti[f], André Koebsch[g]

Abstract

Some structures installed inside of Oil & Gas plants as refiners and oil exploration platforms have been presenting several external corrosion problems. The causes of this corrosion have been attributed to salinity, presence of acidic contaminants, low coating efficiency and coatings failure. This work has the objective to evaluate the performance of Solventless Epoxy Anticorrosive Coating (SEC) comparing with N-2680 (Epoxy Coating - EC), N-2677 (Polyurethane Coating - PC) and to evaluate the anticorrosive performance of Polyurethane Protective Tape (PPT) by salt spray test.

Keywords: anticorrosive, corrosion, epoxy coating, polyurethane coating, salt spray**,** polyurethane tape.

1. Terminology

Petrobras Standard N - 2680 – Epoxy coatings (several brands at market) knew at Oil & Gas industry for wet surfaces.
Petrobras Standard N - 2677 - Polyurethane coatings (several brands at market) knew at Oil & Gas industry for wet surfaces.
EC – Epoxy Coating.
SEC – Solventless Epoxy Coating.
PC – Polyurethane Coating.
PPT – Polyurethane Protective Tape.

[a] Chemist – 3M do Brasil Ltda.
[b] Chemist – 3M do Brasil Ltda.
[c] Chemist – 3M do Brasil Ltda.
[d] Industrial Chemist – 3M do Brasil Ltda.
[e] Mechanical Engineer – 3M do Brasil Ltda.
[f] Chemical Engineer – 3M do Brasil Ltda.
[g] Consultant - Petrobras

2. Introduction

When metallic structures are installed inside of Oil & gas plants several corrosion problems can occur decreasing the lifetime of the assets. In order to control and mitigate the corrosion problems of these assets, Oil & Gas companies are looking for anticorrosive coatings and diverse materials with high performance to reduce maintenances costs and necessity of interventions assuring the production levels, integrity and security of the metallic structures.
In practice, there are some methods to mitigate and reduce corrosion problems in metallic structures, among them can be cited: anticorrosive coating, cathodic and anodic protection and corrosion inhibitors. All methods are important to ensure metallic structure integrity but anticorrosive coatings application is the most important of all. The others anticorrosive methods mentioned above are very important too and they are complementary to anticorrosive coatings.
According to mentioned above, it is necessary the development of anticorrosive materials and field/laboratory tests to evaluate performance of these materials. In practice, some pipelines installed under severe environmental conditions are coated with N-2680 Epoxy Anticorrosive Coating, N-2677 Polyurethane Coating to ensure the integrity of the structure. However, some corrosion problems have been observed with this protection scheme due to aggressive environment.
This work has two purposes:

- to evaluate the performance of Solventless 3M Scotchkote™ Epoxy Anticorrosive Coating SK-323 (SEC) as a product against corrosion, comparing with N-2680 (EC).
- to evaluate the performance of 3M Polyurethane Protective Tape 8672 (PPT) as a product to increase lifetime of epoxy coatings when applied in areas with a severe environmental conditions as high salinity, high quantity of contaminants (refiners, petrochemicals, platforms).

This paper will show the partial tests results until 3000 hours for plates and 2500 hours for pipes. The test will continue until degradation of coatings or when other conclusion could be made considering the level of corrosion.

3. Methodology

In order to compare the performance of Solventless Epoxy Anticorrosive Coating (SEC) against N-2680 (Epoxy Coating - EC) and the performance of Polyurethane Protective Tape (PPT) as a product to increase lifetime of epoxy coatings laboratory tests were conducted by salt spray test [ASTM B-117-11]. The coatings were applied on AISI 1020 carbon steel plates with dimensions 55 mm x 130 mm x 2 mm (see Figure 1) and on AISI 1020 carbon steel pipe with dimensions: Length – 200 mm; External diameter – 115 mm; Wall thickness – 7.5 mm (see Figure 2). Before coatings applications, the carbon steel surface was blasted with steel grid Sa 2½ with (50 – 70) µm profile roughness [ISO 8501-1]. It was prepared three plates for each condition [N-2680, ASTM – D-1654 -08].

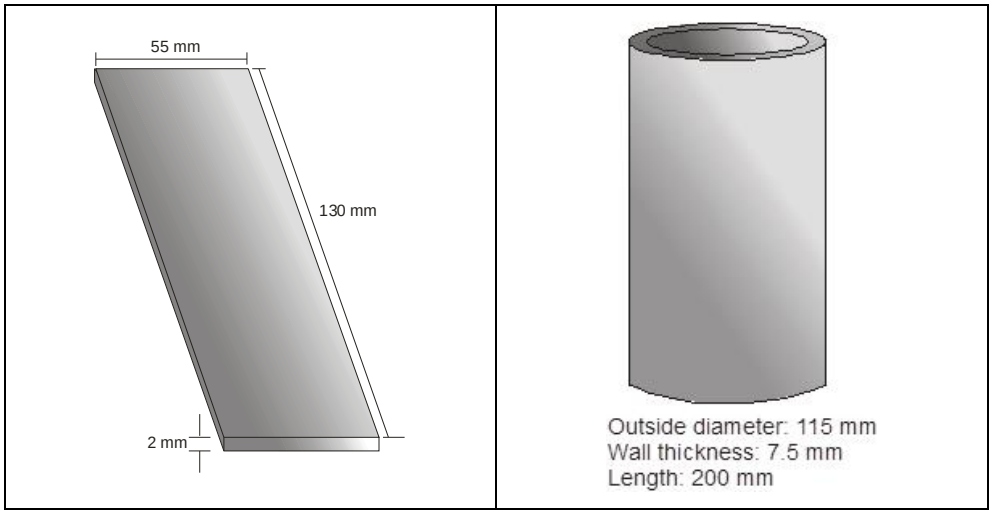


Figure 1 - AISI 1020 carbon steel plate. **Figure 2** - AISI 1020 carbon steel pipe.

It follows below the protection scheme used for anticorrosive coatings evaluation performance. For better understanding, item 3.1 describes the protection scheme for the carbon steel plates and item3.2 describes the protection scheme for the carbon steel pipe.

3.1 Protection scheme for carbon steel plate

The AISI 1020 carbon steel plates were coated according to described below.

- Anticorrosive Epoxy Coating (EC).
- Anticorrosive Epoxy Coating (EC) plus Polyurethane Coating (PC).
- Solventless Epoxy Anticorrosive Coating (SEC).

The coatings were scribed in the middle of plate in order to evaluate the corrosion advance over metal surface. (see Figure 3).

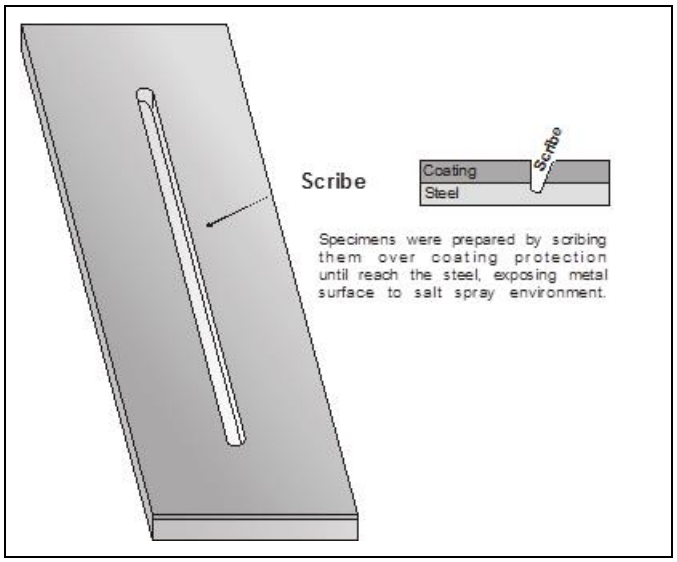


Figure 3 – Scribed specimen.

In addition, it was also prepared steel plates with the same coatings mentioned above and covered with the PPT. Figure 4 shows all conditions of steel plate to be tested.

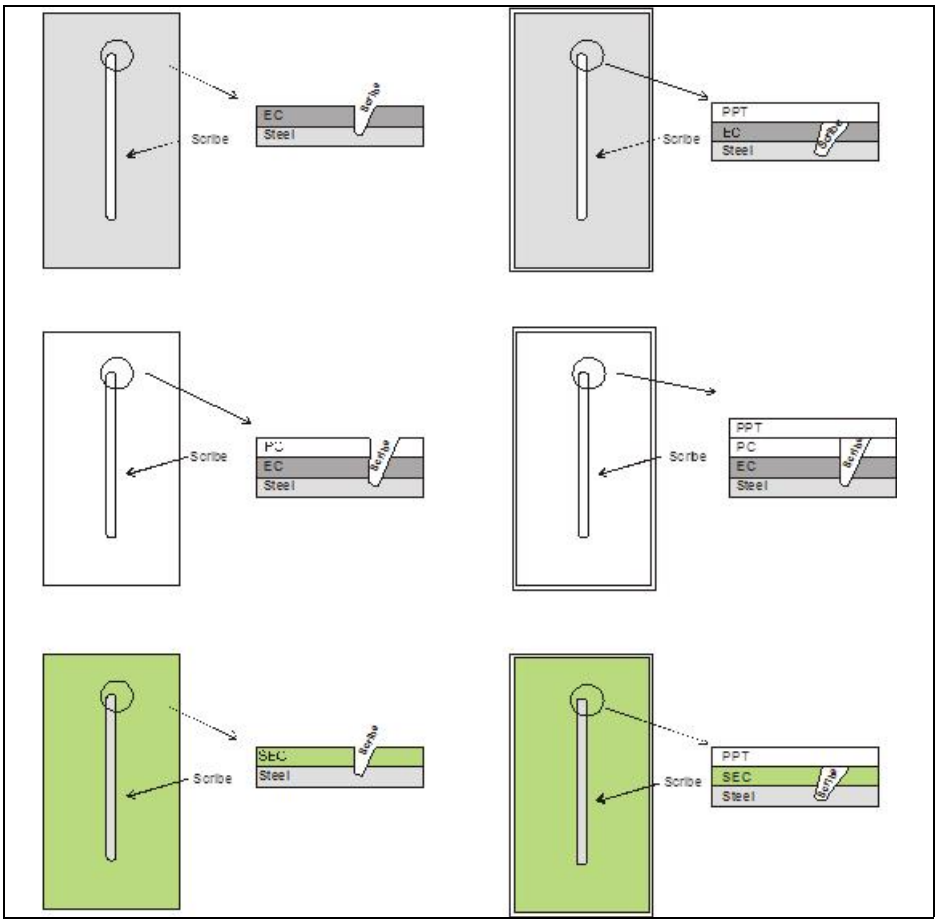


Figure 4 – Schematic of plates.

3.2 Protection scheme for carbon steel pipe

The carbon steel pipes samples were coated according to Figure 5, Figure 6 and Figure 7. According to the Figure 5, the pipe was coated with Epoxy Anticorrosive Coating (EC) and over half pipe the Polyurethane Coating (PC) was added. This has left half portion of the pipe exposed with EC, and the other half exposed with EC plus PC. The pipe was scribed in order to evaluate corrosion advances. From the middle to the top of the pipe it was applied a PPT over the coated surface mentioned before and from the middle to the bottom, the coating remain the same.

The pipe was placed at fog chamber, in a way we have both different coatings exposed at the appropriated position (30º from the vertical and parallel to the principal direction of flow of fog through the chamber).

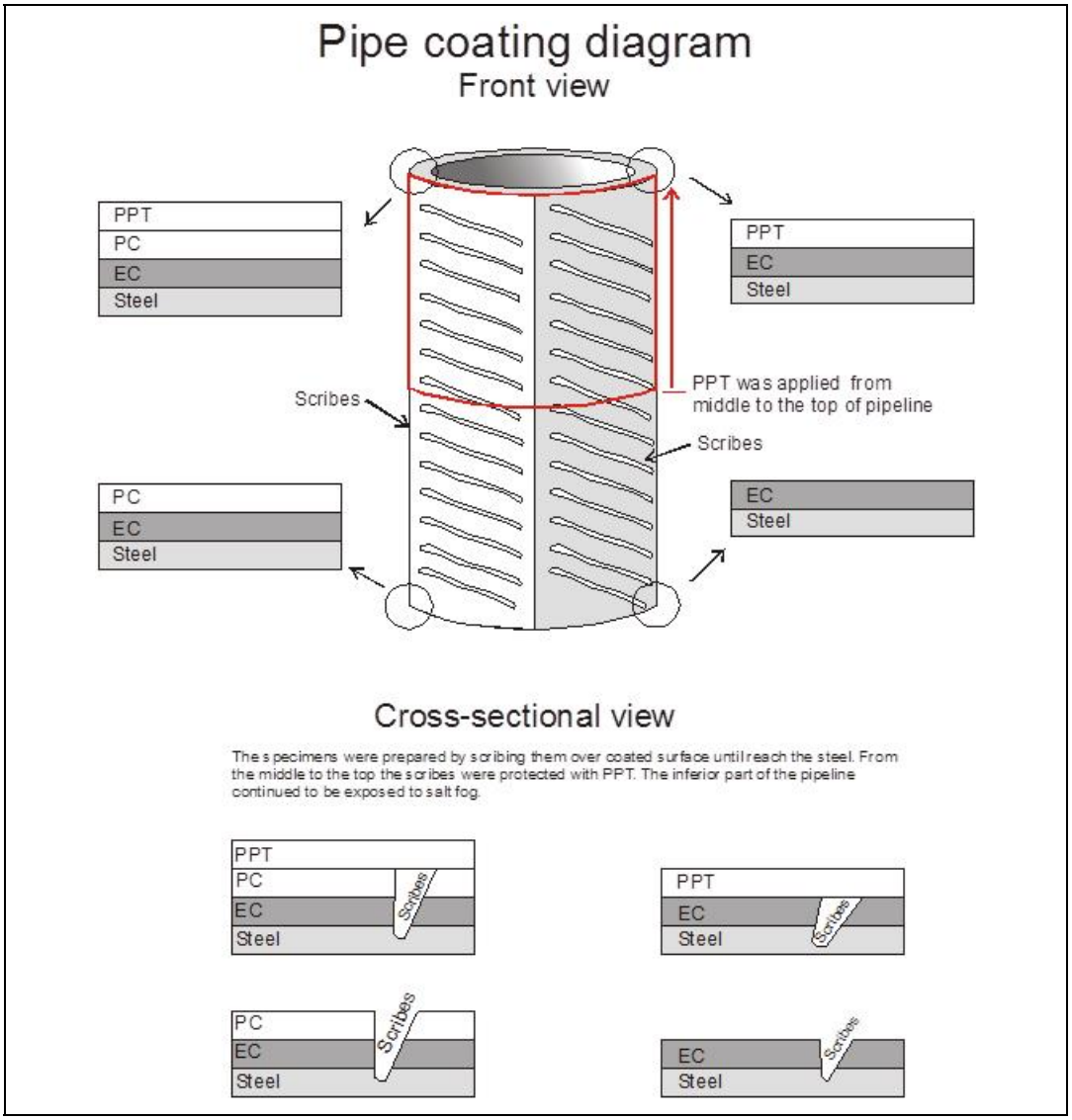


Figure 5 – Schematic diagram of pipe coated with EC, EC plus PC and PPT.

According to the Figure 6, the pipe was coated with Solventless Epoxy Anticorrosive Coating (SEC). The pipe was scribed in order to evaluate corrosion advances. From the middle to the top of the pipe it was applied a PPT over the coated surface mentioned before and from the middle to the bottom, the coating remain the same.

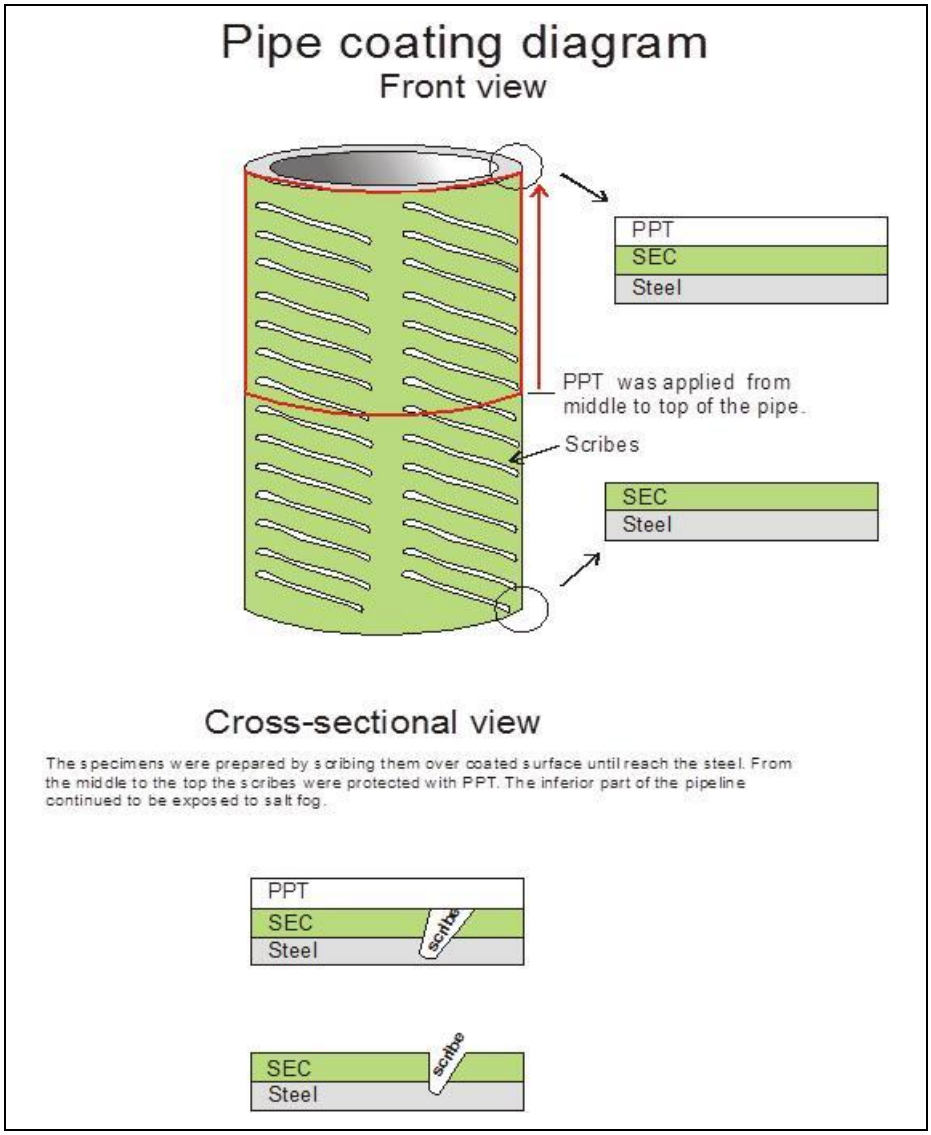


Figure 6 – Schematic diagram of pipe coated with SEC and PPT.

According to Figure 7, the carbon steel pipe was not coated but it was covered with PPT applied from bottom to the top, leaving 2.5 cm without protection on each extreme of the pipe. The edge of the top extreme was protected by two different ways.

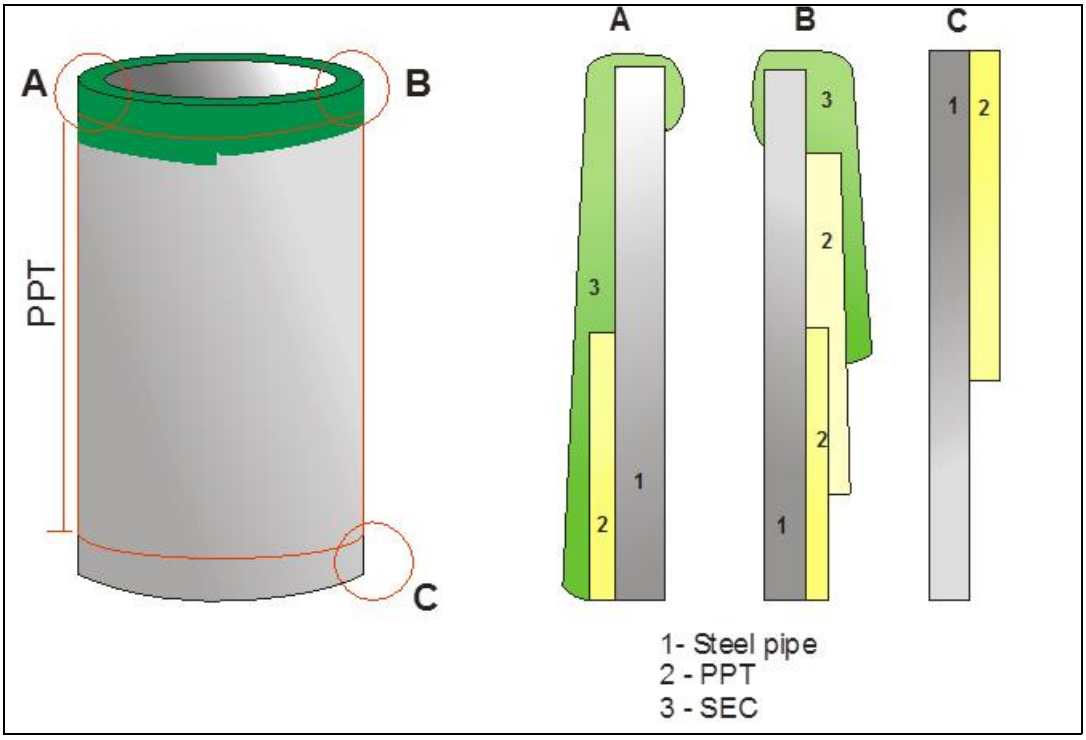


Figure 7 – Schematic diagram of pipe covered with PPT, with and without edge protection.

The tests were conducted in a Salt Spray Apparatus *Vötsch Industrietechnik GmbH* Model SC 1000 (see Figure 8).

Figure 8 – Salt Spray Apparatus.

To prepare the salt spray electrolyte, sodium chloride P.A. was added to deionized water (5 % w/w) and mixed until complete solubilization. The electrolyte pH was controlled in 6.5 – 7.2.

4. Results and discussion

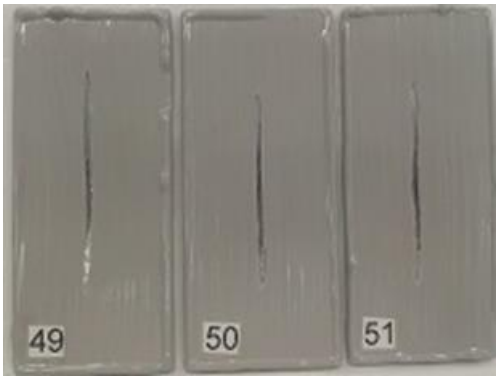
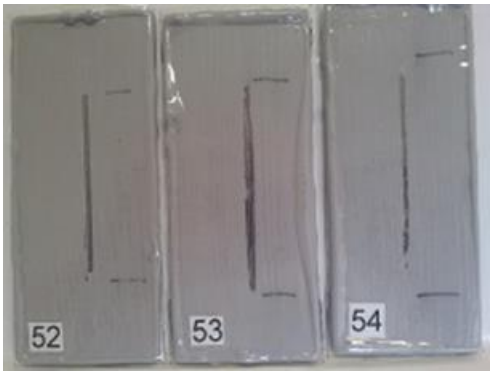
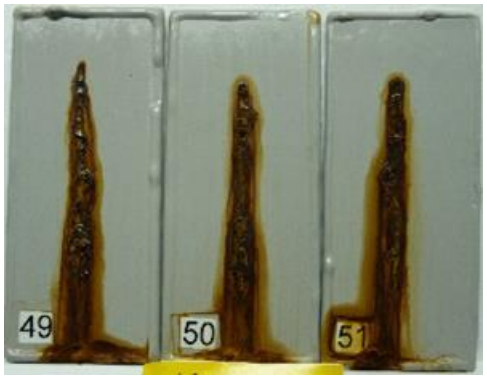
For a better understanding, the results and discussion regarding carbon steel plates coated are shown in the item 4.1 and the results and discussion regarding carbon steel pipe coated are shown in the item 4.2.

4.1 Carbon steel plates results

Table 1 shows the images of carbon steel plates coated with EC and coated with EC plus PPT obtained before starting Salt Spray test, after 1000 hours and 3000 hours of exposure.

Table 1

Salt Spray results of steel plate coated with EC and coated with EC plus PPT.

Time Test	Protection Type	
	EC	**EC plus PPT**
Initial		
1000 h		
3000 h		

Obs.: Plates have different colors due to light exposure during photo taking process. Corrosion was observed on steel surface and the corrosion product (iron oxide) has run over the protected surface. The corrosion advance underneath the coating layer it will be evaluated only after 4000 hours (final test).

Analyzing the images showed on Table 1 (EC), could be realized that after the exposure at salt spray fog, the unprotected scribes presented corrosion in all extension after 3000 hours of test.

The corrosion level increases as exposure time runs. This could be realized when looking at the size of stain at pictures. The portion protected by EC remains intact in all extension, which was already expected, considering that this product is already qualified. It was not noticed blistering on the EC coating or corrosion spots.

When analyzing the images showed on Table 1 (EC plus PPT), could be realized that after the exposure at salt spray fog, the scribes made on EC, but covered with PPT did not present any signal of corrosion in all extension after 3000 hours of test.
The integrity of the steel remains the same during all the test timing, as well the integrity of EC coating.

Table 2 shows the images of carbon steel plates coated with EC plus PC and coated with EC plus PC plus PPT obtained before starting Salt Spray test, after 1000 hours and 3000 hours of exposure.

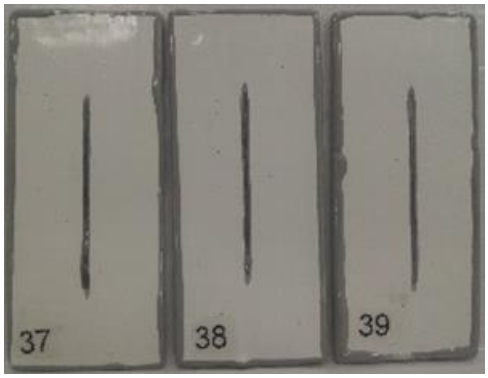
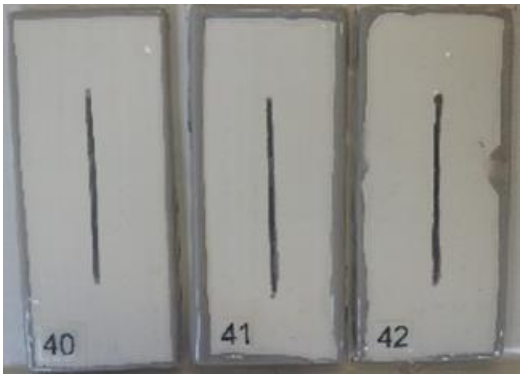
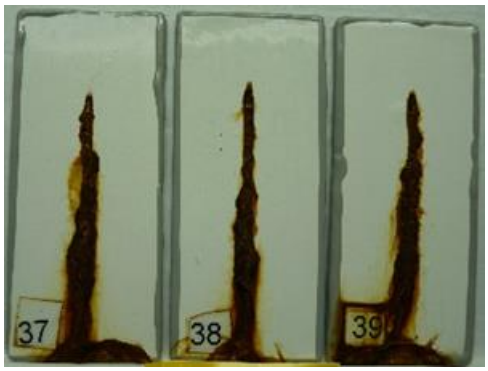
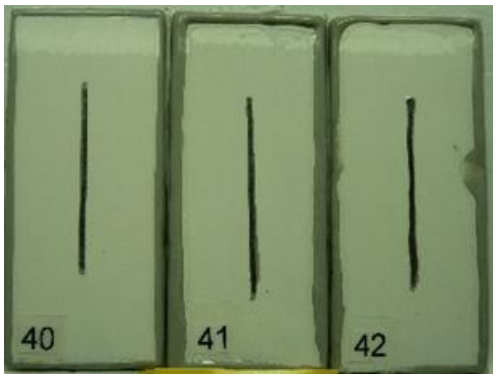
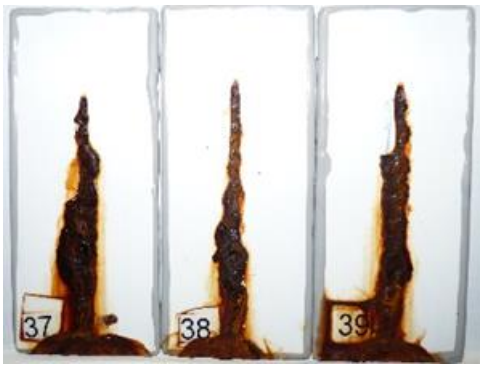
Analyzing the images showed on Table 2 (EC plus PC), could be realized that after the exposure at salt spray fog, the unprotected scribes presented corrosion in all extension after 3000 hours of test. The corrosion level increases as exposure time runs. This could be realized when looking at the size of stain at pictures. The portion protected by EC plus PC remains intact in all extension, which was already expected, considering that both products are already qualified.

It was not noticed blistering on the PC coating or corrosion spots, considering this is the coated surface which is exposed to the salt spray fog.

When analyzing the images showed on Table 2 (EC plus PC plus PPT), could be realized that after the exposure at salt spray fog, the scribes made at EC plus PC, but covered with PPT did not present any signal of corrosion in all extension after 3000 hours of test.
The integrity of the steel remains the same during all the test timing, as well the integrity of PC coating.

Table 2

Salt Spray results of steel plate coated with EC plus PC and coated with EC plus PC plus PPT.

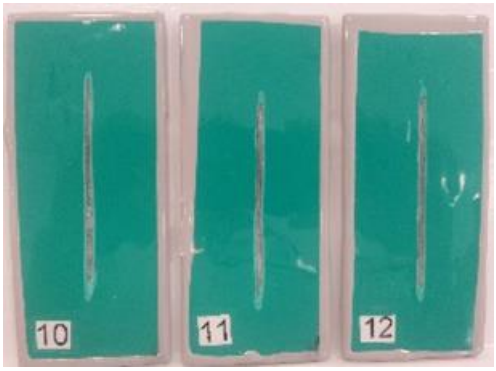
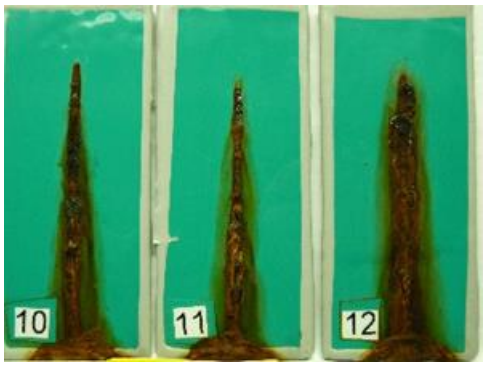
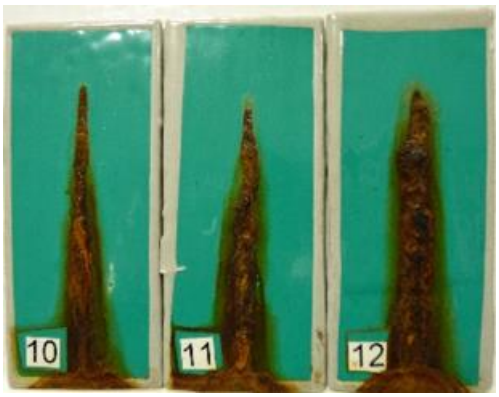
Time Test	Protection Type	
	EC plus PC	EC plus PC plus PPT
Initial		
1000 h		
3000 h		

Obs.: Plates have different colors due to light exposure during photo taking process. Corrosion was observed on steel surface and the corrosion product (iron oxide) has run over the protected surface. The corrosion advance underneath the coating layer it will be evaluated only after 4000 hours (final test).

Table 3 shows the images of carbon steel plates coated with coated with SEC and coated with SEC plus PPT obtained before starting Salt Spray test, after 1000 hours and 3000 hours of exposure.

Table 3

Salt Spray results of steel plate coated with SEC and coated with SEC plus PPT.

Time Test	Protection Type	
	SEC	SEC plus PPT
Initial		
1000 h		
3000 h		

Obs.: Plates have different colors due to light exposure during photo taking process. Corrosion was observed on steel surface and the corrosion product (iron oxide) has run over the protected surface. The corrosion advance underneath the coating layer it will be evaluated only after 4000 hours (final test).

Analyzing the images showed on Table 3 (SEC), could be realized that after the exposure at salt spray fog, the unprotected scribes presented corrosion in all extension after 3000 hours of test.

The corrosion level increases as exposure time runs. This could be realized when looking at the size of stain at pictures. The portion protected by SEC remains intact in all extension. It was not noticed blistering on the SEC coating or corrosion spots.

When analyzing the images showed on Table 3 (SEC plus PPT), could be realized that after the exposure at salt spray fog, the scribes made on SEC, but covered with PPT did not present any signal of corrosion in all extension after 3000 hours of test.

The integrity of the steel remains the same during all test timing, as well the integrity of SEC.

4.2 Carbon steel pipes results

Table 4 shows the images of carbon steel pipes coated with EC, EC plus PC with and without PPT; SEC with and without PPT and steel pipe covered with PPT (extreme edges protected and unprotected).

Table 4

Salt Spray results of steel plate coated with EC, EC plus PC with and without PPT; SEC with and without PPT and Steel pipe covered with PPT with extreme edges protected and unprotected.

Time Test	Protection Type		
	EC, EC plus PC with and without PPT	SEC with and without PPT	PPT
Initial			
1000 h			
2500 h			

Obs.: Plates have different colors due to light exposure during photo taking process. Corrosion was observed on steel surface and the corrosion product (iron oxide) has run over the protected surface.

Analyzing the images showed in table 4 can be observed the same results for the pipes protected with EC, EC plus PC and SEC, all with and without PPT. It was realized that after the exposure at salt spray fog, the unprotected scribes presented corrosion in all extension. The corrosion level increases as exposure time runs. This could be realized when looking at the size of stain at pictures. When analyzing the images it was realized that after the exposure at salt spray fog, the scribes covered with PPT did not present any signal of corrosion in all extension.

It was also observed that where scribes comes from uncovered portion with PPT and towards and underneath the portion protected with PPT, the corrosion runs freely until the end of the scribes. See corrosion progression (red squares).

It can also be observed the results for pipes protected only by PPT, with and without edges protection. It was realized that at the bottom where there is no edge protection, the corrosion occurred at the uncoated metal as expected and run underneath the PPT towards the top of the pipe. As humidity runs to the top, corrosion goes after, damaging the pipe. See corrosion progression (blues squares). At the top, the two ways the edges were protected avoided the presence of corrosion.

5. Conclusions

According to the results mentioned above, it was concluded:

- Considering the salt spray test and the time which products were tested the performance of SEC could be considered equivalent than the performance of EC. The steel samples coated with SEC did not present blistering or other damages at the coating surface. Corrosion run only at the exposure metal surface to the salt spray fog.

- Where the scribed coating were completely covered by PPT there was not noticed any corrosion. This is an evidence that PPT has presented a satisfactory barrier against severe corrosive environment. This suggest an extended protection and lifetime of epoxy and other anticorrosive coatings, reducing maintenance costs and assure the integrity of assets.

- When PPT was applied direct over a metal surface it was realized that where there is no edge protection, the corrosion occurred at the uncoated metal as expected, and run underneath the PPT towards the top of the pipe. PPT was not recommended to be used as a primary protection against corrosion. It could be applied as an extra protection in order to assure the integrity of the assets and reduction of maintenance costs. PPT is recommended for applications at spots where there is a severe environment conditions such as: refiners, petrochemicals, platforms.
  However other tests need to be run in order to prove this statement.

6. References

Petrobras N-2680 – *Tinta Epoxi, Sem Solventes, Tolerante à Superfícies Molhadas,* SC-14 Pintura e Revestimentos Anticorrosivos, May/2007.

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ISO 8501-1 – *Protecção Anticorrosiva de Estruturas De Aço Por Pintura*, Feb/2011.