

Offshore Atmospheric Coating Performance Evaluation Test Standards - NACE vs. ISO

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ABSTRACT

There are two well recognized international standards to evaluate offshore atmospheric coatings. One is ISO-12944-9 (historically referenced as ISO 20340) and the other one is NACE TM 0404 (new construction) /TM 0304 (maintenance) with acceptance criteria referenced in NACE SP 0108. The major differences between the ISO and the NACE standards are the cyclic test method and the test duration for the rust creepage test. The ISO requires a 25-week cyclic test duration and NACE standard requires 12 weeks only. Furthermore, the NACE standard requires other coating properties - edge coverage (retention), thermal cycling and coating flexibility to be evaluated.

In this experimental program, ten coatings (zinc rich epoxy and non-zinc rich epoxy) systems are evaluated using both test standards. The coatings were applied on grit blasted new steel panels to SP-10 surface cleanliness. The rust creepage test results reveal both standards can differentiate the same good and bad coating systems. In a comparative coating performance evaluation, the NACE method provides an efficient and holistic approach towards reliable coating system selection for offshore platforms.

Key words: Rust creepage, scribe, edge coverage, thermal cycling, cathodic blister, underfilm corrosion

INTRODUCTION

ISO 12944 (& ISO 9223) has six different corrosivity categories and assigns offshore environment CX (previously C5-M) the highest corrosion category. In such a corrosive offshore environment, combined with imperfect application and risk of damage, the offshore platform coating service life can be short (<8 years) resulting in large scale maintenance programs. The price per square foot of maintenance programs are typically an order of magnitude higher than the new construction / erection costs. The maintenance costs can vary but is high and depends on ease of execution, type of maintenance and

other factors influencing execution. Therefore, it is desirable for facility owners to select long service life offshore coatings and optimize the total expenditure related to maintenance.

There are two well recognized international standards to evaluate offshore atmospheric coatings. One is ISO-12944-9¹ (historically referenced as ISO 20340²) and the other one is NACE TM 0404³ (new construction) / TM 0304⁴ (maintenance) with acceptance criteria referenced in NACE SP 0108⁵. The differences of these two standards are listed in Table 1.

Table 1 - Difference between ISO 12944-9 and NACE TM 0404/ TM 0304

	ISO 12944-9	NACE TM 0404 / TM 0304
Test Time	25 weeks	12 weeks
Rust Creep Test	72 hr constant salt fog (5% NaCl) 72 hr QUV chamber, 4 hr/ 60 °C, UV+ 4 hr/ 50 °C condensation 24 hr -20 °C freezer 1 week/cycle	1 week QUV chamber, 4 hr/ 60 °C, UV+ 4 hr/ 50 °C condensation 1 week cyclic salt fog, 1 hr 25 °C salt fog + 1 hr 35 °C dry air 2 week/ cycle
Pull-off Adhesion	Before and after the rust creep test	No requirement
Edge Coverage	No requirement	peak DFT/flat DFT on aluminum angle bar
Thermal Cycling	No requirement	60 °C/ -30 °C cycling, 252 cycles or 3 weeks
Coating Flexibility	No requirement	>1%

The qualification criterion of candidate coating systems for ISO 12944-9 is only based on the rust creepage test (ageing resistance test) and the pull-off adhesion test. While the qualification criteria for NACE TM 0404/ TM 0304 are based on the rust creepage resistance and other coating physical properties – edge coverage, thermal cycling, and flexibility, which are also related to the major failure modes on offshore platforms with a short term test duration (< 4 weeks).

The rust creepage test method and test duration for these two test standards are quite different. It is an essential question – do these two test standards lead to same or different coating selection? There were some efforts in the coating industries to compare the difference between the two standards. Darren Ward⁶ has conducted a study in 2006 to test seven candidate coating systems and correlated with test results in the coastal environment as shown in Table 2 . The NACE results are correlated with the coastal test results reasonably well.

Table 2 - Comparison of Rust Creepage Results between ISO 20340 and NACE SP 0108

Coating System	ISO	NACE	Coastal Exposure
Zinc rich epoxy (1)/epoxy/PU	1.8	0.4	No degradation in 44 months
Inorganic zinc/epoxy/PU	0.5	0.8	No degradation in 44 months
Zinc rich epoxy (2)/epoxy/PU	4.0	1.6	Blisters 10-20 mm from scribe in 44 months
Epoxy/Epoxy (1)	5.5	2.7	No degradation in 52 months
Hydrocarbon filled Epoxy (1)	13.0	3.6	blisters, 1-2 mm from scribe in 52 months
Epoxy/epoxy (2)	4.5	4.9	Blisters, 1-2 mm from scribe in 52 months
Hydrocarbon filled Epoxy (2)	8.5	5.5	Blisters /cracks, 20-30 mm from scribe in 52 months

Darren Ward⁷ has also conducted another comparison study on ISO 20340 and NACE SP0108 on eight coating systems in 2008. The test results are listed in Table 3. It is also shown that the NACE and ISO results have a good match to each other and with the coastal test results.

Table 3 - Comparison of Rust Creepage Results between ISO 20340 and NACE SP0108

Coating System	ISO 20340, mm	NACE, mm	6-year Coastal Exposure, mm
Zinc rich /epoxy/PU (3)	1.0	0.1	1
Zinc rich/epoxy/PU (1)	1.1	0.2	1
Zinc rich /epoxy/PU (4)	1.7	0.4	0
Zinc rich/epoxy/PU (2)	3.2	1.9	30
Hydrocarbon Epoxy/Epoxy/PU	13	4.2	0
Hydrocarbon Epoxy/Epoxy/PU	7.7	4.3	30
Hydrocarbon Epoxy/Epoxy/PU	6.5	6.0	40
Hydrocarbon Epoxy/Epoxy/PU	4.2	6.8	12

N. LeBozec⁸ did a study in 2014 on the comparisons between ISO 20340 standard and NACE SP0108 with 12 different coating systems. She found out rather similar coating material ranking, as listed in Table 4.

Table 4- Rust Creepage (in mm) Comparison btw ISO 20340 and NACE SP0108

Coating System	ISO 20340	NACE
S12-Epoxy primer	2.2	1.1
S2-Zinc Rich	2.0	1.4
S1-Zinc Rich	2.3	1.5
S3-Zinc Rich	4.3	1.7
S4-Zinc Rich	4.2	2.1
S6-Epoxy primer	7.6	3.1
S5-Zinc Rich	7.2	3.2
S11-Epoxy primer	10.5	4.0
S10-Epoxy primer	9.0	4.2
S7-Epoxy primer	10.1	5.0
S9-Epoxy primer	5.0	5.8
S8-Epoxy primer	19	9.0

ISO 20340 has been merged with ISO 12944-9 and the acceptance criteria has also been changed. The NACE TM 0304 and TM 0404 is under revision and the rust creepage test has also been modified with the new salt solution of 5%w NaCl instead of ASTM D1141⁹ synthetic seawater. The purpose of this study is to conduct rust creepage test of the two test standards and compare their differences on a suite of maintenance coatings and assess the outcome from the different tests. Physical testing in accordance to NACE SP0108 requirements were also conducted to understand the performance behavior of the different coatings.

EXPERIMENTAL PROCEDURE

Candidate Coating Systems

The candidate coating systems include three epoxy and seven zinc rich epoxy coating systems. They are listed in Table 5.

Table 5 - Candidate Coating Systems

Coat #	Type of Coating and (No. of coats)	DFT, mil/μm
1	Epoxy primer based (3)	20.6 / 523
2	Epoxy primer based (3)	16.7 / 424
3	Epoxy primer based (3)	29.4 / 747
4	Zinc Epoxy primer (3)	27.3 / 693
5	Epoxy primer based (2)	19.1 / 485
10	Zinc Epoxy primer (3)	13.2 / 335
11	Zinc Epoxy primer (3)	13.8 / 351
12	Zinc Epoxy primer (3)	13.7 / 348
14	Zinc Epoxy primer (3)	12.9 / 328
15	Zinc Epoxy primer (3)	12.4 / 315

Test Method – Rust Creepage (Underfilm Corrosion)**ISO 12944-9 – Aging Test (Rust Creepage)**

The test procedure is described as follows;

- (1) 72 hr of exposure to UV and condensation (ISO 16474-3=ASTM G53), 4 hr UVA-340 60 °C / 4 hr condensation at 50 °C
- (2) 72 hr exposure to neutral salt spray (ISO 9227=ASTM B117), 5%w NaCl salt fog
- (3) 24 hr exposure to -20 °C.

The NACE TM 0404 Test Standard

The test procedure is described as follows;

- (1) 7 days exposure to UV and condensation, 4 hr UVA-340, 60°C / 4 hr condensation at 50 °C.
- (2) 7 days exposure to cyclic salt spray, 1 hr, 25 °C, 5%w NaCl salt fog , 1 hr, 35 °C air dry

Thermal Cycling Test – NACE TM 0404 Test Standard

The C-channel samples in accordance to NACE TM 0404 methodology was used to measure the thermal cycling resistance. The inner surface of the C-channel was applied with the different coating systems. The test conditions for the temperature cycle was from 60°C to -30°C for every 2 hours and the test ran for 3 weeks (252 cycles).

Edge Coverage Test – NACE TM 0404 Test Standard

90 degree aluminum bar in accordance to NACE TM 0404 was sprayed with each coating system. The coated aluminum bar was cold mounted and 5 samples were cut (1/2 inch thick) and polished on sandpapers. DFT was measured at the peak and the flat surface under a digital microscope and their ratio was reported as the edge coverage/retention.

TEST RESULTS**Rust creepage**

The rust creepage test results are listed in **Table 6**. They are ranked in accordance with their rust creepage performance. It is readily seen that the rust creepage result for ISO test is always higher than the NACE test considering the longer duration of the ISO test. The top and bottom tier of three coating systems, as shown in **Table 6** for both standards are the same. **Figure 1** shows the images of the NACE test (left) and ISO test (right) of top and the bottom coating performers. The results indicate that

either test standard can differentiate good and bad performers from a pool of candidate coating systems.

ISO and NACE have different Pass/Fail Criterion on rust creepage, as listed in **Table 7**. ISO 12944-9 acceptance criterion is ≤ 3.0 mm for all zinc rich or non-zinc coatings. Zinc rich coatings will always have lower rust creepage than the non-zinc coatings. It is to be noted that the 3mm rust creepage for non-zinc rich coatings in ISO 12944 is recent. Previous ISO standard (ISO 20340) had an acceptance criterion of 8 mm for non-zinc rich coatings and 3mm for zinc rich coatings.

In NACE SP 0108 standard, the rust creepage acceptance is 1.5 mm for zinc rich coatings. This requirement is met by inorganic zinc coatings and has been challenging for organic zinc epoxy coatings. The revising NACE SP 0108 standard includes a rust creepage acceptance criterion for organic zinc epoxy to be < 2.5 mm instead of < 1.5 mm.

Table 6 - Rust Creepage Test Results, Ranking in Performance

Coating System	NACE SP 0108 – Rust Creepage (mm)	ISO 12944 – Rust Creepage (mm)
15 (OZ)	2.0	4.0
4 (OZ)	2.2	3.0
12 (OZ)	2.6	4.4
14 (OZ)	2.7	5.1
10 (OZ)	3.1	7.1
1 (Epoxy)	3.2	7.1
11 (OZ)	4.9	4.9
3 (Epoxy)	7.9	11.4
5 (Epoxy)	8.1	15.5
2 (Epoxy)	8.2	11.4

Table 7 - Rust Creepage Pass/Fail Criterion on Rust Creepage

Standard	Rust Creepage, Acceptance Criterion	
	NACE SP 0108 (revising)	ISO 12944-9
Zinc Rich Primer	< 2.5 mm ¹	≤ 3.0 mm
Non-zinc Rich Primer	< 3.5 mm	≤ 3.0 mm ²

Note:

1 – NACE SP 0108 (2008) standard indicates the zinc-rich primer acceptance criterion is 1.5 mm

2 – ISO 20340 requirement for non-zinc rich primer was 8 mm or less and there was a change in ISO 12944-9 to 3 mm for all coatings with exceptions: (a) unless it is agreed with the interested parties (b) or high impact areas, in which case the rust creepage is 8 mm or less