



Final report

Immersion testing on coated and uncoated panels in ozone treated water

Requester:

Desmi Ocean Guard

Attn.: Christian Ingvorsen

4C 1303031- 433373 DSP/BBJ 2012.01.31

Danish Technological Institute, Centre for Materials Testing has according to agreement examined and evaluated painted and unpainted panels after 6 months exposure to water treated by DesmiOceanGuards ozone water treatment system.

Summary

The performed test is an accelerated test designed to investigate any effect from ozone treated ballast water onto painted test panels and bare metal panels. The test is made as a comparison test with a reference system consisting of similar panels immersed in untreated water. Artificial seawater prepared after ISO 15711:2003 with a total salt concentration of 42,9g/l was used as test solution.

13 panels were exposed in treated water and 13 panels were exposed in untreated water where 20 of the panels were coated with epoxy painting. The remaining 6 panels were un-coated steel panels and un-coated Cu/Ni panels. An overview of panels and coating systems is available in enclosure 1.

The water in both test system and reference system was changed once every week; between water changes the immersed panels were placed at room temperature without agitation of the water.

The theoretical ozone level needed for water treatment is calculated to be 1,2mg/l, during the test the system ran with an ozone concentration of 2,4mg/l, equal to twice the standard concentration.

The overall conclusion of the test exposure is that the result from the panels tested in ozone treated water is comparable with the result from the panels tested in untreated water. No significant difference in adhesion loss, weight change or visual change is observed.

Background

Possible effects from the ozone on the panels are to be tested and test result is to be presented to Lloyds Registry.

Lloyd's Register has provide independent verification and witnessed that the test have been carried out in accordance with the specified test plan.

Procedure and test plan can be found in enclosure 1.

The panels have been inspected after 1week, 4 weeks, 3 months and finally after 6 months. Inspection plan and observations from initial inspection, 1week, 4 weeks and 3 months inspection can be found in enclosure 2 and 3 respectively.

Results

In the tables below the results of 6 months visual inspection is presented together with the results from the destructive test performed on the panels.

The general visual impression of the panel was that no difference detectable by the eye can be seen. Generally no significant difference was found on the panels by visual inspection by the naked eye. No measurement of gloss and colour was made.

Adhesion test by knife was made as a comparison test between panels from the reference system and test panels, and no noticeable difference was registered.

For the panel 70, 71, 3, 4, 78, 79, 19 and 20 the adhesion test was made after drying for 1 week at room temperature.

Measurement of coating thickness showed a slight increase in thickness both for the panels measured wet and the panels measured dry, no difference in thickness increase was noted between reference panels and test panels.

Results from painted panels:

Panel no.	Paint system	Blisters	Loose paint [mm]	Weight change
70	Pure epoxy	None	-	0,051
71 (ref.)		None	-	0,063
3	Modified epoxy	None	-	0,042
4 (ref.)		None	-	0,039
66	Pure epoxy Scribed	None	34,51	-
68 (ref.)		One blister at scribe 2(S4)	33,67	-
9	Modified epoxy Scribed	One blister below scribe 2(S4)	39,88	-
10 (ref.)		None	41,92	-
78	Zinc primer Pure epoxy	None	-	0,061
79 (ref.)		None	-	0,058
19	Zinc primer Modified epoxy	None	-	0,04
20 (ref.)		None	-	0,042
74	Zinc primer Pure epoxy Scribed	One blister at scribe 2(S4)	6,24	-
77 (ref.)		Two blisters at scribe 2(S4)	8,54	-

25	Zinc primer	None	4,97	-
27 (ref.)	Modified epoxy Scribe	None	3,29	-
75	Zinc primer	One blister at scribe 2(S4)	12,21	-
73 (ref.)	Pure epoxy Scribe Zinc anode	Two blisters around scribe 2(S4)	14,78	-
26	Zinc Primer	None	6,63	-
18 (ref.)	Modified epoxy Scribe Zinc anode	None	6,35	-

The weight change for the reference panels and the test panels is measured to be similar.

The measured width of the adhesion loss around the scribe is evaluated to be comparable for reference panels and test panels.

Panel	Type and exposure	Weight loss [g]
Sa1	Sandblasted test panels in closed container	1,85
Sa2		1,73
Cu2	Copper/nickel test panel	0,40
Sa5	Sandblasted test panel in open container*	4,29
Sa3	Sandblasted reference panels in closed container	1,36
Sa4		1,38
Cu1	Copper/nickel reference panel	0,24
Sa6	Sandblasted reference panel in open container*	4,59

*test started in week 6

In general the untreated test panels show a slightly higher weight loss than the reference panels, although the difference is small. Taking the measured difference and the samples size into consideration the difference is evaluated to be no more than a tendency.

Conclusion

The result of the 6 months exposure of the panels is evaluated to be comparable between the reference panels and the test panels.

Generally there is no indication that the painted test panels have a higher adhesion loss, weight change or visual change than the painted reference panels.

The sandblasted test panels tested in a closed container show a slightly higher weight loss than the sandblasted reference panels tested in a closed container; however the weight loss is not significant enough to conclude that there is a difference.

Aarhus, 31th of January 2012
Materials Testing

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Procedure

The panels are tested in an immersion test in according to ISO 2812-2:2007 Paints and Varnishes – Determination of resistance to liquids as a reference.

The panels are exposed in artificial seawater prepared according to ISO 15711:2003. Intermediate inspections are made after 1 week, 4 weeks and 3 months. Final inspections and evaluation is made after 6 months.

Panels submitted for test

Following paint systems are tested on the coated panels:

Pure: Pure epoxy system

Modified: Modified epoxy system

Further are uncoated steel panel and cupper/nickel panels tested (panel Sa1 to Sa4 and Cu1 to Cu2)

Test media	Base panel	Surface preparation Abrasive blasted to Sa½	Zinc silicate shop primed	Artificial damage (scribe)	Zinc anode	System	Panel number
Artificial seawater ozone treated	Steel	Yes	No	No	No	Pure	70
						Modified	3
	Steel	Yes	No	Yes	No	Pure	66
						Modified	9
	Steel	Yes	Yes	No	No	Pure	78
						Modified	19
	Steel	Yes	Yes	Yes	No	Pure	74
						Modified	25
Reference system with artificial seawater	Steel	Yes	Yes	Yes	Yes	Pure	75
						Modified	26
	Steel	Yes	No	No	No	-	Sa1
	Steel	Yes	No	No	No	-	Sa2
	CuNi 90/10	No (as received)	No	No	No	-	Cu1
	Steel	Yes	No	No	No	Pure	71
						Modified	4
	Steel	Yes	No	Yes	No	Pure	68
						Modified	10
	Steel	Yes	Yes	No	No	Pure	79
						Modified	20
	Steel	Yes	Yes	Yes	No	Pure	77
						Modified	27
	Steel	Yes	Yes	Yes	Yes	Pure	73
						Modified	18

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Procedure and testplan

	Steel	Yes	No	No	No	-	Sa3
	Steel	Yes	No	No	No	-	Sa4
	CuNi 90/10	No (as received)	No	No	No	-	Cu2

Inspection plan

All panels are to be inspected according to the following plan.

Initial inspection	Visual evaluation and documentation of imperfections on the panels. Measurement of coating thickness for coated panels. Weight measurement of panels.
1 week inspection	Visual evaluation of coated panels including inspection for <ul style="list-style-type: none">• Degree of blistering (ISO 4628-2)• Degree of rusting (ISO 4628-3)• Degree of cracking (ISO 4628-4)• Degree of flaking (ISO 4628-5) Visual evaluation of uncoated panels including inspection of <ul style="list-style-type: none">• Density and size of corrosion attack (ISO 11463 and ASTM G46)
4 week inspection	Visual evaluation including inspection for <ul style="list-style-type: none">• Degree of blistering (ISO 4628-2)• Degree of rusting (ISO 4628-3)• Degree of cracking (ISO 4628-4)• Degree of flaking (ISO 4628-5)
3 month inspection	Visual evaluation including inspection for <ul style="list-style-type: none">• Degree of blistering (ISO 4628-2)• Degree of rusting (ISO 4628-3)• Degree of cracking (ISO 4628-4)• Degree of flaking (ISO 4628-5) Visual evaluation of uncoated panels including inspection of <ul style="list-style-type: none">• Density and size of corrosion attack (ISO 11463 and ASTM G46)
6 month inspection	Visual evaluation including inspection for <ul style="list-style-type: none">• Degree of blistering (ISO 4628-2)• Degree of rusting (ISO 4628-3)• Degree of cracking (ISO 4628-4)• Degree of flaking (ISO 4628-5)• Degree of delamination (ISO 4628-8)

	<p>Visual evaluation of uncoated panels including inspection of</p> <ul style="list-style-type: none">• Density and size of corrosion attack (ISO 11463 and ASTM G46) <p>Measurement of coating thickness for coated panels. Weight measurement of all panels. Evaluating adhesion by knife according to ASTM D 6677-01 on coated panels. Measurement of pit depth on uncoated panels according to ISO11463/ASTM G46.</p>
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 Observations

Initial inspection				
Panel no.	Visual evaluation	Coating thickness (avg.)	Weight (g total)	Comments
70	OK	318	137,098	
3	OK	343	137,285	
66	OK	310	136,864	
9	OK	311	137,188	
78	OK	332	137,772	
19	OK	331	136,306	
74	OK	345	137,323	
25	OK	330	136,996	
75	OK	359	138,373	
26	OK	323	137,194	
Sa1	OK	N/A	243,810	
Sa2	OK	N/A	244,067	
Cu1	OK	N/A	165,554	
Initial inspection – Reference panels				
Panel no.	Visual evaluation	Coating thickness	Weight (g total)	Comments
71	OK	372	139,841	
4	OK	350	137,268	
68	OK	307	138,080	
10	OK	326	136,827	
79	OK	327	139,430	
20	OK	322	134,433	
77	OK	327	138,838	
27	OK	329	137,617	
73	OK	359	136,400	
18	OK	327	135,689	
Sa3	OK	N/A	241,210	
Sa4	OK	N/A	241,831	
Cu2	OK	N/A	155,733	

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 Observations

1 week inspection, date: 2011.07.06						
Panel no.	Visual evaluation	Blistering	Rusting	Cracking	Flacking	Comments
70	OK	NO	NO	NO	NO	OK
3	OK	NO	NO	NO	NO	OK
66	OK	NO	NO	NO	NO	Rust in 70% of scribe
9	OK	NO	NO	NO	NO	Rust in 60% of scribe
78	OK	NO	NO	NO	NO	Paint flake missing on <u>the</u> top of <u>the</u> panel
19	OK	NO	NO	NO	NO	OK
74	OK	NO	NO	NO	NO	Rust in 20% of scribe
25	OK	NO	NO	NO	NO	Rust in 10% of scribe
75	OK	NO	NO	NO	NO	OK
26	OK	NO	NO	NO	NO	OK
Panel no.	Visual evaluation	Rust density	Rust size	Comments		
Sa1	OK	See comments	See comments	Panel is covered with a black layer. Small red rust mark on top corner is observed where number marking has been made. Red rust also observed on top rim of panel.		
Sa2	OK	See comments	See comments	Panel is covered with a black layer. Small red rust mark on top corner is observed where number marking has been made. Red rust also observed on top rim of panel.		
Cu1 Cu2*	OK	See comments	See comments	OK		

*panel Cu1 and Cu2 has been switched during startup of test

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1 week inspection, reference panels, date: 2011.07.06						
Panel no.	Visual evaluation	Blistering	Rusting	Cracking	Flacking	Comments
71	OK	NO	NO	NO	NO	OK
4	OK	NO	NO	NO	NO	OK
68	OK	NO	NO	NO	NO	Rust in 40% of scribe
10	OK	NO	NO	NO	NO	Rust in 50% of scribe
79	OK	NO	NO	NO	NO	OK
20	OK	NO	NO	NO	NO	OK
77	OK	NO	NO	NO	NO	Rust in 30% of scribe
27	OK	NO	NO	NO	NO	Rust in 10% of scribe
73	OK	NO	NO	NO	NO	OK
18	OK	NO	NO	NO	NO	OK
Panel no.	Visual evaluation	Rust density	Rust size	Comments		
Sa3	OK	See comments	See comments	Panel is covered with black layer. Small red rust mark on top corner is observed where number marking has been made. Red rust also observed on top rim of panel.		
Sa4	OK	See comments	See comments	Panel is covered with black layer. Small red rust mark on top corner is observed where number marking has been made. Red rust also observed on top rim of panel.		
Cu2 Cu1	OK	See comments	See comments	OK		

*panel Cu1 and Cu2 has been switched during startup of test

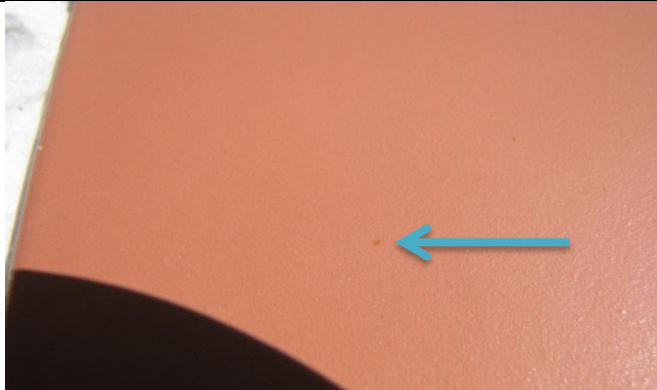
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 Observations

4 week inspection, date: 2011.07.27						
Panel no.	Visual evaluation	Blistering	Rusting	Cracking	Flacking	Comments
70	OK	NO	NO	NO	NO	OK
3	OK	NO	NO	NO	NO	OK
66	OK	NO	NO	NO	NO	Rust in 70% of scribe
9	OK	NO	NO	NO	NO	Rust in 70% of scribe
78	OK	NO	See comments	NO	NO	Ono rust mark is seen on upper 1/3 of the panel (picture)
19	OK	NO	See comments	NO	NO	Two rust marks are seen. One in top and one in bottom of the panel. (picture)
74	OK	NO	NO	NO	NO	Rust in 30% of scribe
25	OK	NO	NO	NO	NO	Rust in 20% of scribe
75	OK	NO	NO	NO	NO	Beginning white rust in scribe
26	OK	NO	NO	NO	NO	Beginning white rust in scribe
Panel no.	Visual evaluation	Rust density	Rust size	Comments		
Sa1	OK	See comments	See comments	Black layer thicker than a week 1 inspection. Rust on top rim. (picture)		
Sa2		See comments	See comments	Black layer thicker than a week 1 inspection. Rust on top rim.		

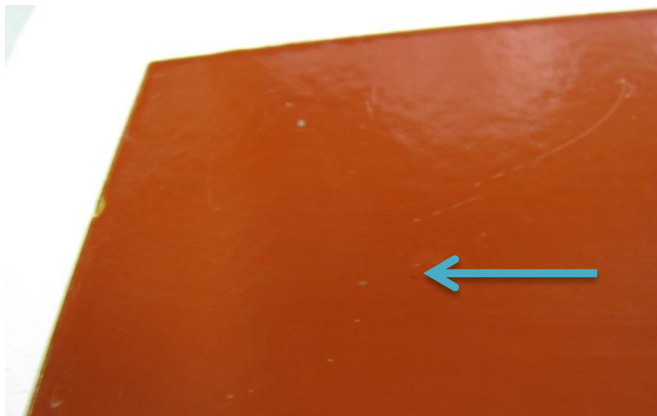
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				(picture)
Cu1 Cu2*		See comments	See comments	OK (picture)



1 week: Panel 19, rust mark



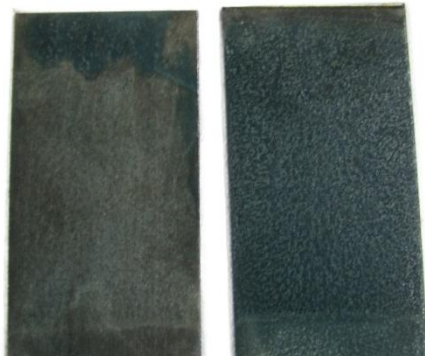
1 week: Panel 19, rust mark

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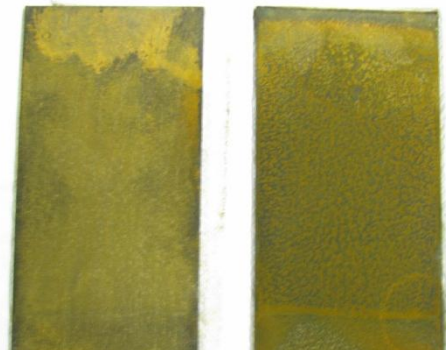


1 week: Panel Cu2, rust development



Right after removal from water

1 week: Panels Sa1 and Sa2



Approx. 10min after removal from water

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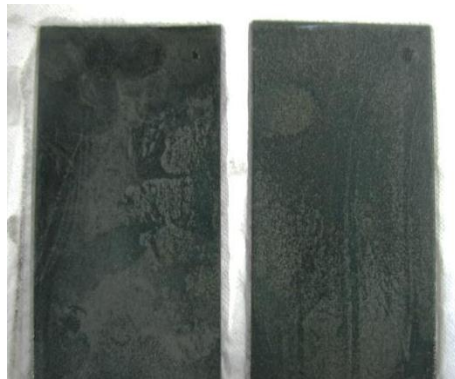
4 week inspection, reference panels, date: 2011.07.27						
Panel no.	Visual evaluation	Blistering	Rusting	Cracking	Flacking	Comments
71	OK	NO	NO	NO	NO	OK
4	OK	NO	NO	NO	NO	OK
68	OK	NO	NO	NO	NO	Rust in 50% of scribe
10	OK	NO	NO	NO	NO	Rust in 55% of scribe
79	OK	NO	NO	NO	NO	OK
20	OK	NO	NO	NO	NO	OK
77	OK	NO	NO	NO	NO	Rust in 45% of scribe
27	OK	NO	NO	NO	NO	Rust in 25% of scribe
73	OK	NO	NO	NO	NO	Beginning white rust in scribe
18	OK	NO	NO	NO	NO	Beginning white rust in scribe
Panel no.	Visual evaluation	Rust density	Rust size	Comments		
Sa3	OK	See comments	See comments	Black layer thicker than a week 1 inspection. Rust on top rim. (picture)		
Sa4	OK	See comments	See comments	Black layer thicker than a week 1 inspection. Rust on top rim. (picture)		
Cu2 Cu1*	OK	See comments	See comments	OK (picture)		

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Panel Cu1, rust development



Right after removal from water
Panels Sa3 and Sa4



Approx. 5 min after removal from water

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 Observations

3 month inspection, date: 2011.10.05						
Panel no.	Visual evaluation	Blistering	Rusting	Cracking	Flacking	Comments
70	OK	NO	Comment	NO	NO	Marking middle left side Marking ¼ from bottom middle of plate
3	OK	NO	Comment	NO	NO	Small mark 1/3 from top
66	OK	NO		NO	NO	70% rust in scribe
9	OK	Comment		NO	NO	One blister at scribe and one at side, Size S3 60% rust in scribe
78	OK		Comment	NO	NO	Minimal development. Possi- ble 1 new 1/3 from top
19	OK		Comment	NO	NO	Chip missing R.S. middle minimal development
74	OK		Comment	NO	NO	80% rust in scribe Possible 3 blisters very small.
25	OK		Comment	NO	NO	80% rust in scribe
75	OK	Comment	Comment	NO	NO	60% rust in scribe Small indication of blister below scribe
26	OK	Comment	NO	NO	NO	
Panel no.	Visual evaluation	Rust density	Rust size	Comments		
Sa1	Black rust					
Sa2	Black rust					
Cu1 (Cu2)	Green coloring					

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Observations

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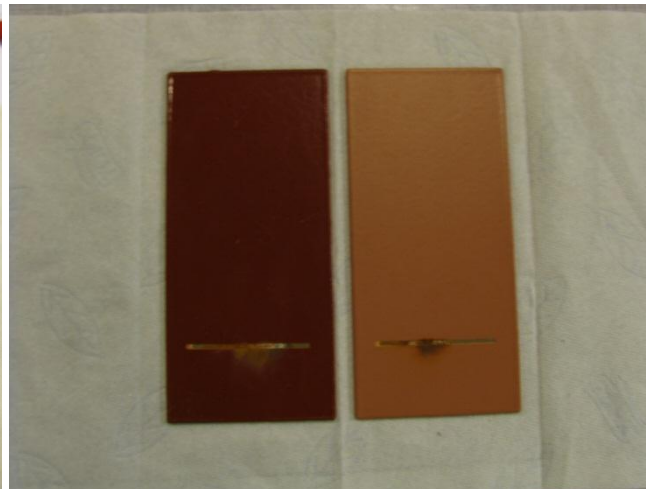
3 month: Panel 70 and 3



3 month: Panel 66 and 9



3 month: Panel 78 and 19



3 month: Panel 74 and 25

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3 month: Panel 75 and 26



3 month: Panel Sa1 and Sa2



3 month: Panel Cu2 backside



3 month: Panel Cu2 front side

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3 month inspection, reference panels, date: 2011.10.05						
Panel no.	Visual evaluation	Blistering	Rusting	Cracking	Flacking	Comments
71	OK	OK	OK	OK	OK	OK
4	OK	OK	OK	OK	OK	Blister 1/5 down from top?
68	OK	Comment	OK	OK	OK	Blister R.S. of scribe 90% rust in scribe
10	OK		OK	OK	OK	Possible blister left side at scribe 80% rust in scribe
79	OK		OK	OK	OK	Possible list at top and 1/2 down
20	OK		OK	OK	OK	Mark (paint error) 1/3 down
77	OK	Comment	OK	OK	OK	2 blisters along scribe 90% rust in scribe
27	OK		OK	OK	OK	70% rust in scribe
73	OK	Comment	OK	OK	OK	Blister at scribe and left side approx. 1/3 up
18	OK		OK	OK	OK	
Panel no.	Visual evaluation	Rust density	Rust size	Comments		
Sa 3	Black rust					
Sa 4	Black rust					
Cu 2 (Cu1)	Green coloring			Dents on backside of panel that looks like blister		

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3 month: Panel 71 and 4



3 month: Panel 68 and 10



3 month: Panel 79 and 20



3 month: Panel 77 and 27

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Observations

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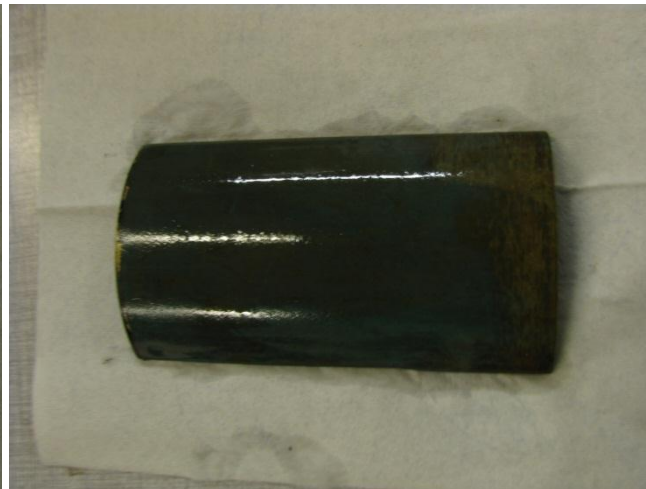
3 month: Panel 73 and 18



3 month: Panel Sa3 and Sa4



3 month: Panel Cu1 backside



3 month: Panel Cu1 front side

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 Observations

Panel no.	Visual evaluation after 6 months	Coating thickness [µm]	Adhesion loss around scribe [mm] minus the scribe (2mm)	Weight [g]
70	No blistering, small marks in the paint layer already seen at initial inspection	338,329,331,313,323,312,344, 336,331,344 Avg.: 330 Dry panel measurements: 345,315,334,324,325,344,353, 310,328,325 Avg.: 330		137,047
3	No blistering, small marks in the paint layer already seen at initial inspection	360,368,361,346,378,354,365, 357,396,381 Avg.: 367 Dry panel measurements: 361,344,340,356,348,381,367, 349,373,360 Avg.:358		137,243
66	Blister at edge	309,327,328,325,313,323,300, 332,320,339 Avg.: 322	1: 38,12 2: 37,05 3: 35,41 4: 35,06 5: 32,85 6: 28,58 Avg.: 34,51	-
9	Blister at edge, one blister just below scribe 2(S4)	332,330,345,319,336,320,327, 317,324,308 Avg.: 326	1: 40,41 2: 40,44 3: 38,75 4: 38,83 5: 40,26 6: 40,59 Avg.: 39,88	-
78	No blistering, small marks in the paint layer already seen at initial inspection	367,344,342,340,348,346,352, 356,333,352 Avg.: 348 Dry panel measurements: 358,353,334,344,330,321,334,		137,711 Small pieces of paint are broken off.

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		360,352,347 Avg.:343		
19	No blistering, small marks in the paint layer already seen at initial inspection	343,352,337,342,340,331,354, 348,346,356 Avg.: 345 Dry panel measurements: 336,353,337,330,334,342,343, 357,354,350 Avg.:343		136,266
74	One blister at scribe 2(S4)	351,373,365,363,358,330,370, 368,380,372 Avg.: 363	1: 7,09 2: 7,10 3: 6,21 4: 6,28 5: 4,84 6: 5,84 Avg.: 6,24	-
25	Ok	354,368,328,342,336,335,343, 328,352,365 Avg.: 345	1: 6,13 2: 5,42 3: 3,74 4: 3,76 5: 4,76 6: 6,00 Avg.: 4,97	-
75	Blister at edge, one blister just below scribe 2(S4)	387,357,374,372,359,382,356, 393,387,376 Avg.: 374	1: 11,88 2: 11,72 3: 11,73 4: 11,37 5: 13,09 6: 13,45 Avg.: 12,21	-
26	Ok	338,338,325,350,350,328,340, 347,356,374 Avg.: 345	1: 6,62 2: 6,19 3: 6,21 4: 6,76 5: 7,33 6: 6,66 Avg.: 6,63	-

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Observations

Panel no.	Visual evaluation	Weight (g total)
Sa1	Black rust	241,965
Sa2	Black rust	242,341
Cu2	Green deposits	165,312
Sa5	Black and red rust	233,548

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Panel no.	Visual evaluation	Coating thickness [µm]	Adhesion loss around scribe [mm] minus the scribe (2mm)	Weight [g]
71	No blistering, small marks in the paint layer already seen at initial inspection	405,385,392,384,392,378, 366,383,385,393 Avg.: 386 Dry panel measurements: 393,380,390,376,383,367, 364, 372,396,385 Avg.:381		139,778
4	No blistering, small marks in the paint layer already seen at initial inspection	360,368,361,346,378,354, 365,357,396,381 Avg.: 367 Dry panel measurements: 356,352,358,333,372,369, 365,350,369,366 Avg.:359		137,229
68	Blister at edge, one blister at right side of scribe 2(S4)	333,308,330,296,332,331, 325,319,324,329Avg.: 323	1: 34,74 2: 35,55 3: 36,84 4: 33,51 5: 34,07 6: 31,28 Avg.: 33,67	-
10	Blister at edge	344,341,347,317,335,316, 328,336,346,346 Avg.: 336	1: 47,37 2: 46,59 3: 45,32 4: 41,48 5: 36,69 6: 34,08 Avg.: 41,92	-
79	No blistering, small marks in the paint layer already seen at initial inspection	338,348,328,350,336,342, 349,338,340,344 Avg.: 341 Dry panel measurements: 342,352,336,342,340,323,		139,372

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		335,336,348,328 Avg.:338		
20	No blistering, small marks in the paint layer already seen at initial inspection	342,354,319,332,329,356, 328,349,338,352 Avg.: 340 Dry panel measurements 328,331,327,327,331,315, 346,332,334,344 Avg.:332		134,391
77	Two blisters at scribe 2(S4)	338,369,349,320,337,324, 348,332,356,343 Avg.: 342	1: 11,81 2: 9,25 3: 7,68 4: 6,77 5: 7,44 6: 9,30 Avg.: 6,54	-
27	Ok	334,352,347,340,317,333, 323,346,344,365 Avg.: 340	1: 3,95 2: 3,87 3: 3,11 4: 1,84 5: 3,24 6: 3,74 Avg.: 3,29	-
73	Blisters at edge, two blisters around scribe 2(S4)	380,382,377,381,374,376, 351,376,388,395 Avg.: 378	1: 13,52 2: 12,45 3: 15,01 4: 15,67 5: 15,77 6: 16,26 Avg.: 12,78	-
18	Ok	349,357,336,342,338,353, 330,323,354,352 Avg.: 343	1: 6,37 2: 5,94 3: 6,11 4: 5,49 5: 6,33 6: 7,88 Avg.: 6,35	-

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Observations

Panel no.	Visual evaluation	Weight [g]
Sa3	Black rust	239,847
Sa4	Black rust	240,452
Cu2	Green deposits	155,334
Sa6	Black and red rust	235,830

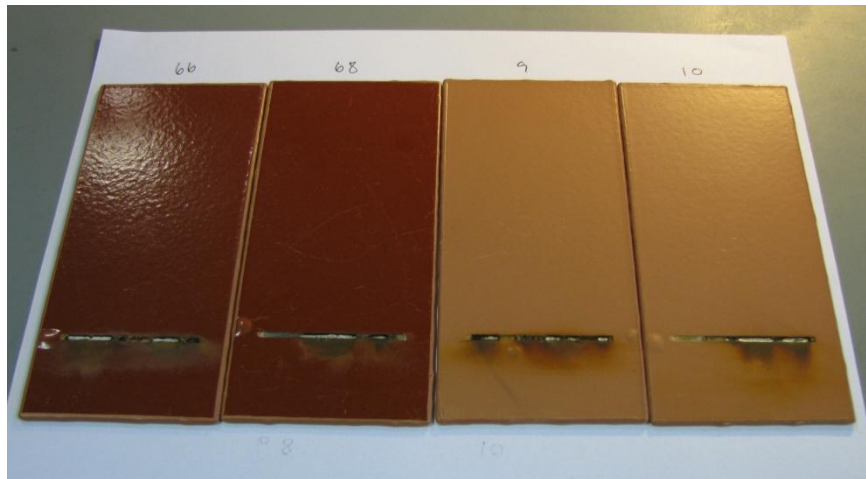
2012.01.20
DSP/BBJ
4C 1303031-433373
Enclosure 3.21
Observations

**DANISH
TECHNOLOGICAL
INSTITUTE**

Panels after 6 month exposure

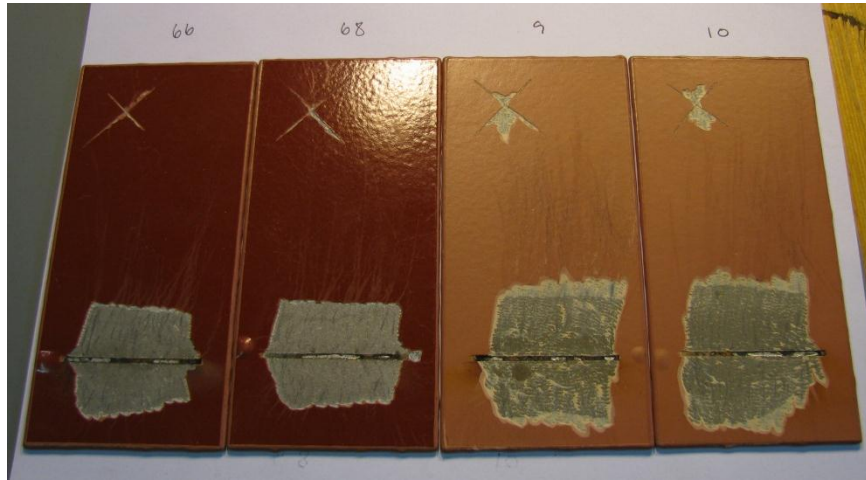


Panels 70 – 71 – 3 - 4



Panels 66 – 68 – 9 – 10

2012.01.20
DSP/BBJ
4C 1303031-433373
Enclosure 3.22
Observations

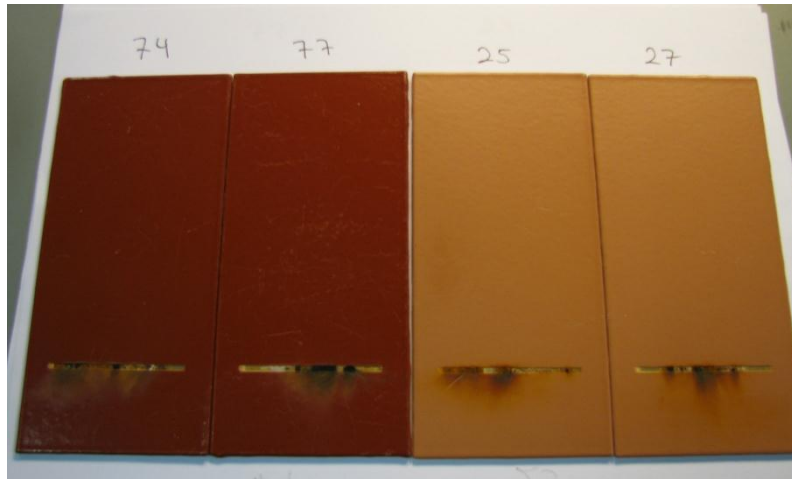


Panels 66- 68 – 9 – 10 after removal of loose paint.



Panels 78 – 79 – 19 - 20

2012.01.20
DSP/BBJ
4C 1303031-433373
Enclosure 3.23
Observations

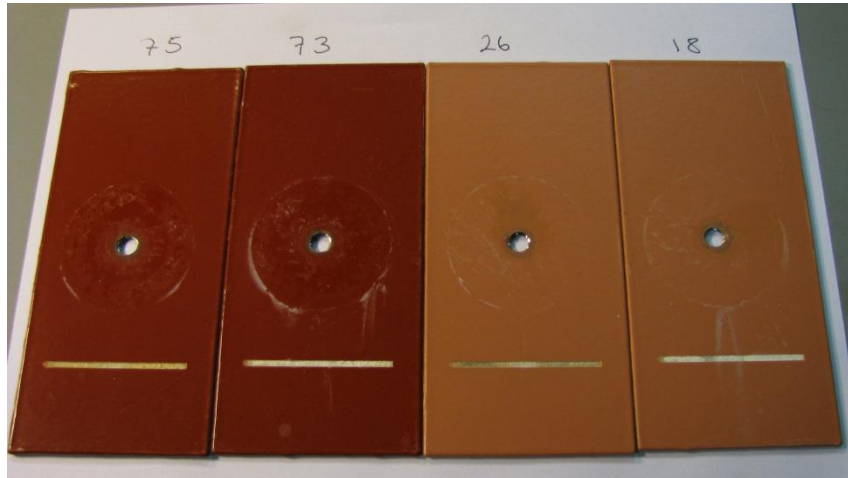


Panels 74 – 77 – 25 - 26



Panels 74 – 77 – 25 – 26 after removal of loose paint

2012.01.20
DSP/BBJ
4C 1303031-433373
Enclosure 3.24
Observations



Panels 75 – 73 – 26 - 18



Panels 75 – 73 – 26 – 18 after removal of loose paint