NASA TEERM Principal Center
Non-Chrome Projects

Technology Programs & Partnerships Branch

Applied Technology Directorate

Kennedy Space Center, FL

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Senior Engineer

Overview

- TEERM Overview
- Non-Chrome Systems Testing Phase I
- International Coatings Project
- Non-Chrome Phase II – Developing Test Plans
- Electronic Housing Pretreatments

TEERM Principal Center
Mission

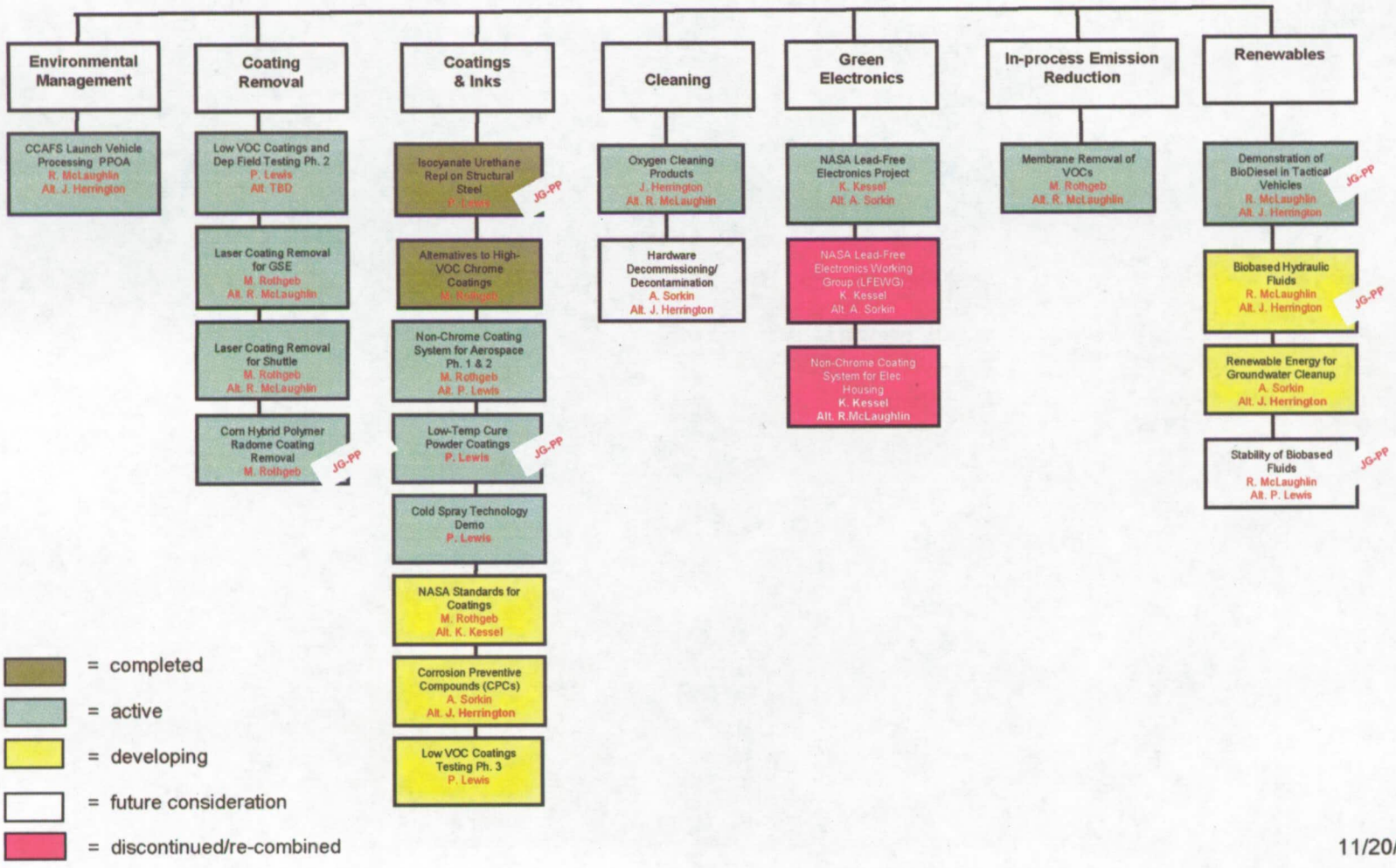
TEERM =

Technology Evaluation for Environmental Risk Mitigation

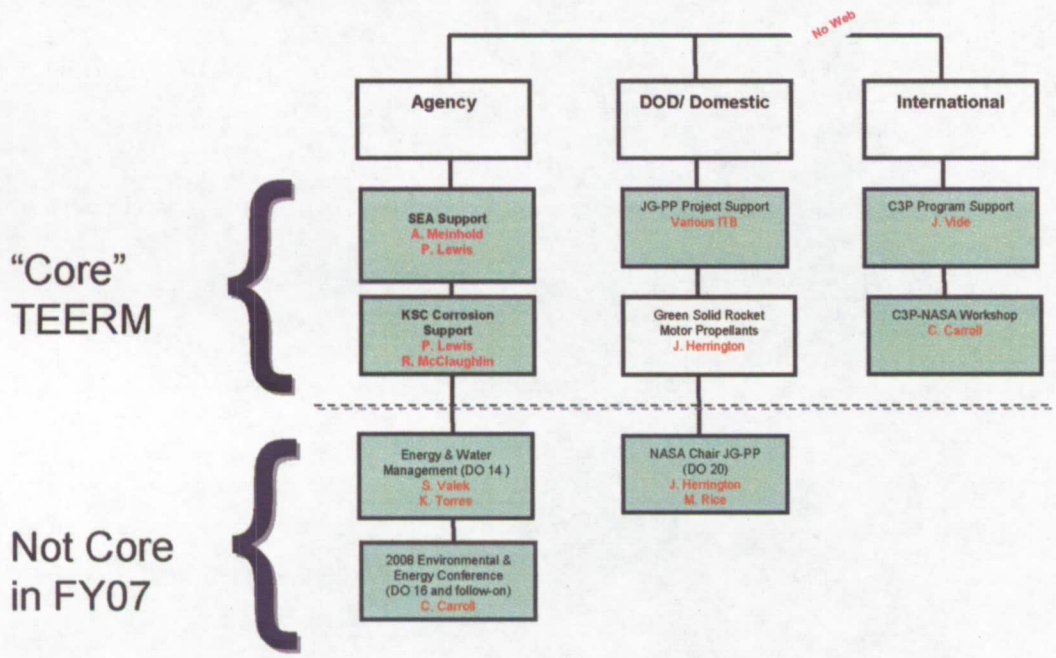
TEERM Principal Center Mission:

To identify and validate environmental technologies through **joint activities** that **enhance mission readiness** and **reduce risk** while **minimizing duplication and associated costs**.

TEERM Work Breakdown Structure
Demonstration/Evaluation Projects



TEERM Work Breakdown Structure
Technical Exchange Projects



= active

= developing

= future consideration


NASA

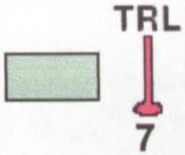
Non-Chrome Coating Systems Tested

- Non-Chrome Systems Project:
  - Five Coating Systems Tested for Phase I
  - Two Controls
- C3P Low VOC/Non-Chrome Project:
  - Two Coatings Systems Tested

C	O	D
Alodine 1200s	Alodine 1200s	Boegel AC-131CB
Deft 02-Y-40	PPG Aerospace 515K012 Chromated MB0125-055	Dupont Corlar 13570S
Deft 99-GY-001		Deft 03-GY-321
H	**N**	**S**
Alodine 5700	Prekote	Prekote
Hentzen Primer 05510WEP-X / 05511CEH-X	Mg-Rich Primer	AquaSurTec Crosslinker
Deft 03-GY-321	Deft 03-GY-321	AquaSurTec D45 AMS-MO / D45-AMS
T	**M**	**P**
Alodine 5700	M790E	Prekote SP
Sicopoxy 577-630	Aviox CF Primer	Aviox CF Primer
Deft 03-GY-321	Aviox Finish 77702	Aviox Finish 77702

O - System for Dissimilar Metals Tests Only

M, P - Systems for International Project



Non-Chrome Coating Systems for Aerospace Applications (NASA-DoD)

Description:

- Evaluation and testing of non-chromated coating systems as replacements for hexavalent chrome coatings in aircraft and aerospace applications.
- Recently added: evaluation of non-chrome coatings for electronic housings as a focus area of Phase II.

Stakeholders:

- NASA (KSC, MSFC, Boeing, Hill AFB, United Space Alliance, SEA) (Constellation has shown interest)
- Air Force (Hill AFB, WPAFB AFRL & MLBT)

Benefits:

- Meet EPA and OSHA requirements
- Reduce maintenance cost and government liability associated with continued use of chrome-containing coatings
- Addresses NASA and Air Force requirements on AL alloys 2219, 2195, 6061, 2024 Bare, 2024 Clad, and 7075.

Achievements:

- Completed 2,000 hour salt-spray testing (Hill AFB)
- Completed 2,000 Cyclic Corrosion testing (MSFC)
- Completed Hydrogen Embrittlement testing on Mg-Rich Coatings.
- Completed Adhesion testing (Hill AFB)
- Began drafting Joint Test Report (October 2007)

Future Plans:

- Complete Test Report for Phase I testing (Jan 2008)
- Complete PAR and JTP for Phase II (Feb 2008)
- Begin testing for Phase II (Feb–Mar 2008)

TEERM Non-Chrome Systems
Phase I Test Progress

Laboratory Tests Performed:

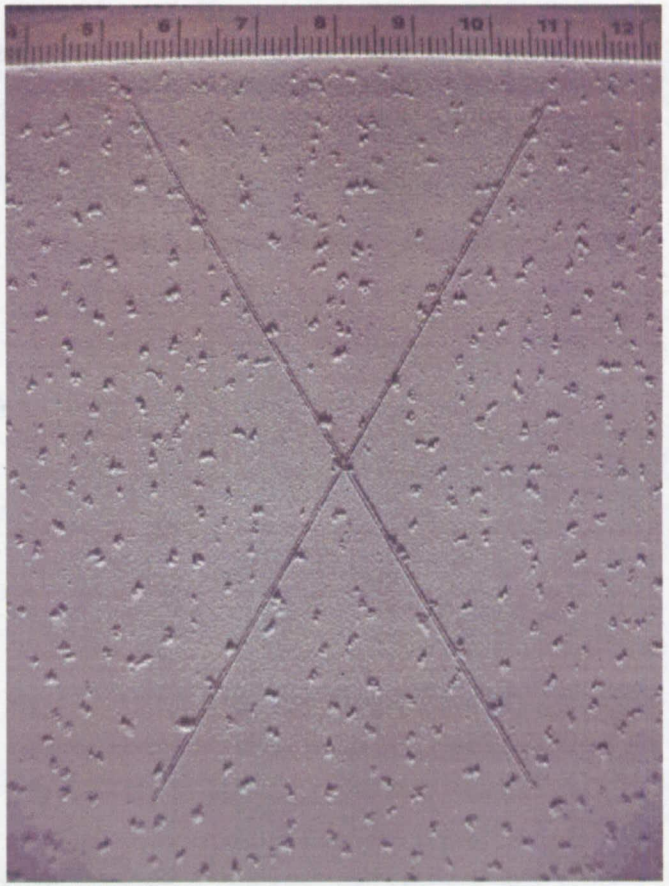
- Kennedy Space Center, Marshall Space Flight Center
- Hill AFB, Wright-Patterson AFB

Tests:

- Filiform Corrosion – 1,000 Hrs – Complete
- Cyclic Corrosion – 2,000 Hrs – Complete
- Dissimilar Metals – 2,000 Hrs – Complete
- Hydrogen Embrittlement – (Mg Rich Only) - Complete
- Salt Fog – 3,000 Hrs – 2,000+ Hrs as of Feb 08
- Adhesion Testing – Complete
- Post-Cyclic Corrosion Adhesion – Underway

Non-Chrome Systems Phase I Results

- **Fliliform Corrosion Results:**
  - All Systems performed well
  - System S was resistant to filiform corrosion but was heavily blistered
  - All experience some form of filiform corrosion, except for Control System C
- Best Performers:
  - System N (PreKote / Mg-Rich System)
  - System D (Bogel / Dupont Corlar)
- Worst Performers:
  - System T (*Alodine 5700 / Sicopoxy)
  - System H (*Alodine 5700 / Hentzen)



System S

* *Systems containing Alodine 5700 showed differing results when compared to testing performed by USA for SRB Coating Qualification Testing.*

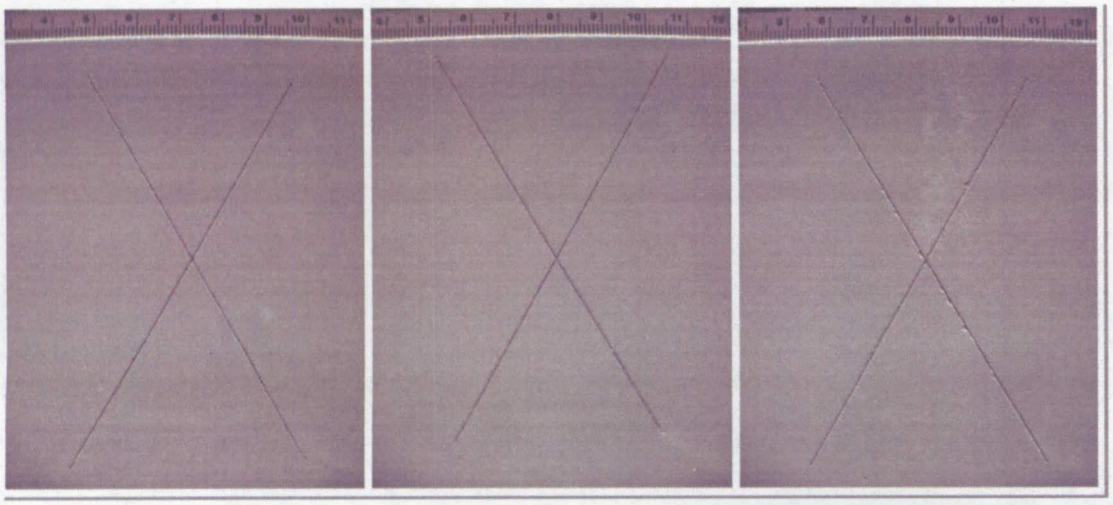
Non-Chrome Systems Phase I Results

Filiform Corrosion Results

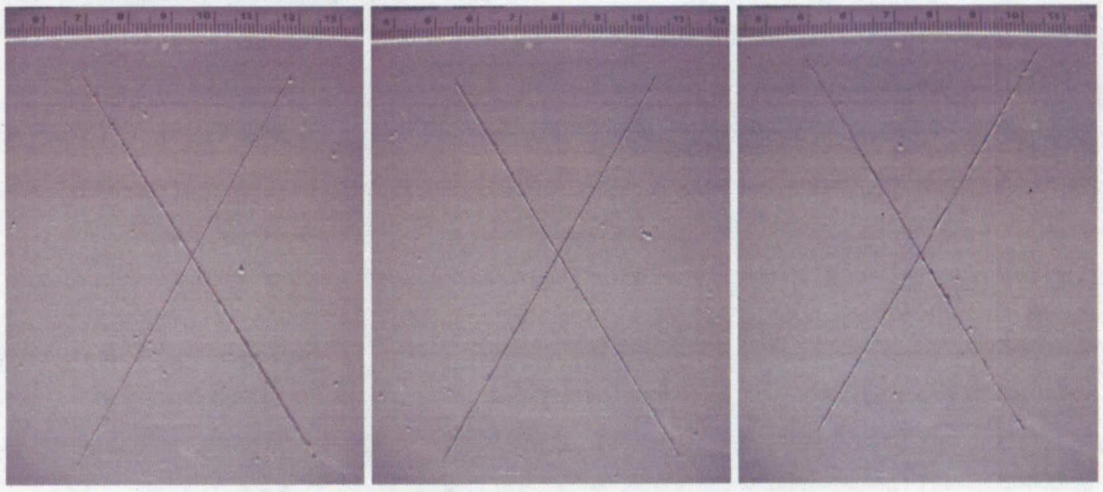
Sample	Filiment Growth (mm) Average	Max	Frequency	Group Avg.	ASTM D714 Blister Rating
Control 1	3	4	>30		none
Control 2	3	4	>30	3	none
Control 3	3	4	20< x <30		none
N1	0	0	0		none
N2	0	0	0	0.3	none
N3	1	1	10< x <20		none
S1	0	0	0		4, dense
S2	0	0	0	0.0	4, dense
S3	0	0	0		4, dense
D1	1	1	<10		none
D2	0	0	0	0.7	none
D3	1	1	<10		none
C1*	0	0	0		none
C2*	0	0	0	0.0	none
C3*	0	0	0		none
H1	2	4	20< x <30		none
H2	1.5	3	<10	1.8	none
H3	2	3	<10		none
T1	1	1	<5		none
T2	1	1	<5	1.3	none
T3	2	2	<5		none

Non-Chrome Systems Phase I Results

System N

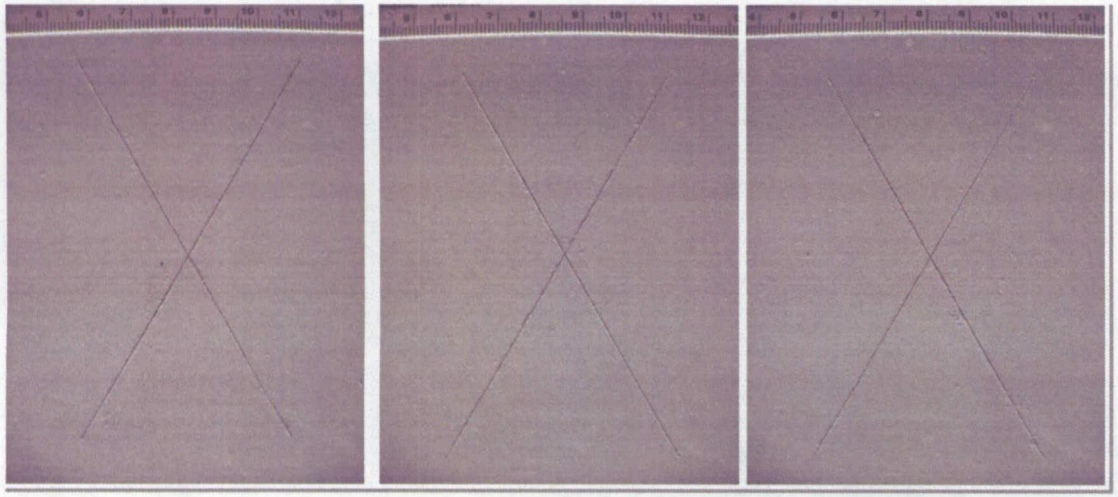


System D

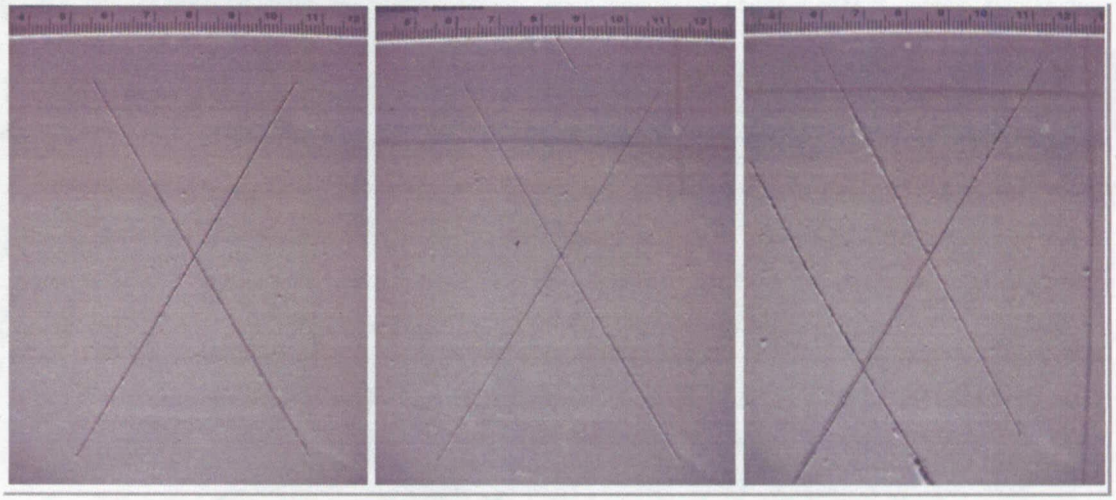


Non-Chrome Systems Phase I Results

System H



System T



Non-Chrome Systems Phase I Results

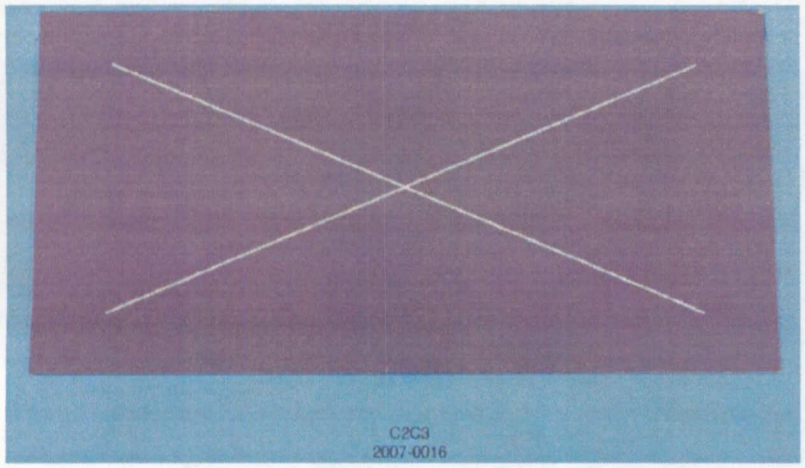
Cyclic Corrosion - Full Systems

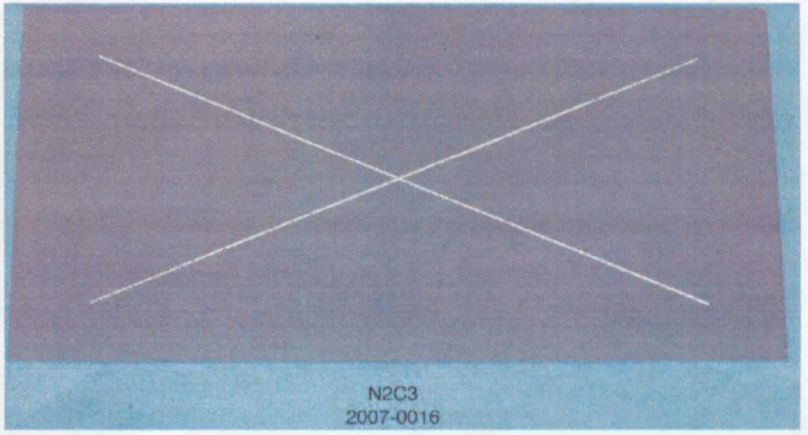
Cyclic Corrosion Testing (2024-T3, 2024-T3 Clad, 2195-T8M4, 2219-T87, 6061-T6, 7075-T6)			
Pretreatment	Primer	Topcoat	Average Rating
System C			9.67
Alodine 1200s	Deft 02-Y-40	Deft 99-GY-001	
System D			9.42
Boegel AC-131CB	Dupont Corlar 13570S	Deft 03-GY-321	
System H			9.47
Alodine 5700	Hentzen Primer 05510WEP-X	Deft 03-GY-321	
System N			9.61
Prekote	Mg-Rich Primer	Deft 03-GY-321	
System S			4.95
Prekote	AquaSurTec Crosslinker	AquaSurTec D45-AMS-MO	
System T			8.47
Alodine 5700	Sicopoxy 577-630	Deft 03-GY-321	

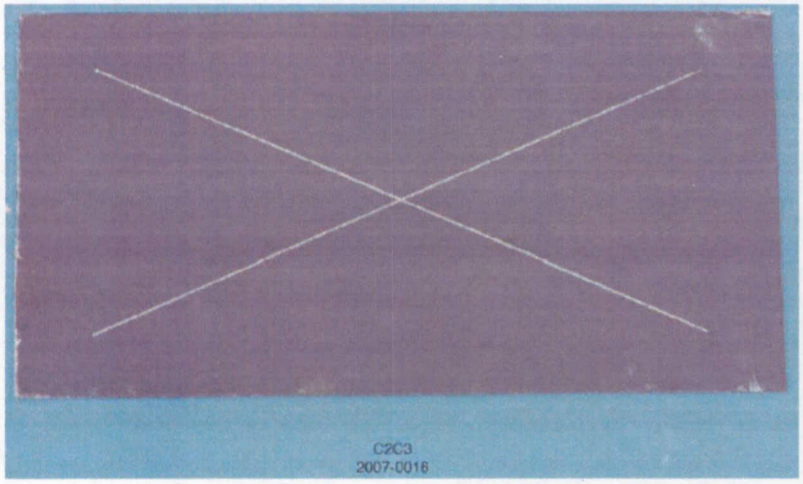
According to ASTM D1654-05 the samples were rated by 2 different methods:

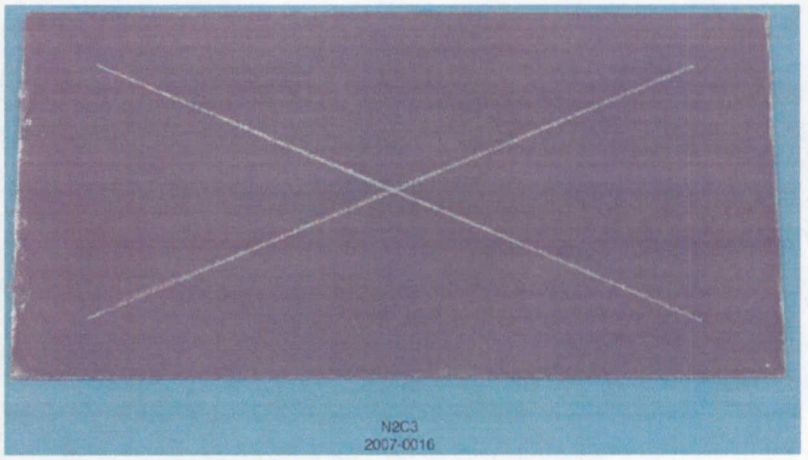
- Method 1 - percent area coverage by corrosion defects such as blisters, corrosion pits, peeling, etc. (Table 2 – ASTM D 1654-05)
- Method 2 - consisted of blowing high pressure air along the scribe marks and assigning a rating based on measurement of length of paint peel off from the scribe mark (Table 1 – ASTM D 1654-05)

Non-Chrome Systems Phase I Results

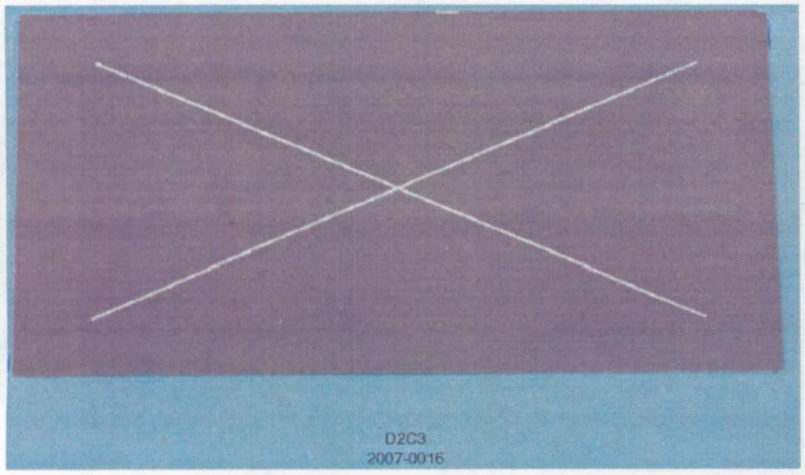


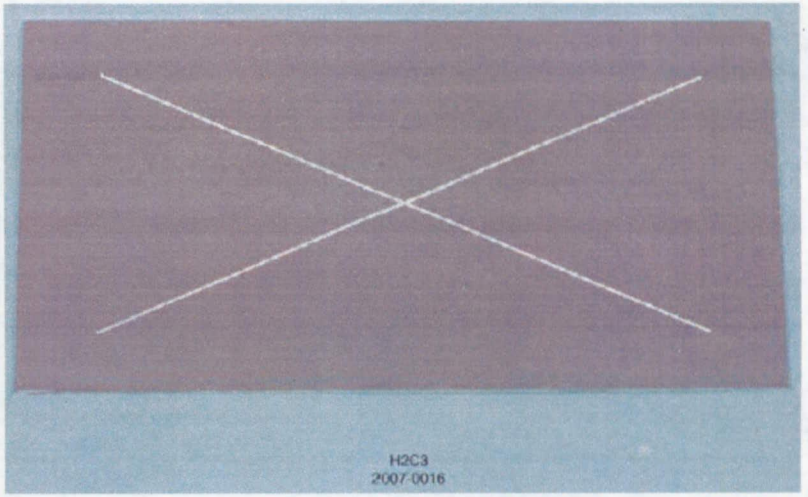


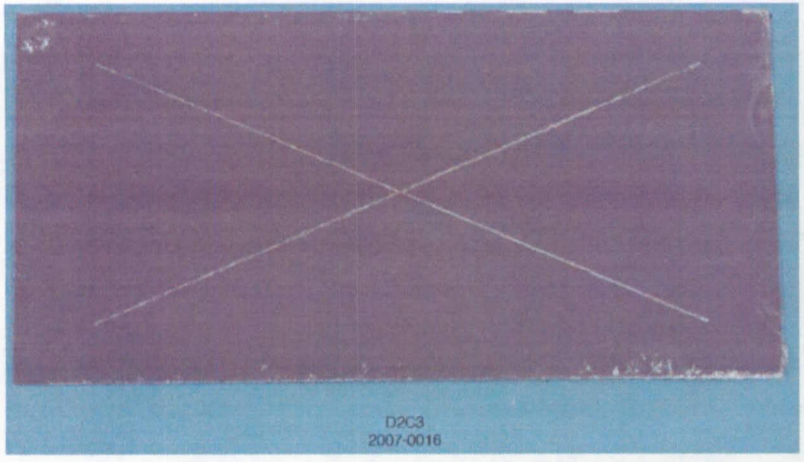


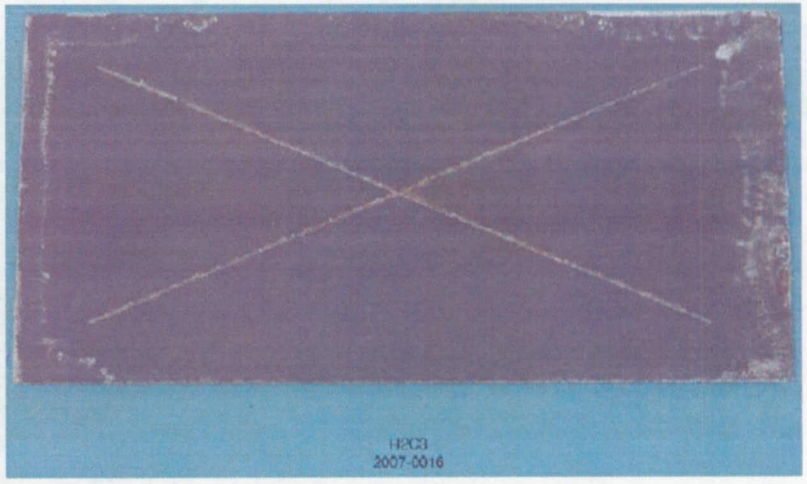


Non-Chrome Systems Phase I Results









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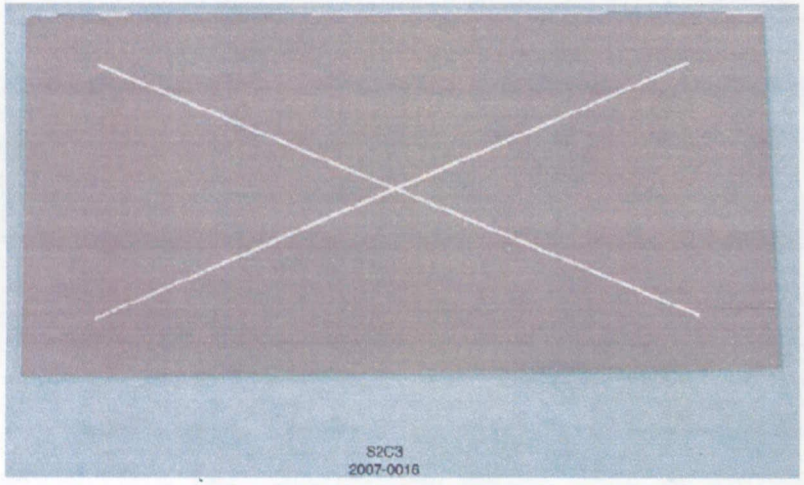
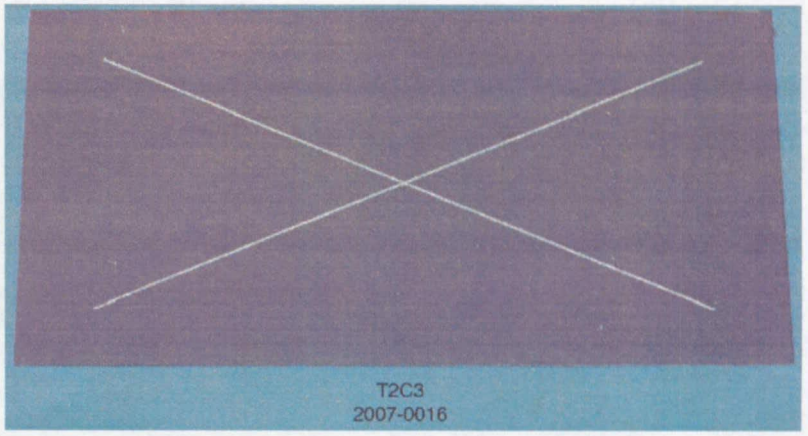
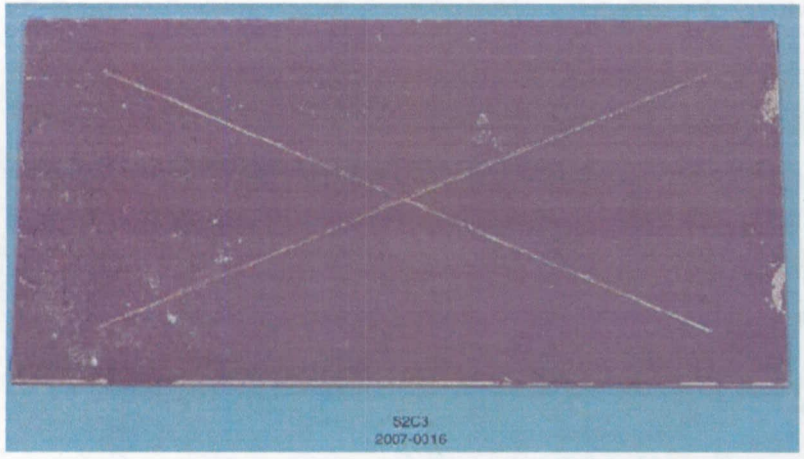
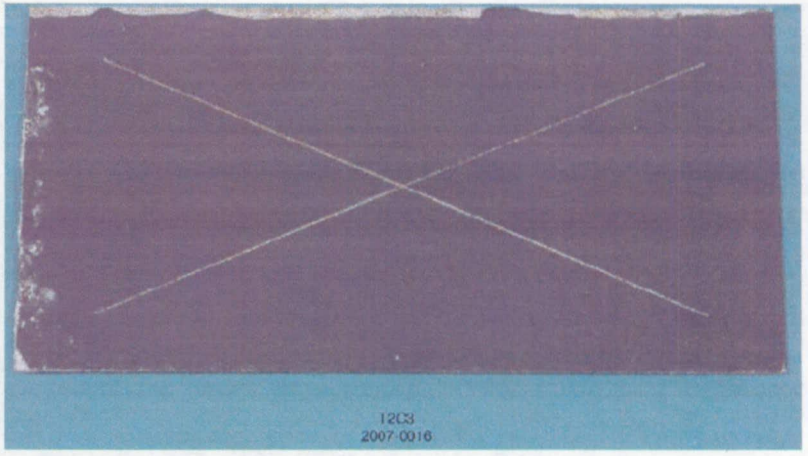








Non-Chrome Systems Phase I Results

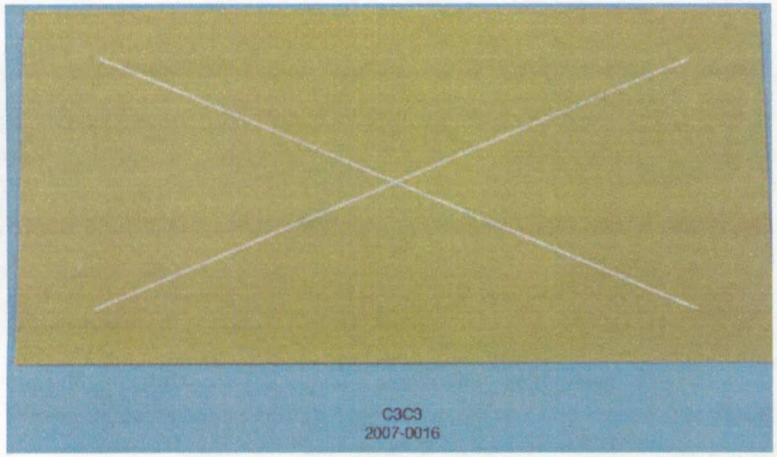
Cyclic Corrosion – No Topcoat

Cyclic Corrosion Testing			
(2024-T3, 2024-T3 Clad, 2195-T8M4, 2219-T87, 6061-T6, 7075-T6)			
Pretreatment	Primer	NO TOPCOAT	Average Rating
System C			9.73
Alodine 1200s	Deft 02-Y-40		
System D			9.42
Boegel AC-131CB	Dupont Corlar 13570S		
System H			9.61
Alodine 5700	Hentzen Primer 05510WEP-X		
System N			8.89
Prekote	Mg-Rich Primer		
System S			8.42
Prekote	AquaSurTec Crosslinker		
System T			8.31
Alodine 5700	Sicopoxy 577-630		

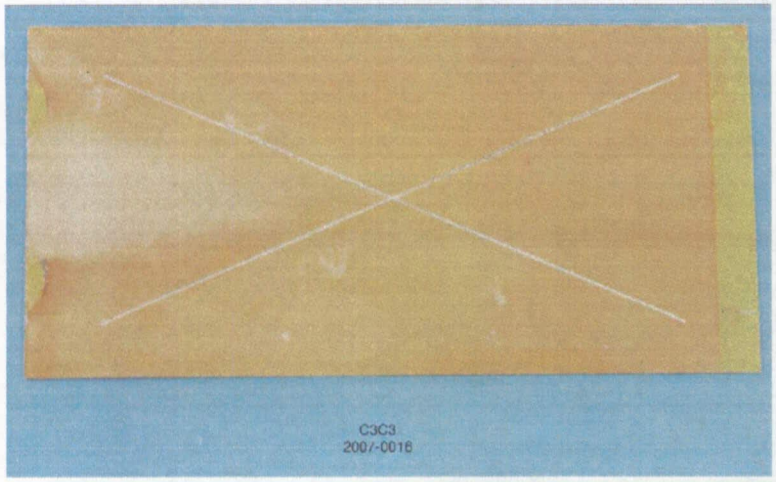
According to ASTM D1654-05 the samples were rated by 2 different methods:

- Method 1 - percent area coverage by corrosion defects such as blisters, corrosion pits, peeling, etc. (Table 2 – ASTM D 1654-05)
- Method 2 - consisted of blowing high pressure air along the scribe marks and assigning a rating based on measurement of length of paint peel off from the scribe mark (Table 1 – ASTM D 1654-05)

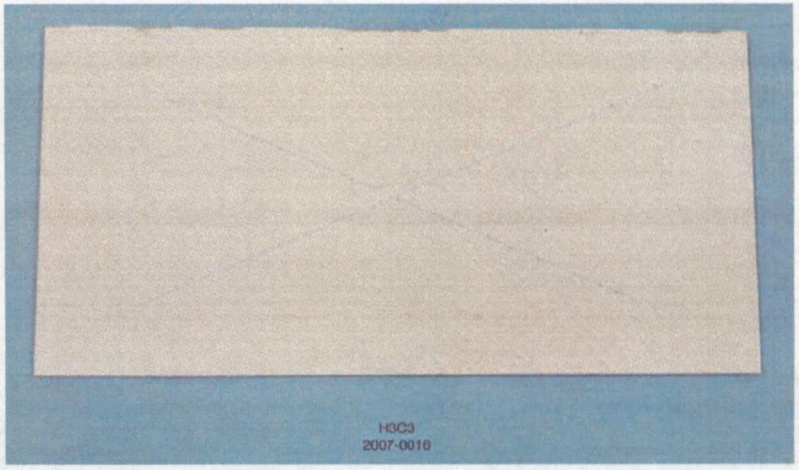
Non-Chrome Systems Phase I Results



(a) Before Test



(b) After Test (no change after discoloration)



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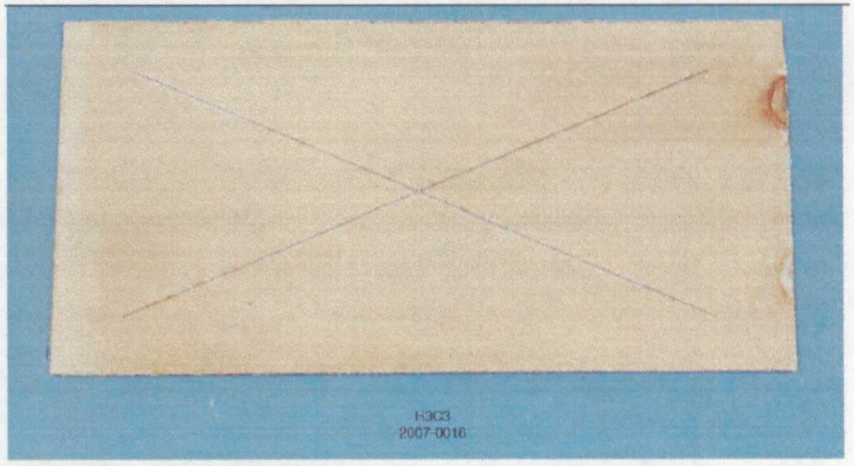
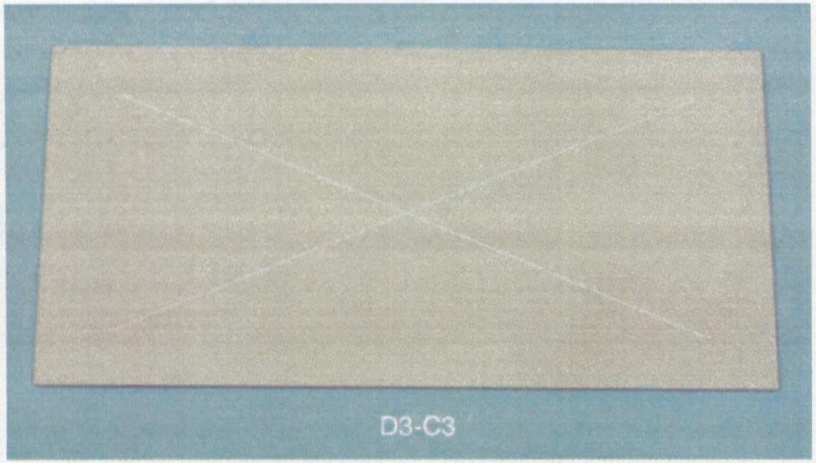


(b) After Test (no change after air blowing)

Non-Chrome Systems Phase I Results



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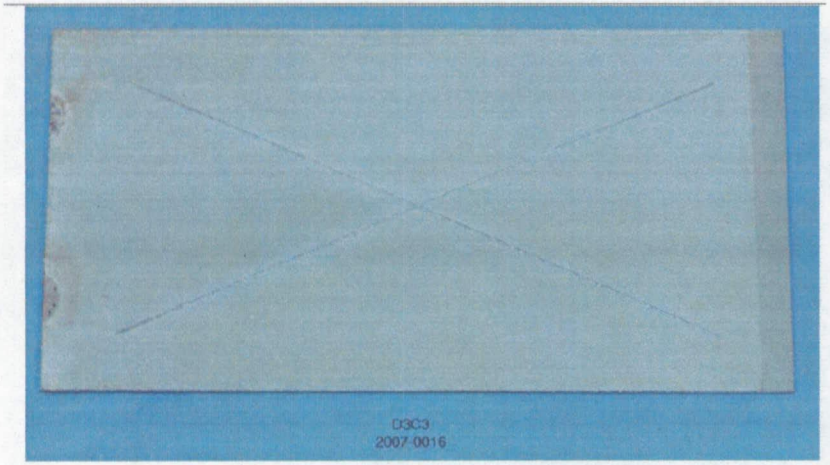
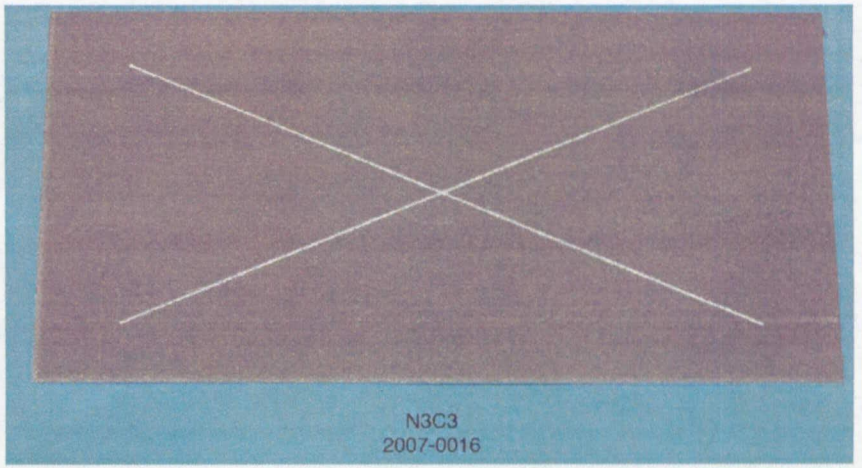


(b) After Test (No change after air blowing)



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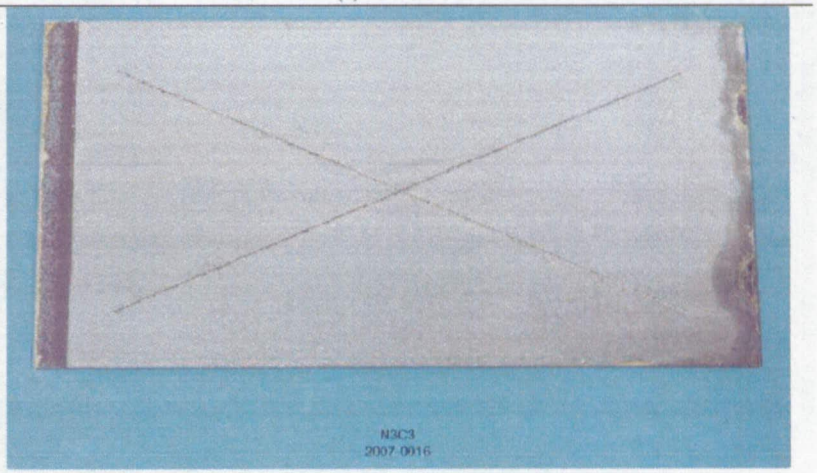
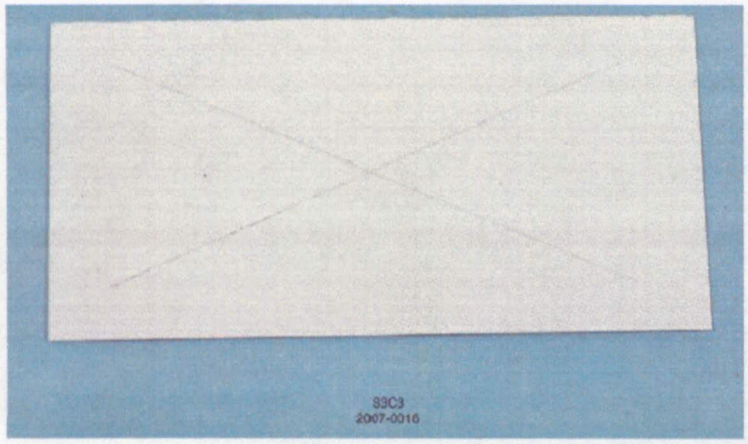


(b) After Test

Non-Chrome Systems Phase I Results



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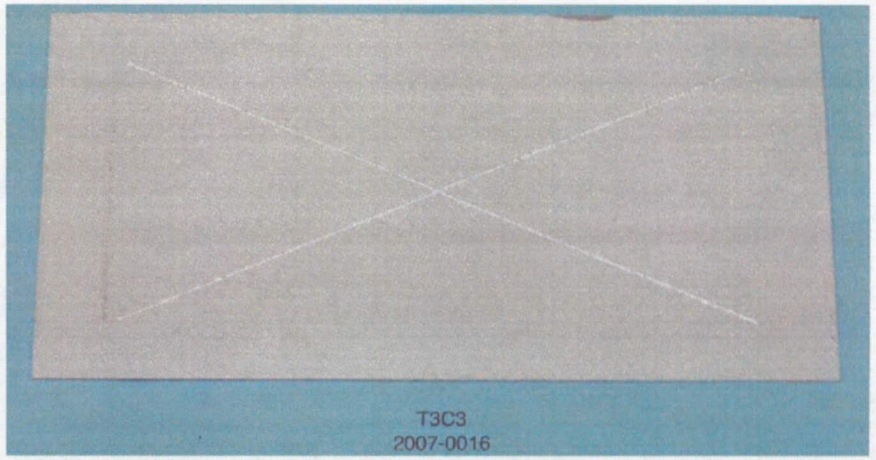
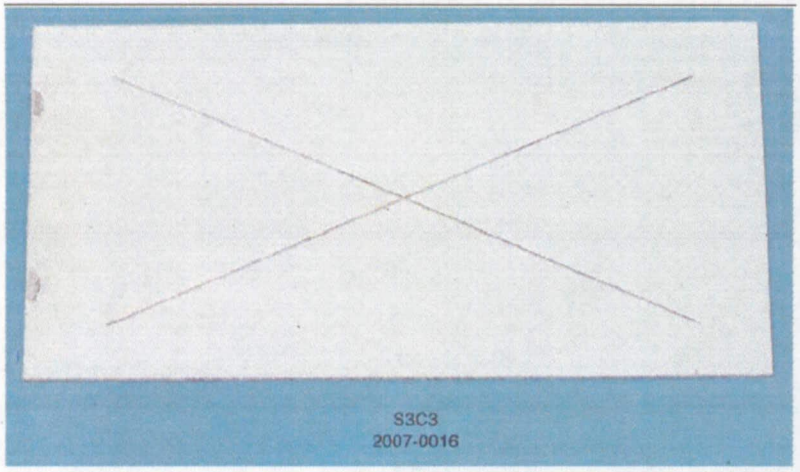
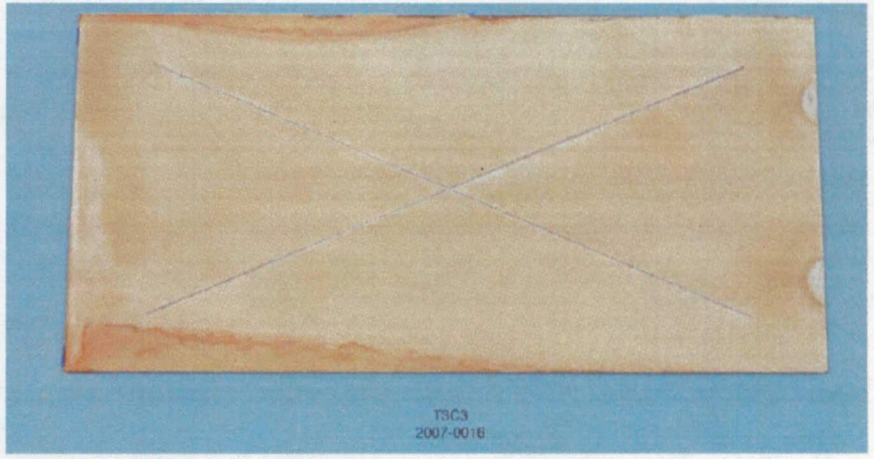


(a) Before Test



(b) After Test (no change after air blowing)

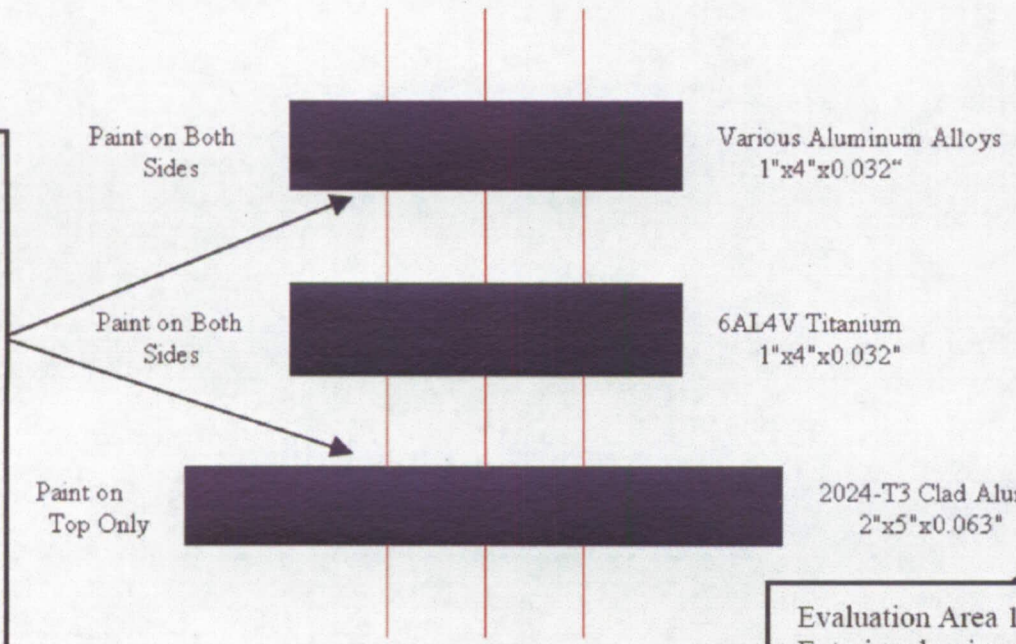


(b) After Test (no change after air blowing)

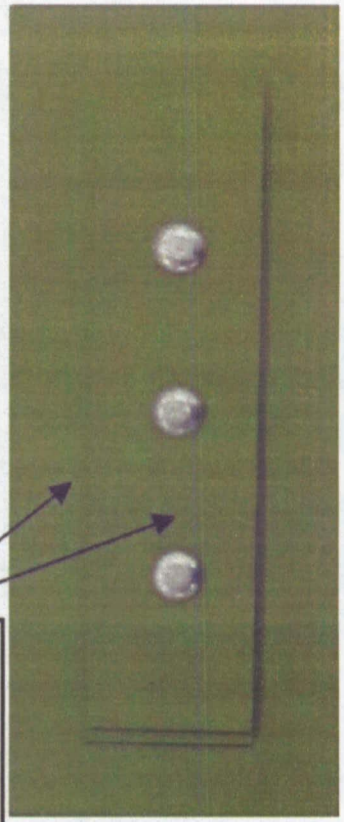
Non-Chrome Systems Phase I Results

Dissimilar Metals – Sandwich Corrosion Test

Evaluation Area 2: After 2000 hours of salt fog, faying aluminum surfaces in contact with the titanium panel are evaluated for crevice corrosion and a corrosion rating (0 to 10) is assigned to each panel in accordance with Figure 2.



Sandwich Assembled with Three MS20470 B5-5 Aluminum Rivets Drilled and Installed Along the Red Lines



Evaluation Area 1: Exterior aluminum surfaces are examined for signs of coating degradation every 500 hours up to 2000 hours of salt fog exposure. Coating systems are ranked from best to worst (1 to 7).

Configurations:

A = 7075-T6 Alclad

B = 7075-T6 Bare

C = 2024-T3 Bare

D = 2024-T3 Alclad

Non-Chrome Systems Phase I Results

Coating System Exterior Appearance Rank During Salt Fog Exposure

Designation	500-Hour Exposure	1000-Hour Exposure	1500-Hour Exposure	2000-Hour Exposure
System C Chromated Control 1	2	2	2	1
System D	3	3	3	4
System H	5	4	4	3
System N	6	6	6	6
System O Chromated Control 2	1	1	1	2
System S	7	7	7	7
System T	4	5	5	5

Non-Chrome Systems Phase I Results

Overall Coating System Performance:

(Faying Surface in Contact with Titanium – Corrosion Rating)

C – 2nd

D – 6th

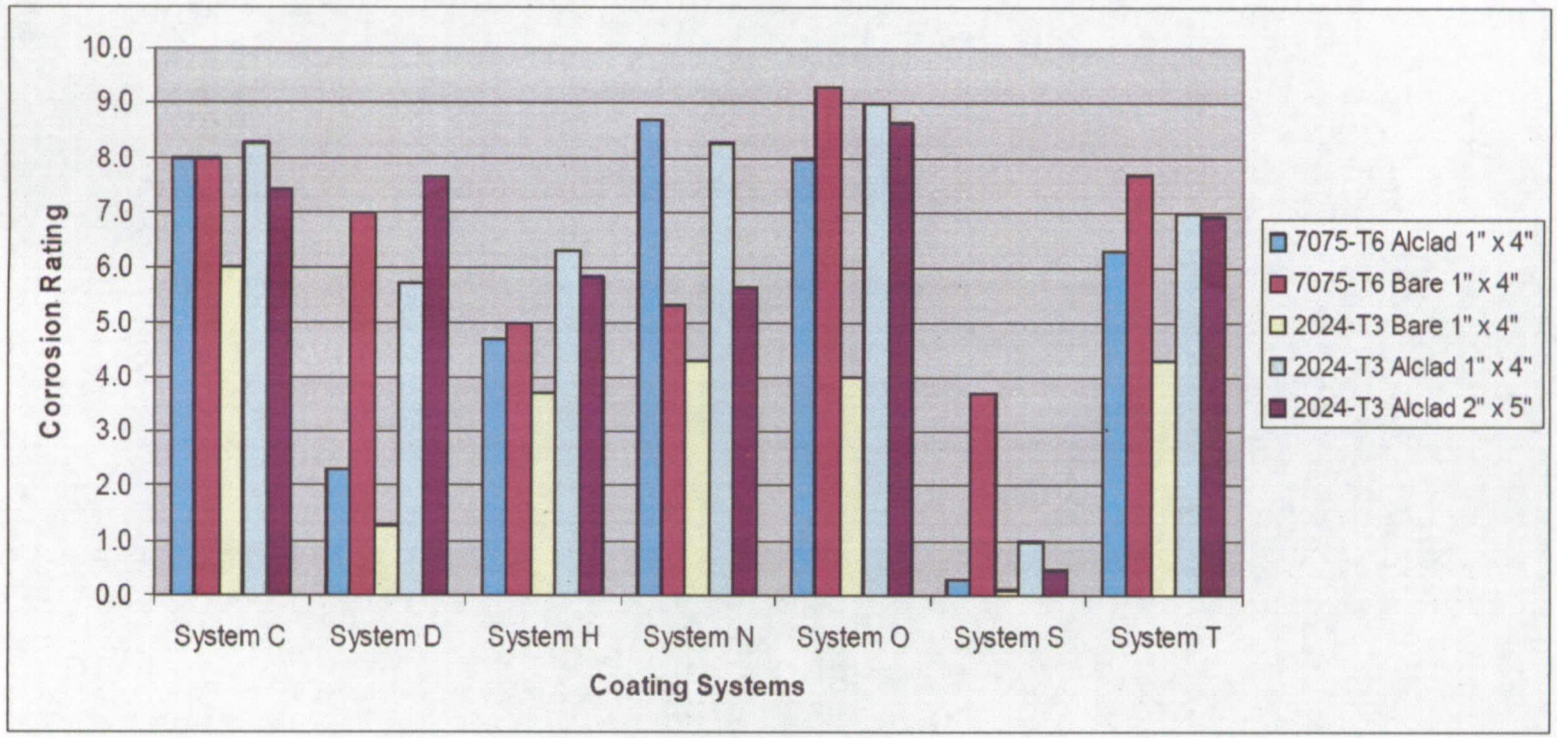
H – 5th

N – 3rd

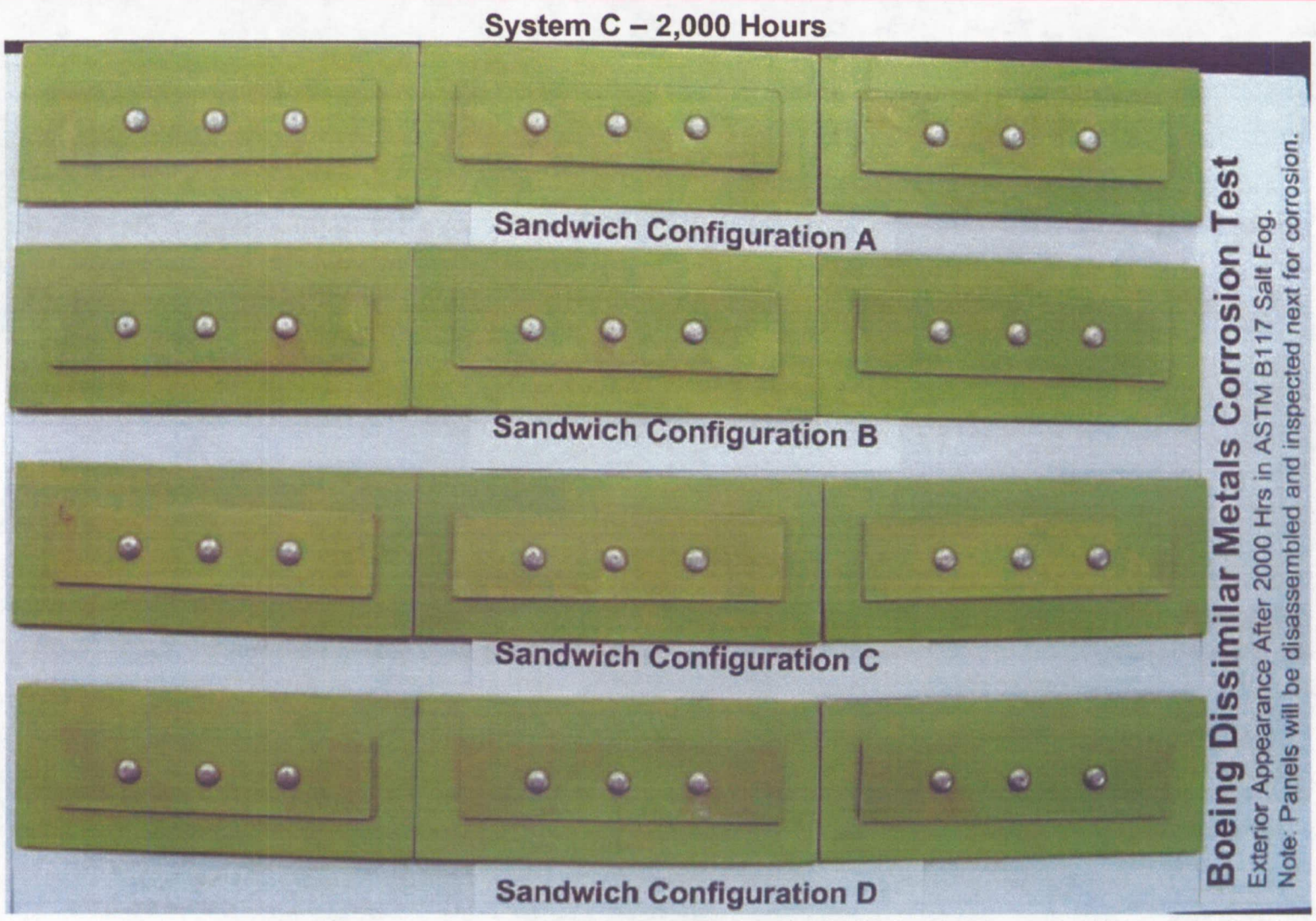
O – 1st

S – 7th

T – 4th

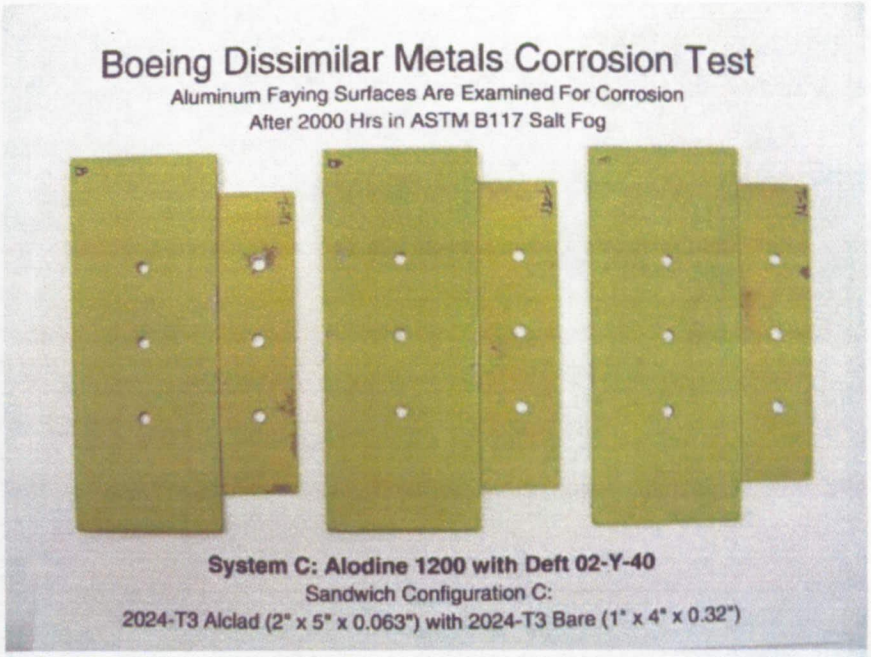


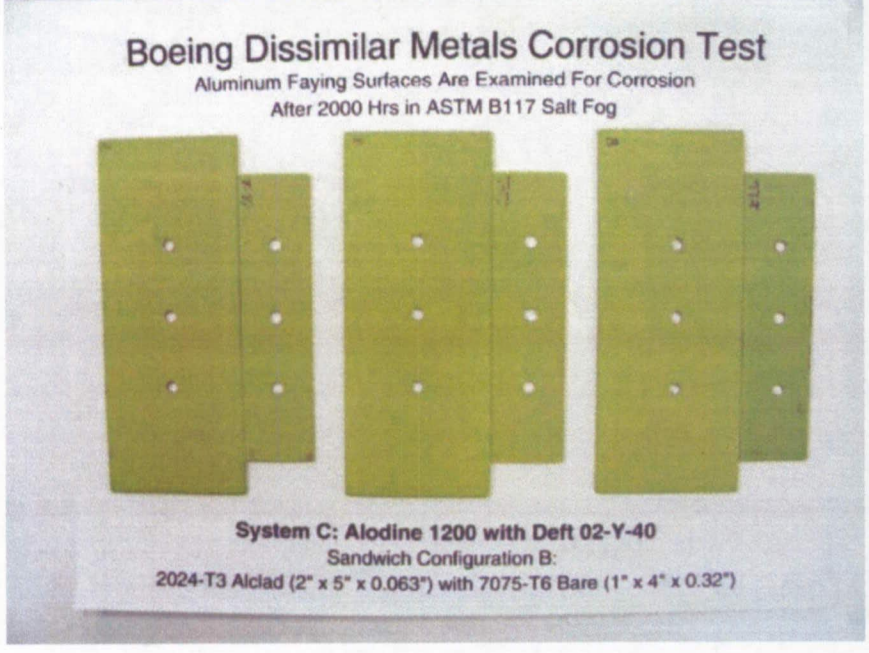
Non-Chrome Systems Phase I Results



System C


Boeing Dissimilar Metals Corrosion Test
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog
System C: Alodine 1200 with Deft 02-Y-40
Sandwich Configuration A:
2024-T3 Alclad (2" x 5" x 0.063") with 7075-T6 Alclad (1" x 4" x 0.32")

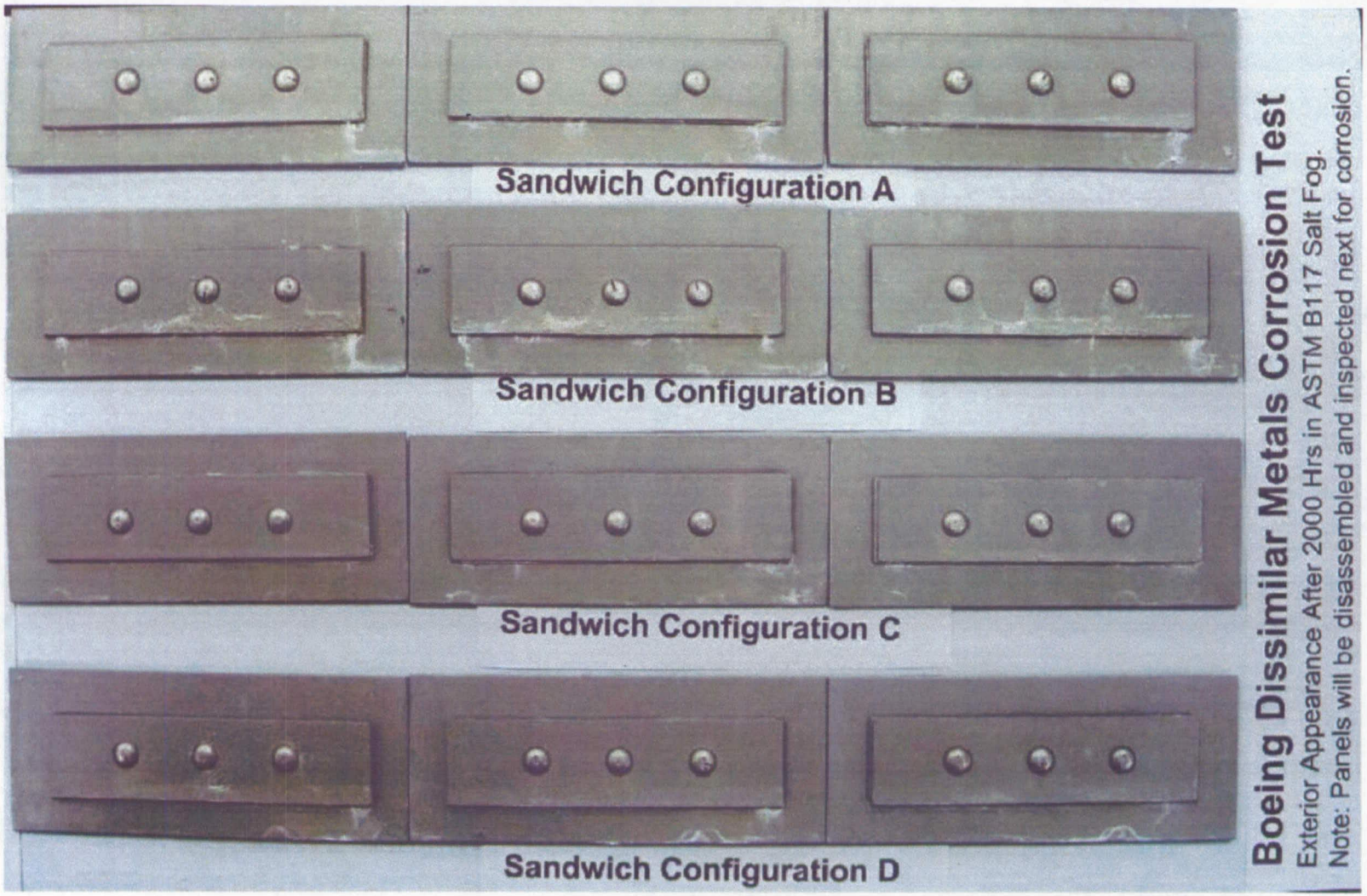

Boeing Dissimilar Metals Corrosion Test
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog
System C: Alodine 1200 with Deft 02-Y-40
Sandwich Configuration C:
2024-T3 Alclad (2" x 5" x 0.063") with 2024-T3 Bare (1" x 4" x 0.32")


Boeing Dissimilar Metals Corrosion Test
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog
System C: Alodine 1200 with Deft 02-Y-40
Sandwich Configuration B:
2024-T3 Alclad (2" x 5" x 0.063") with 7075-T6 Bare (1" x 4" x 0.32")


Boeing Dissimilar Metals Corrosion Test
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog
System C: Alodine 1200 with Deft 02-Y-40
Sandwich Configuration D:
2024-T3 Alclad (2" x 5" x 0.063") with 2024-T3 Alclad (1" x 4" x 0.32")

Non-Chrome Systems Phase I Results

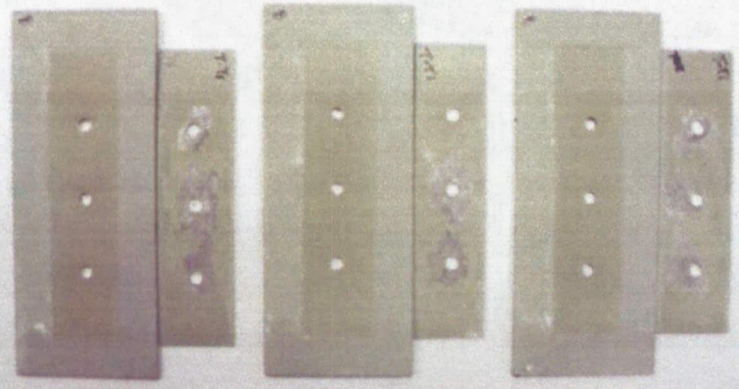
System D – 2,000 Hours



System D

Boeing Dissimilar Metals Corrosion Test

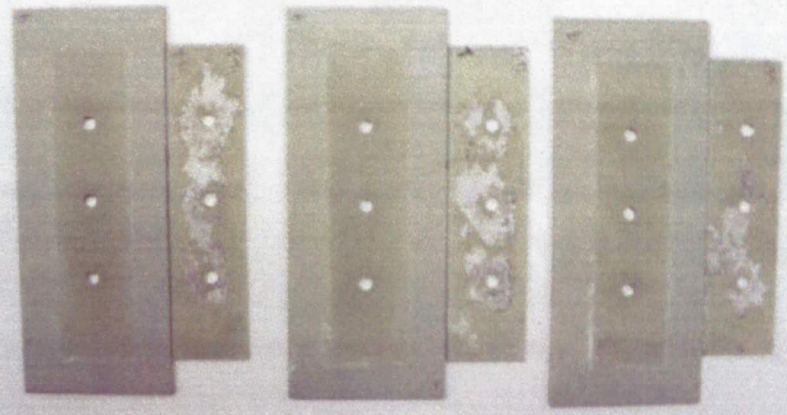
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog



System D: BoeGel EP-II with Dupont Corlan 13570S
Sandwich Configuration A:
2024-T3 Alclad (2" x 5" x 0.063") with 7075-T6 Alclad (1" x 4" x 0.32")

Boeing Dissimilar Metals Corrosion Test

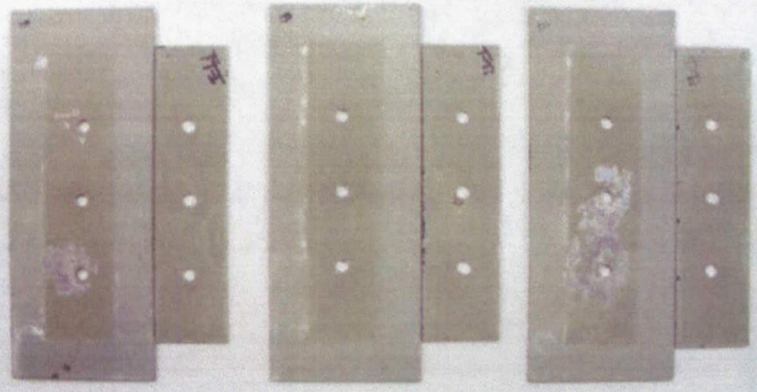
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog



System D: BoeGel EP-II with Dupont Corlan 13570S
Sandwich Configuration C:
2024-T3 Alclad (2" x 5" x 0.063") with 2024-T3 Bare (1" x 4" x 0.32")

Boeing Dissimilar Metals Corrosion Test

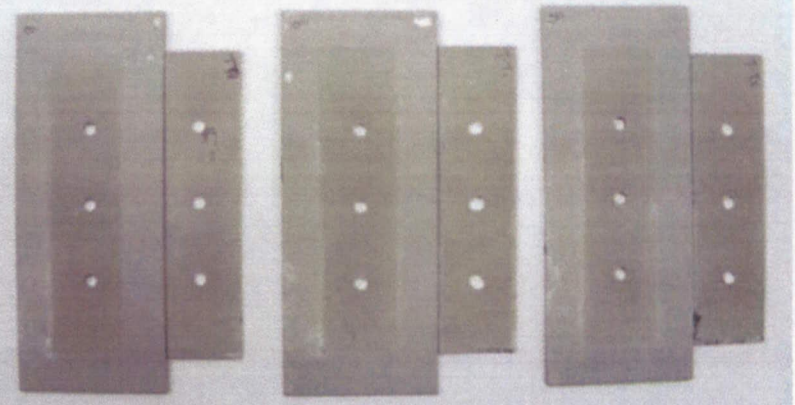
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog



System D: BoeGel EP-II with Dupont Corlan 13570S
Sandwich Configuration B:
2024-T3 Alclad (2" x 5" x 0.063") with 7075-T6 Bare (1" x 4" x 0.32")

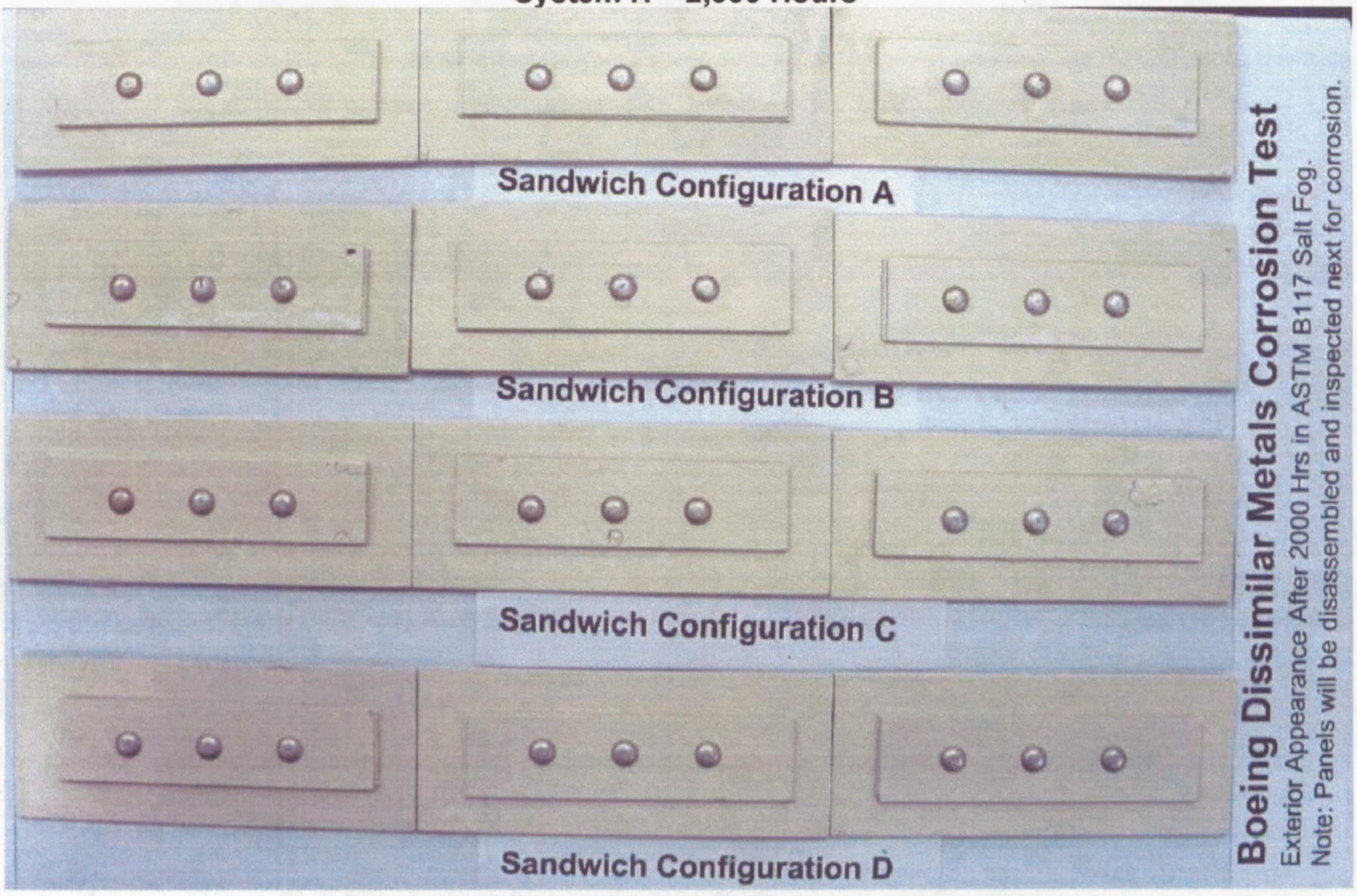
Boeing Dissimilar Metals Corrosion Test

Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog



System D: BoeGel EP-II with Dupont Corlan 13570S
Sandwich Configuration D:
2024-T3 Alclad (2" x 5" x 0.063") with 2024-T3 Alclad (1" x 4" x 0.32")

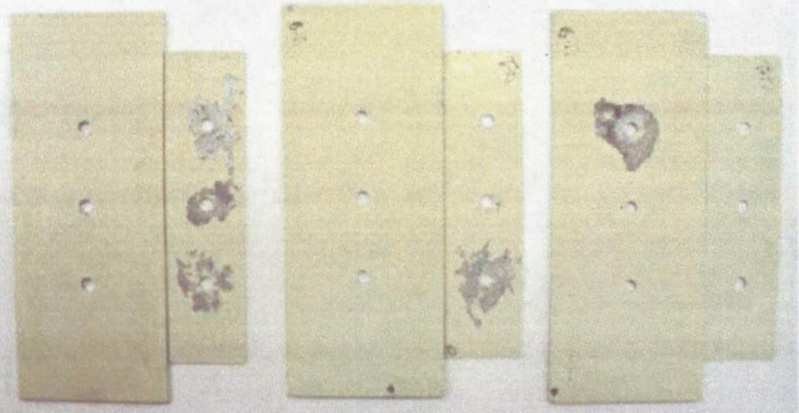
Non-Chrome Systems Phase I Results



System H

Boeing Dissimilar Metals Corrosion Test

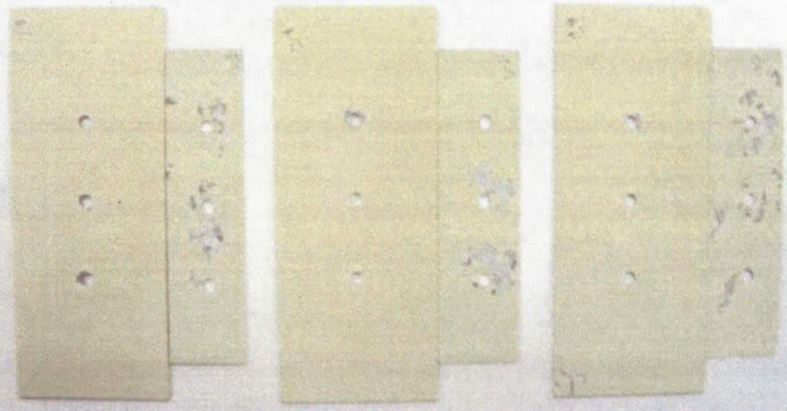
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog



System H: Alodine 5700 with Hentzen Primer 05510WEP-X
Sandwich Configuration A:
2024-T3 Alclad (2" x 5" x 0.063") with 7075-T6 Alclad (1" x 4" x 0.32")

Boeing Dissimilar Metals Corrosion Test

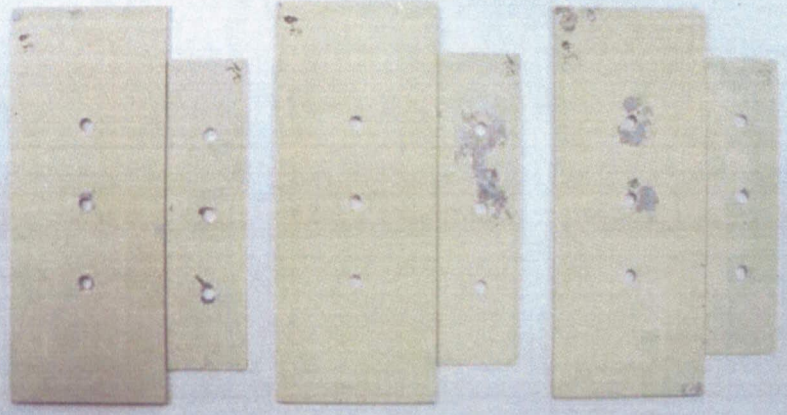
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog



System H: Alodine 5700 with Hentzen Primer 05510WEP-X
Sandwich Configuration C:
2024-T3 Alclad (2" x 5" x 0.063") with 2024-T3 Bare (1" x 4" x 0.32")

Boeing Dissimilar Metals Corrosion Test

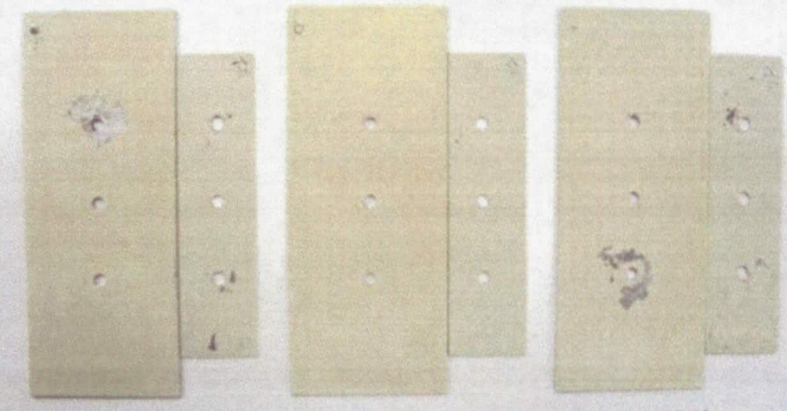
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog



System H: Alodine 5700 with Hentzen Primer 05510WEP-X
Sandwich Configuration B:
2024-T3 Alclad (2" x 5" x 0.063") with 7075-T6 Bare (1" x 4" x 0.32")

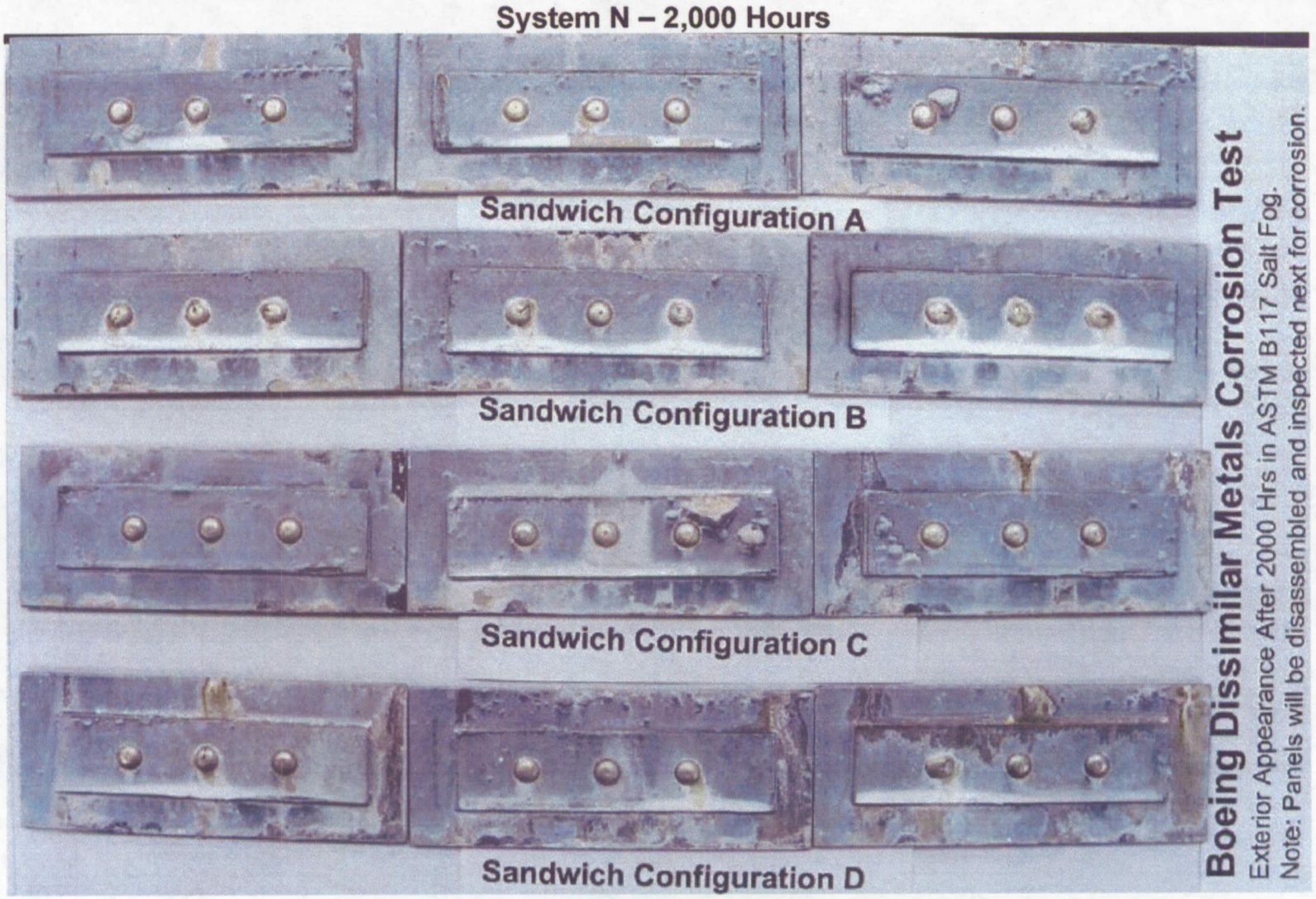
Boeing Dissimilar Metals Corrosion Test

Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog



System H: Alodine 5700 with Hentzen Primer 05510WEP-X
Sandwich Configuration D:
2024-T3 Alclad (2" x 5" x 0.063") with 2024-T3 Alclad (1" x 4" x 0.32")

Non-Chrome Systems Phase I Results



System N

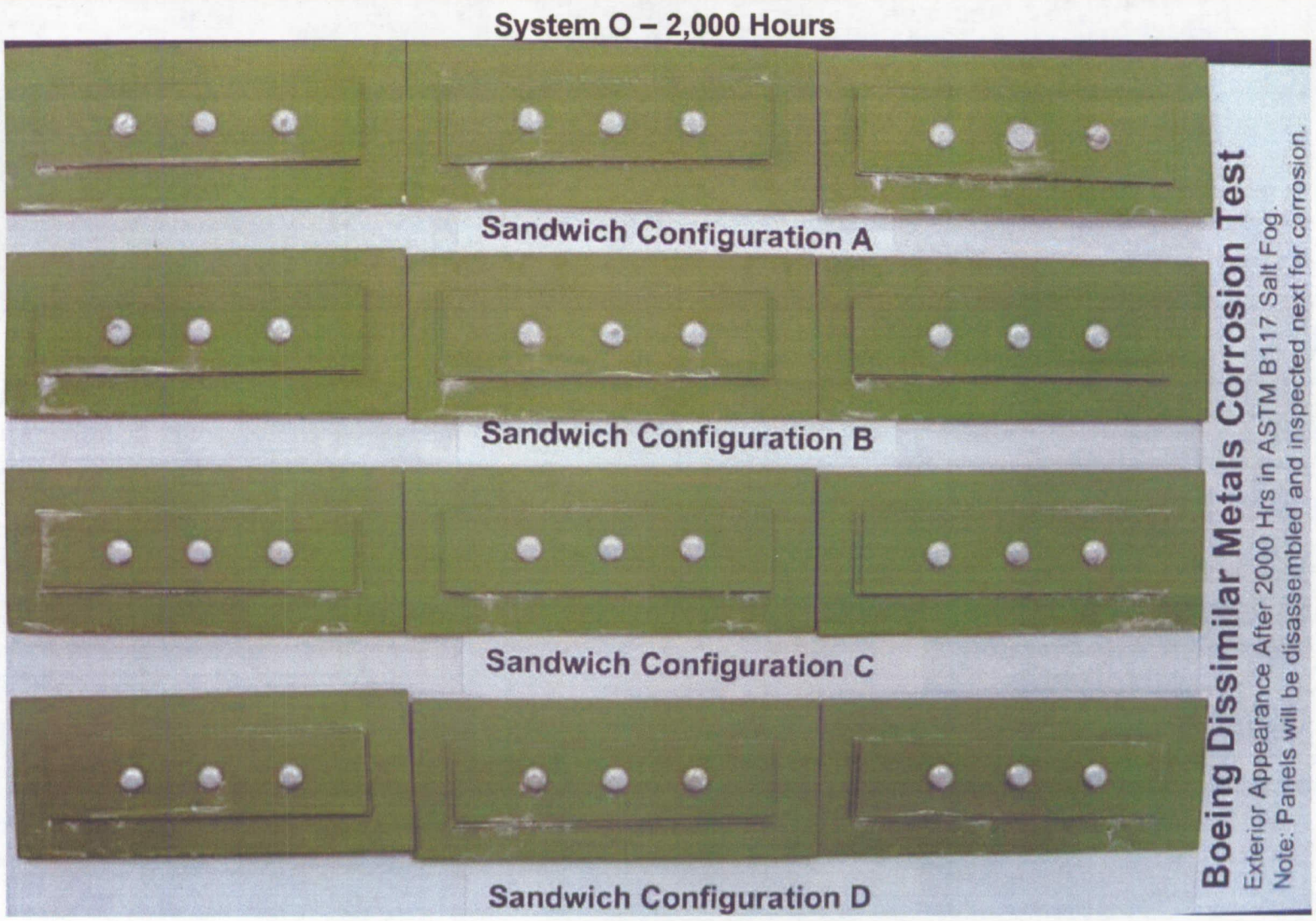

Boeing Dissimilar Metals Corrosion Test
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog
System N: Pre-Kote with Akzo Mg-Rich Primer
Sandwich Configuration A:
2024-T3 Alclad (2" x 5" x 0.063") with 7075-T6 Alclad (1" x 4" x 0.32")


Boeing Dissimilar Metals Corrosion Test
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog
System N: Pre-Kote with Akzo Mg-Rich Primer
Sandwich Configuration C:
2024-T3 Alclad (2" x 5" x 0.063") with 2024-T3 Bare (1" x 4" x 0.32")


Boeing Dissimilar Metals Corrosion Test
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog
System N: Pre-Kote with Akzo Mg-Rich Primer
Sandwich Configuration B:
2024-T3 Alclad (2" x 5" x 0.063") with 7075-T6 Bare (1" x 4" x 0.32")


Boeing Dissimilar Metals Corrosion Test
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog
System N: Pre-Kote with Akzo Mg-Rich Primer
Sandwich Configuration D:
2024-T3 Alclad (2" x 5" x 0.063") with 2024-T3 Alclad (1" x 4" x 0.32")

Non-Chrome Systems Phase I Results



System O


Boeing Dissimilar Metals Corrosion Test
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog
System O: Alodine 1200S with PPG Aerospace 515K012
Sandwich Configuration A:
2024-T3 Alclad (2" x 5" x 0.063") with 7075-T6 Alclad (1" x 4" x 0.32")

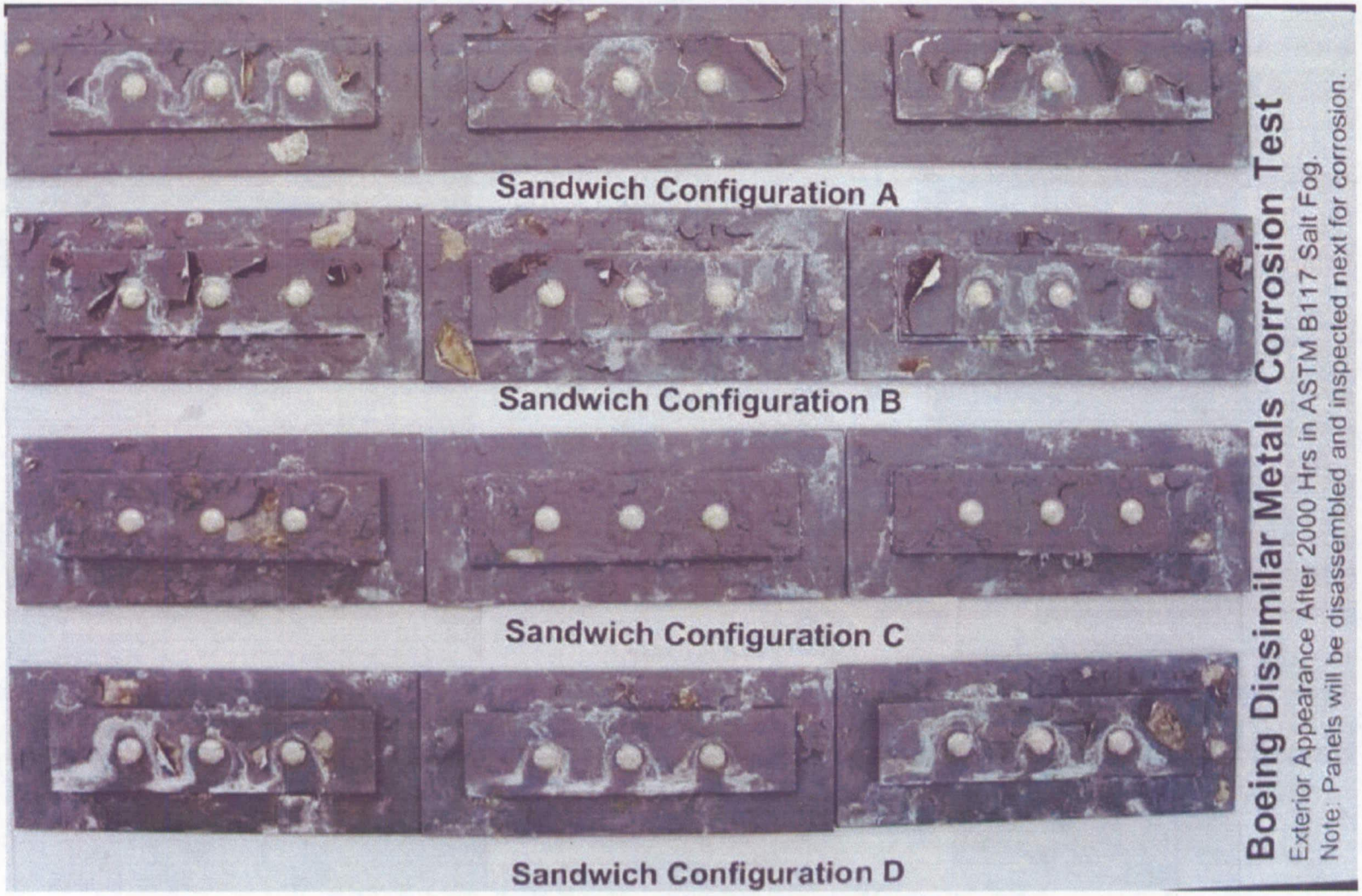

Boeing Dissimilar Metals Corrosion Test
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog
System O: Alodine 1200S with PPG Aerospace 515K012
Sandwich Configuration C:
2024-T3 Alclad (2" x 5" x 0.063") with 2024-T3 Bare (1" x 4" x 0.32")


Boeing Dissimilar Metals Corrosion Test
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog
System O: Alodine 1200S with PPG Aerospace 515K012
Sandwich Configuration B:
2024-T3 Alclad (2" x 5" x 0.063") with 7075-T6 Bare (1" x 4" x 0.32")


Boeing Dissimilar Metals Corrosion Test
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog
System O: Alodine 1200S with PPG Aerospace 515K012
Sandwich Configuration D:
2024-T3 Alclad (2" x 5" x 0.063") with 2024-T3 Alclad (1" x 4" x 0.32")

Non-Chrome Systems Phase I Results

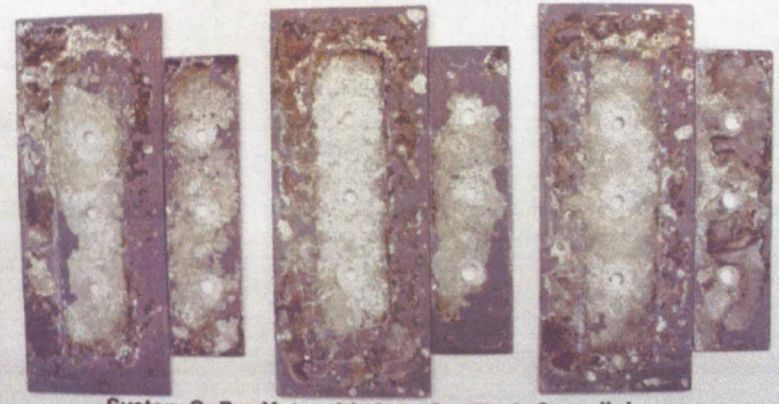
System S – 2,000 Hours



System S

Boeing Dissimilar Metals Corrosion Test

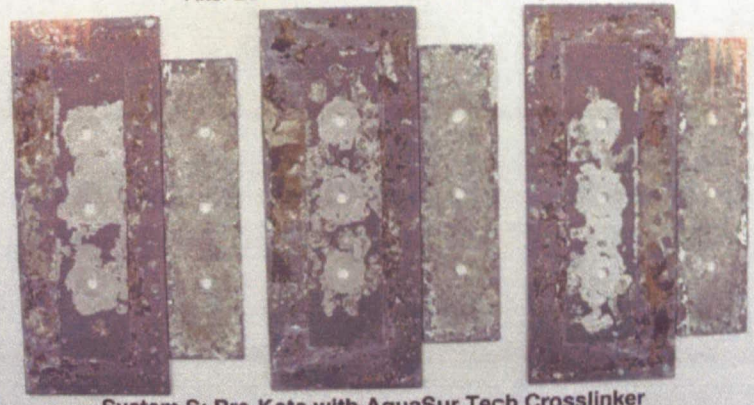
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog



System S: Pre-Kote with AquaSur Tech Crosslinker and AST-D45-AMS-MO
Sandwich Configuration A:
2024-T3 Alclad (2" x 5" x 0.063") with 7075-T6 Alclad (1" x 4" x 0.32")

Boeing Dissimilar Metals Corrosion Test

Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog



System S: Pre-Kote with AquaSur Tech Crosslinker and AST-D45-AMS-MO
Sandwich Configuration C:
2024-T3 Alclad (2" x 5" x 0.063") with 2024-T3 Bare (1" x 4" x 0.32")

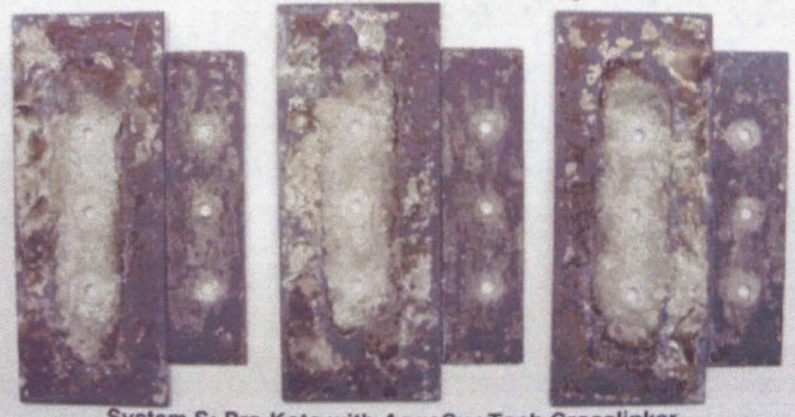
Boeing Dissimilar Metals Corrosion Test

Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog

System S: Pre-Kote with AquaSur Tech Crosslinker and AST-D45-AMS-MO
Sandwich Configuration B:
2024-T3 Alclad (2" x 5" x 0.063") with 7075-T6 Bare (1" x 4" x 0.32")

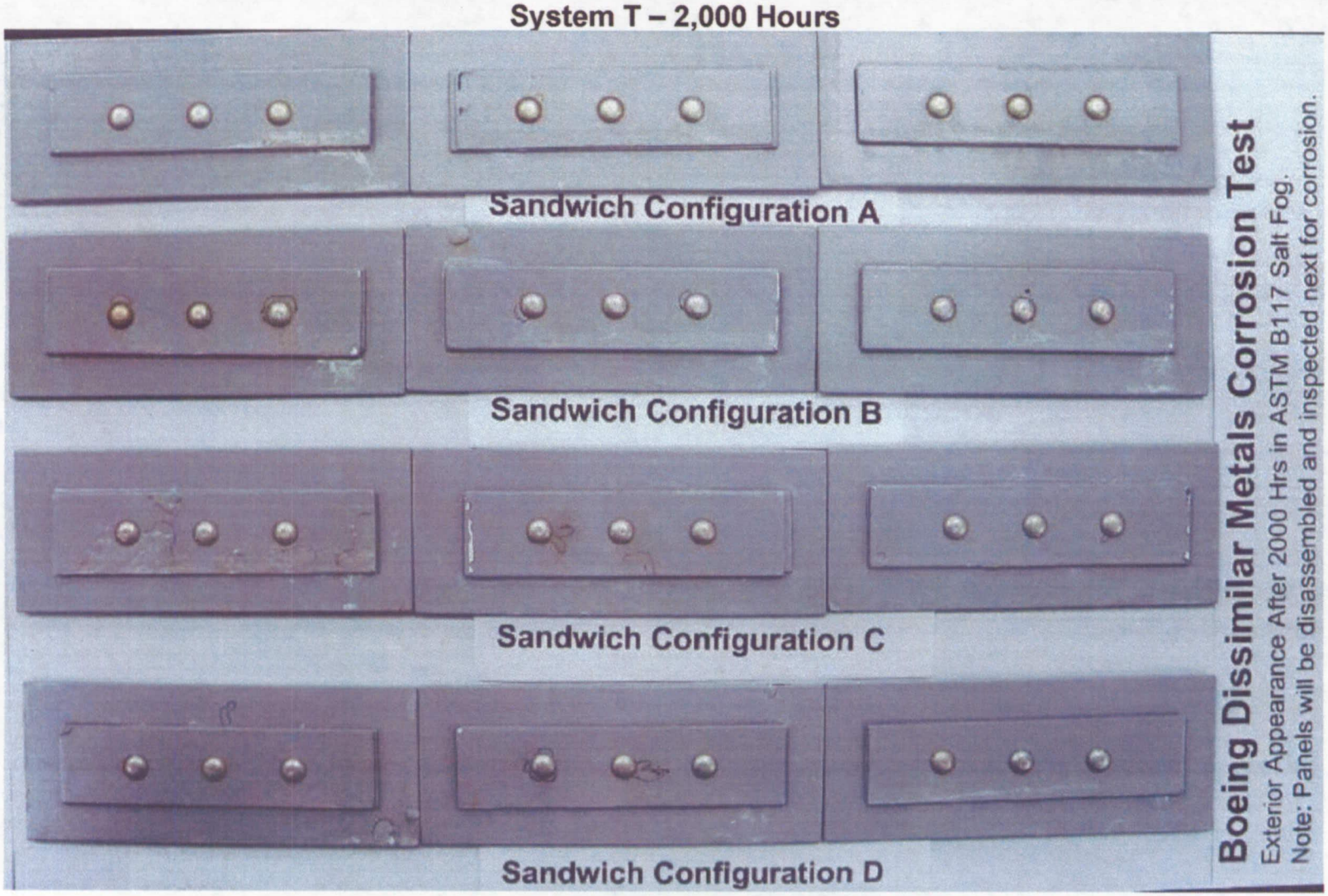
Boeing Dissimilar Metals Corrosion Test

Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog



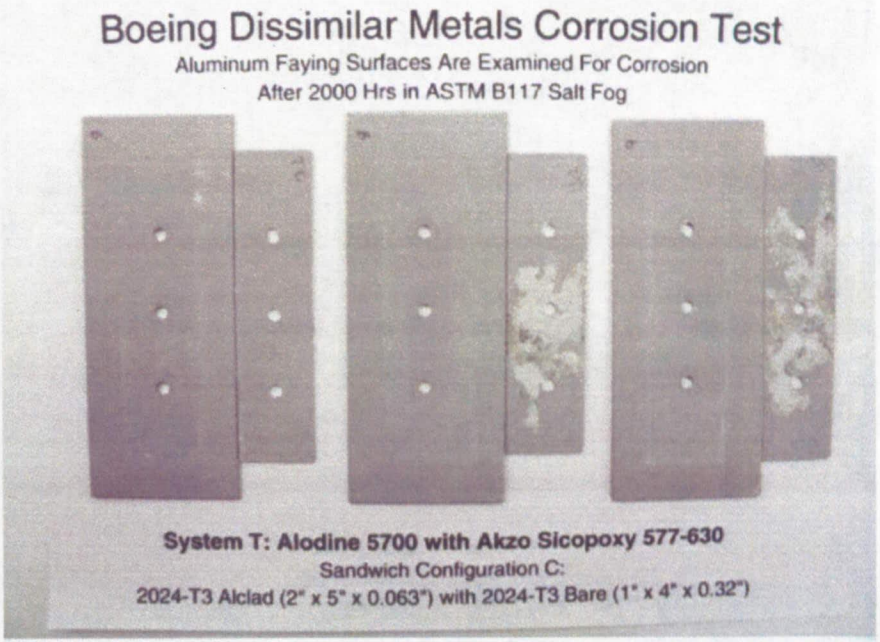
System S: Pre-Kote with AquaSur Tech Crosslinker and AST-D45-AMS-MO
Sandwich Configuration D:
2024-T3 Alclad (2" x 5" x 0.063") with 2024-T3 Alclad (1" x 4" x 0.32")

Non-Chrome Systems Phase I Results



System T


Boeing Dissimilar Metals Corrosion Test
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog
System T: Alodine 5700 with Akzo Sicopoxy 577-630
Sandwich Configuration A:
2024-T3 Alclad (2" x 5" x 0.063") with 7075-T6 Alclad (1" x 4" x 0.32")


Boeing Dissimilar Metals Corrosion Test
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog
System T: Alodine 5700 with Akzo Sicopoxy 577-630
Sandwich Configuration C:
2024-T3 Alclad (2" x 5" x 0.063") with 2024-T3 Bare (1" x 4" x 0.32")


Boeing Dissimilar Metals Corrosion Test
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog
System T: Alodine 5700 with Akzo Sicopoxy 577-630
Sandwich Configuration B:
2024-T3 Alclad (2" x 5" x 0.063") with 7075-T6 Bare (1" x 4" x 0.32")


Boeing Dissimilar Metals Corrosion Test
Aluminum Faying Surfaces Are Examined For Corrosion
After 2000 Hrs in ASTM B117 Salt Fog
System T: Alodine 5700 with Akzo Sicopoxy 577-630
Sandwich Configuration D:
2024-T3 Alclad (2" x 5" x 0.063") with 2024-T3 Alclad (1" x 4" x 0.32")

Non-Chrome Systems Phase I Results

Sandwich Corrosion (Dissimilar Metals)

- Two non-chrome coating systems outperformed the others on faying surfaces in this study.
- They were System N (Pantheon Pre-Kote with Akzo Mg-Rich Primer) and System T (Henkel Alodine 5700 with Akzo Sicopoxy 577-630 Primer).
- System N experienced a blistering problem in direct salt fog, which may indicate it requires a supplemental topcoat.
- Further testing is recommended to investigate possible synergistic effects between surface treatments and primers to identify a non-chrome coating system capable of widespread use in aircraft and aerospace applications.

Systems Recommended for Future Study

Surface Treatment	Primer
Pantheon PreKote	Akzo Mg-Rich Primer
Henkel Alodine 5700	Akzo Mg-Rich Primer
BoeGel EP-II (AC-131-CB)	Akzo Mg-Rich Primer
MIL-A-8625 Type IIB or BSAA	Akzo Mg-Rich Primer
Pantheon PreKote	Akzo Sicopoxy 577-630
Henkel Alodine 5700	Akzo Sicopoxy 577-630
BoeGel EP-II (AC-131-CB)	Akzo Sicopoxy 577-630
MIL-A-8625 Type IIB or BSAA	Akzo Sicopoxy 577-630

Non-Chrome Systems Phase I Results

Hydrogen Embrittlement – System N (Mg Rich) Only

Hydrogen Embrittlement Test Results

Serial Number	Relief Bake	Date on Test	Hours at Load	Pass/Fail ASTM F 519
AU0574	24 hrs. at 375° F	5-Oct-07	314.9	Pass
AU0705	24 hrs. at 375° F	5-Oct-07	314.9	Pass
AU0838	24 hrs. at 375° F	5-Oct-07	314.9	Pass
AU0558	24 hrs. at 375° F	5-Oct-07	314.9	Pass
AU0645	None	5-Oct-07	314.9	Pass
AU0752	None	5-Oct-07	314.9	Pass
AU0735	None	5-Oct-07	314.9	Pass
AU0569	None	5-Oct-07	314.9	Pass

Non-Chrome Systems Phase I Results

Salt Fog

1,500 Hours - Full System

System D		
Status	Substrate	Comments
Fail	2219	Pitting out 1900Hrs
Fail	2024 T3	Pitting
OK	2024 T3 Clad	
Fail	7075 T6	Pitting
OK	6061 T6	

System H		
Status	Substrate	Comments
Pass	2219	
Pass	2024 T3	
Pass	2024 T3 Clad	Minor pitting
Pass	7075 T6	Minor pitting
Pass	6061 T6	

System T		
Status	Substrate	Comments
Pass	2219	
Pass	2024 T3	
Pass	2024 T3 Clad	
Pass	7075 T6	Minor pitting
Pass	6061 T6	

System N		
Status	Substrate	Comments
Pass	2219	
Pass	2024 T3	
Pass	2024 T3 Clad	
Pass	7075 T6	
Pass	6061 T6	

System C		
Status	Substrate	Comments
Pass	2219	
Pass	2024 T3	
Pass	2024 T3 Clad	
Pass	7075 T6	
Pass	6061 T6	

System S		
Status	Substrate	Comments
Fail	2219	< 500 Hrs
Fail	2024 T3	< 500 Hrs
Fail	2024 T3 Clad	< 500 Hrs
Fail	7075 T6	< 500 Hrs
Fail	6061 T6	< 500 Hrs

1,500 Hours - No Topcoat

System D		
Status	Substrate	Comments
Fail	2219	Pitting
Fail	2024 T3	Pitting
OK	2024 T3 Clad	
Fail	7075 T6	Pitting
OK	6061 T6	

System H		
Status	Substrate	Comments
Pass	2219	
Pass	2024 T3	
Pass	2024 T3 Clad	
Pass	7075 T6	
Pass	6061 T6	

System T		
Status	Substrate	Comments
Pass	2219	
Pass	2024 T3	
Pass	2024 T3 Clad	
Pass	7075 T6	Minor pitting
Pass	6061 T6	

System N		
Status	Substrate	Comments
Fail	2219	
Pass	2024 T3	Minor pitting
Pass	2024 T3 Clad	
Pass	7075 T6	Minor pitting
Pass	6061 T6	

System C		
Status	Substrate	Comments
Pass	2219	
Pass	2024 T3	
Pass	2024 T3 Clad	
Pass	7075 T6	
Pass	6061 T6	

System S		
Status	Substrate	Comments
Fail	2219	< 500 Hrs
Fail	2024 T3	< 500 Hrs
Fail	2024 T3 Clad	< 500 Hrs
Fail	7075 T6	< 500 Hrs
Fail	6061 T6	< 500 Hrs

Non-Chrome Systems Phase I Results

Salt Fog

2,000 Hours - Full System

System D

Status	Substrate	Comments
Fail	2219	1900hours
Fail	2024 T3	1500 hours
OK	2024 T3 Clad	Pits in Scribe
Fail	7075 T6	1500 hours
OK	6061 T6	Pass

System H

Status	Substrate	Comments
Pass	2219	Pass
Pass	2024 T3	Pits in scribe
Pass	2024 T3 Clad	Pits in scribe
Fail	7075 T6	Lifting /Pits in scribe
Pass	6061 T6	Lifting

System T

Status	Substrate	Comments
Pass	2219	Pits in Scribe
Pass	2024 T3	Pits in Scribe
Pass	2024 T3 Clad	Pits in Scribe
Pass	7075 T6	Lifting/Pits in scribe
Pass	6061 T6	good

System N

Status	Substrate	Comments
Pass	2219	Minor pitting in scribe
Pass	2024 T3	good
Pass	2024 T3 Clad	Minor pitting in scribe
Pass	7075 T6	Minor pitting in scribe
Pass	6061 T6	good

System C

Status	Substrate	Comments
Pass	2219	good
Pass	2024 T3	good
Pass	2024 T3 Clad	good
Pass	7075 T6	good
Pass	6061 T6	good

System S

Status	Substrate	Comments
Eliminated after 500 Hrs		

2,000 Hours - No Topcoat

System D

Status	Substrate	Comments
Fail	2219	1500 hours
Fail	2024 T3	1500 hours
OK	2024 T3 Clad	Pits in Scribe
Fail	7075 T6	1500 hours
OK	6061 T6	Pass

System H

Status	Substrate	Comments
Pass	2219	Pits in scribe
Pass	2024 T3	Pits in scribe
Pass	2024 T3 Clad	Good
Pass	7075 T6	Lifting /Pits in scribe
Pass	6061 T6	Good

System T

Status	Substrate	Comments
Pass	2219	Pits in Scribe
Pass	2024 T3	Pits in Scribe
Pass	2024 T3 Clad	Good
Pass	7075 T6	Lifting
Pass	6061 T6	Good

System N

Status	Substrate	Comments
Fail	2219	1500 hours
Pass	2024 T3	surface pits
Pass	2024 T3 Clad	Good
Pass	7075 T6	surface pits
Pass	6061 T6	Good

System C

Status	Substrate	Comments
Pass	2219	Good
Pass	2024 T3	Good
Pass	2024 T3 Clad	Good
Pass	7075 T6	Good
Pass	6061 T6	Good

System S

Status	Substrate	Comments
Eliminated after 500 Hrs		

Non-Chrome Systems Phase I Results

Adhesion Testing

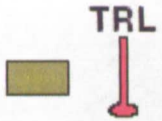
Adhesion Results

System D		System H		System T	
PSI	Comments	PSI	Comments	PSI	Comments
1576	Average	N/A	Anomalous Result	N/A	Anomalous Result
1559	Median	N/A	Anomalous Result	N/A	Anomalous Result
363	Stdev	N/A	Anomalous Result	N/A	Anomalous Result

System N		System C		System S	
PSI	Comments	PSI	Comments	PSI	Comments
1572	Average	1650	Average	Not Tested	
1559	Median	1682	Median		
390	Stdev	345	Stdev		

** Failures of H and T were below recordable PSI ranges and occurred at the Pretreament / Substrate Interface*

*** System H results do not agree with USA / SRB Qualification Testing of Identical Coatings (> 1400 PSI)*



Alternatives to High-VOC Chrome Coatings

(Slide 1 of 2)

Description:

•Demonstrate low-VOC and non-chrome coating systems on Portuguese commercial aircraft

•The identification/qualification of hex-chrome free coating systems is a Portuguese priority due to national & European safety and environmental regulations.

Stakeholders:

•TAP Air Portugal, OGMA (Indústria Aeronáutica de Portugal), C3P, and NASA TEERM.

Benefits:

• Reduced materials obsolescence risk if non-chrome paint system can be qualified for aerospace

• Decreased costs associated with environmental and occupational health/safety regulations.

Achievements:

•Visual inspections appeared favorable with no visual signs of deterioration in thickness or color. Final inspection took place on June 24, 2007 (2 Years, 8 Months in Service)

• System P passed all tests – (PreKote SP, Aviox CF Primer, Aviox Finish 77702).

• System M did not pass all tests – (Akzo Nobel M790E, Aviox CF Primer, Aviox Finish 77702).

Future Plans:

• Findings from door being flight tested may be transferable to new (Ph. 2) TEERM Non-Chrome Coating Systems for Aerospace project (includes DoD stakeholders)

• Leverage data of laboratory testing for new (Ph. 2) TEERM Non-Chrome Coating Systems for Aerospace project (includes DoD Stakeholders)

• Incorporate applicable test data in TEERM Non-Chrome Systems Project Phase 1 Report.

International Non-Chrome Project

Coating Systems Tested

P System	M System
PreKote SP Aviox CF Primer Aviox Finish 77702	M790E Aviox CF Primer Aviox Finish 77702

System M – Failed Some Critical Tests

System P – Passed all Tests

***(Limited corrosion observed in some P test panels, but considered acceptable for TAP)**

International Non-Chrome Project

- Laboratory Testing (AMS 3095):
  - Gloss, Initial Color (ISO 2813)
  - Adhesion - Cross Hatch (ISO 7724; AMS 3095 5.3)
  - Reverse Impact (ISO 6272)
  - Flexibility – Conical Mandrel (ISO 6860)
  - Flexibility – Cylindrical Mandrel (ISO 1519)
  - Water
    - Blister (ISO 4628)
    - Grade (ISO 2409)
    - Penetration (ISO 1518)
  - Fluid Resistance (ISO 1518)
  - Filiform Corrosion (EN 3665)
  - Salt Spray Corrosion (3,000 Hrs) (ISO 7253)
  - Artificial Weathering (ISO 2813; ISO 7724)
  - Washability (ISO 2813)
  - Stripability (AMS 3095 5.4)
  - Restoration (AMS 3095 5.5)
  - Heat Stability (ISO 1519; ISO 3270)

- Field Testing:
  - Airbus A319 Service Door – (2 Years, 8 Months in Service)
  - Thickness and Gloss Tests
  - Visual Inspection for Signs of Corrosion

Results:

- After completing testing, System P passed all tests acceptably
- Numerous failures were seen in System M during testing
- Testing on the Airbus A380 door showed both systems performed well and passed visual inspections. The last inspection was performed 2 years and 8 months after the application of coating systems.
- Although some corrosion was seen on all test panels during Salt-Spray testing, System P performed well and was considered passing for 1,000 and 2,000 hour inspections.
- **Implementation Note:** TAP only performs refurbishment of coatings, leaving some primer and pre-treatment behind when preparing aircraft for new coatings. The OEM sill uses chromated coatings, so TAP will benefit from the presence of this with any implemented coating system.

Test	Test Method	Conditioning	Test Site	System M	System P
Gloss	ISO 2813	ISO 3270	NASA	Pass	Pass
Initital Color	ISO 7724 AMS 3095 5.3	ISO 3270	NASA	Pass	Pass
Adhesion - Cross Hatch	ISO 2409	ISO 3270	ISQ	Failures	Pass
Impact (reverse)	ISO 6272	ISO 3270	ISQ	Failures	Pass
Flexibility - Conical Mandrel	ISO 6860	ISO 3270	ISQ	Failures	Pass
Flexibility - Cylindrical Mandrel	ISO 1519	-	NASA	Pass	Pass
Water		ISO 2812-1 Method 1	ISQ	Failures	Pass
a) Blistering	ISO 4628.5				
b) Grade	ISO 2409				
c) Penetration	ISO 1518				
Hydraulic Fluid Resistance	ISO 1518	ISO 2812-1 Method 1	ISQ	Pass	Pass
Corrosion Resistance - Filiform	EN 3665 1000 hours	EN 3655	ISQ	Pass	Pass
Corrosion Resistance - Salt Spray	ISO 7253 3000 hours	ISO 7253	ISQ	Failures	Acceptable
Artificial Weathering	ISO 2813 ISO 7724	ISO 11570	NASA	Pass	Pass
Washability (cleaning effeciency)	ISO 2813 60° meter	MIL-PRF-85285	ISQ	Pass	Pass
Strippability	AMS 3095 5.4	-	ISQ	Pass	Pass
Restoration	AMS 3095 5.4	-	Repeat all tests	Failures	Pass
Heat Stability	ISO 1519 ISO 3270	-	NASA	Failures	Pass


NASA

Non-Chrome Systems Phase II
Draft Test Plan

Potential Alternatives for Phase II - Systems H, N, T, P from Phase I

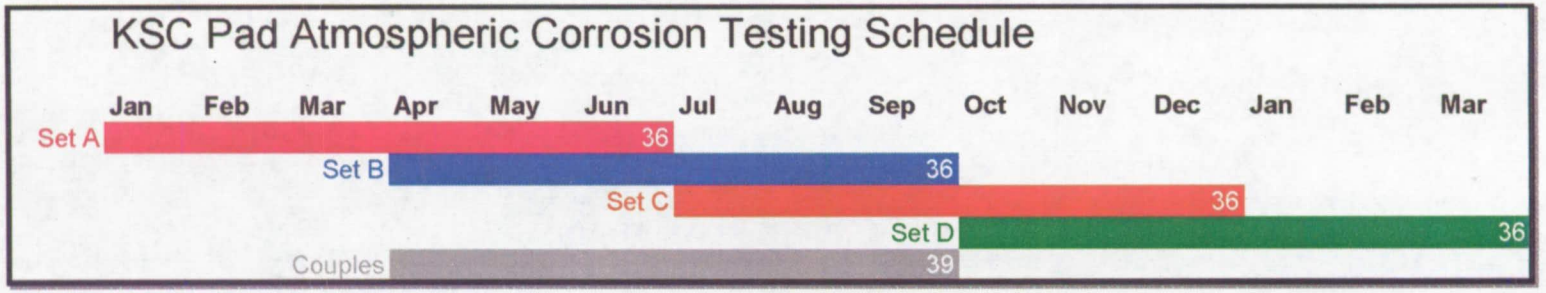
- **Pretreatments:**
  - Alodine 5200/5700
  - Prekote
  - TCP HF
  - TCP HF/EPA
  - VpCI-440
- **Topcoats:**
  - TBD
- **Primers:**
  - Hentzen 05510WEP-X / 05511CEH-X
  - Mg Rich Primer (AeroDur 2100)
  - Sicopoxy 577-630
  - Aviox CF Primer
  - Deft 098 (Waterborne)
  - Deft 084 (High Solid)
  - Hentzen 16708TEP / 16709CEH
  - Hentzen 7176KEP / 16709CEH
  - VpCI-373

Non-Chrome Systems Phase II
Draft Test Plan

- **Repeat some Phase I Testing (2,000+Hrs Salt-Fog, Adhesion) for newly considered systems** (on AA2195, AA2219, AA7075, Potentially Others):
  - CorTec - VpCI-440 Pretreat, + VpCI-373 wash primer + Topcoat
  - Mg-Rich – Akzo Nobel Commercial Version
  - Electro Active Polymer (BAM-PPV)

- **Phase II Tests:**
  - 18 Month Beach Exposure Testing
  - 15-18 Month Corrosion Rate Testing (Pad + Beach)
  - 6 Month Galvanic Couple Corrosion Rate Testing (Pad + Beach)
  - 15-18 Month – 4 or 5 Phase Pad Exposure Testing (1-4 Coatings)
  - 6 Month Galvanic Couple Pad Exposure Testing (1-4 Coatings)
  - 168 Hour Bare Corrosion Resistance (Pretreatments) 6061-T6

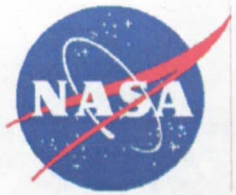
Concurrent Corrosion Study

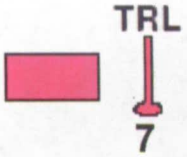


- **Aluminum Substrates**
  - 2195
  - 2024
  - 2219
  - 2014
  - 6061
  - 7075
  - 7050

- **Steel Substrates:**
  - 4340 or D6ac
  - A286
  - 304SS
  - 1080
  - PH17-4

- **Couples**
  - A286 with 7075/2219/6061/2195
  - 4340 (or D6ac) with 6061/7075/2195/7050
  - 304 SS with 6061/7075/2219/2195/2024


NASA



Non-Chrome Coating Systems for Electrical Housings (NASA-DoD)

(Part of Non-Chrome Systems Phase II Testing)

Description:

- Evaluation and testing of non-chromated coating systems as replacements for hexavalent chrome coatings used on electronics housings
- Manufacturers of electronic housings for commercial products are known to be implementing chrome-free coating systems
- Current hexavalent chromium permission exposure limit (PEL) is forcing electronics manufacturers to evaluate chrome-free coatings, it is not known whether the commercial chrome-free coatings will suffice in harsh military/aerospace environments.

Stakeholders:

- NASA KSC, JPL, MSFC, JSC, GSFC, ARC, USA-SRB, Boeing-Orbiter
- Air Force, Army, Navy, Marines, Dept. of Energy
- More than 25 manufacturers and vendors.

Benefits:

- Meet EPA and OSHA requirements
- Meet European RoHS requirements
- Reduced hazardous materials associated with electronics equipment
- Some of the chrome-free coating systems being tested in NASA TEERM projects may also have promise as a replacement, testing of the chrome-free coatings to military/aerospace specs will address concerns about the viability of these coatings
- If implemented, chrome-free coating systems on electronic housings will greatly reduce chromium emissions and waste generation from manufacturing and repair site.

Achievements:

- Identified potential project stakeholders and their requirements
- Project requirements survey and materials identification form sent out.

Future Plans:

- Incorporate testing for this effort into Phase II testing for Non-Chrome Systems Project.


NASA

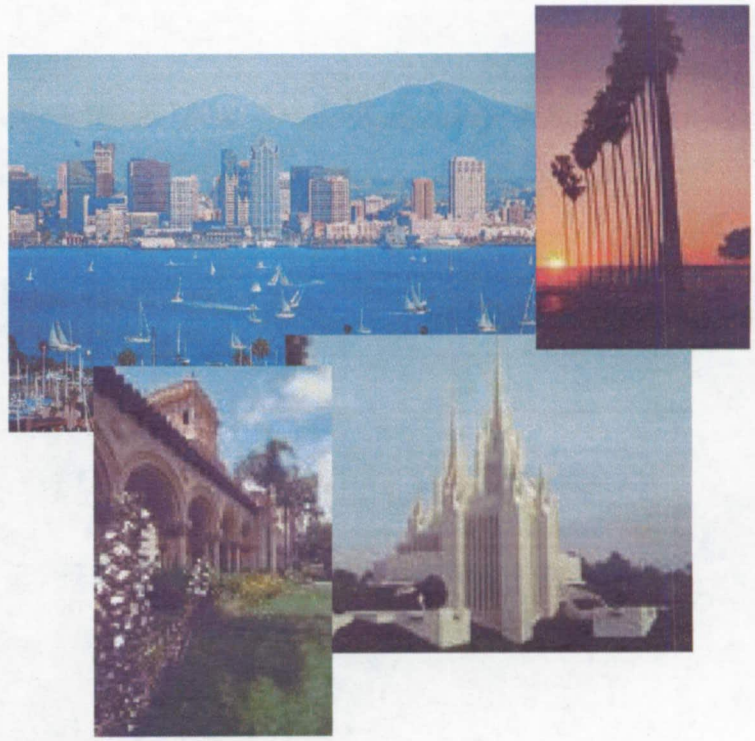
2007 NASA-C3P JOG and P2 Workshop

- November 7-9, 2007
- Peniche, Portugal
  - NASA TEERM co-sponsored a 3-day workshop
  - 243 individuals from 8 countries
  - over 45 speakers
  - Keynote Address from Ms. Olga Dominguez, Assistant Administrator for the Office of Infrastructure and Administration and Dr. Patrick Simpkins, Director of Engineering at KSC
  - New POCs and potential collaboration opportunities

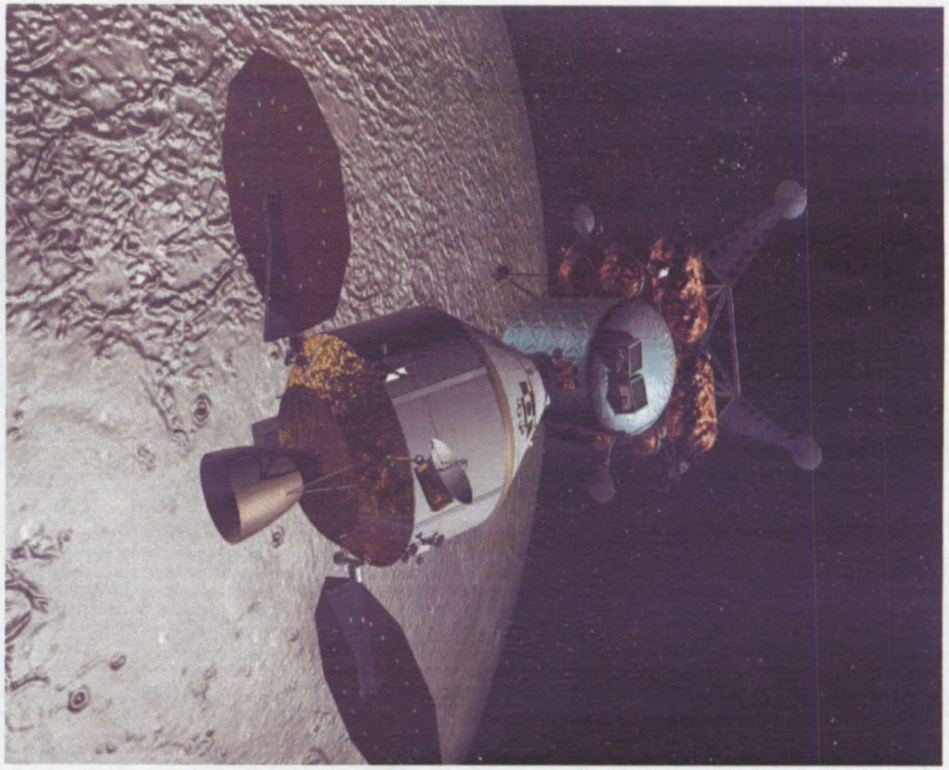
2008 NASA-C3P P2 Workshop

Plans

- ***Location:*** San Diego, CA
- ***Date:*** November 18-20, 2008
- **Potential topics:**
  - Eliminating hexavalent chrome in coating systems
  - Less toxic surface treatment processes
  - Bio-based materials
  - Lead-free electronics
  - De-painting/coating removal
  - Low HAPs/VOC cleaning/degreasing
  - Sustainable corrosion protection
  - Emerging contaminants and options



NASA TEERM Principal Center



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