

C-5 Corrosion Prevention and Control Program Evaluation Plan

ASTM B117 Salt Spray (Fog) Apparatus Evaluation of Inhibited Surface Adhesion Promoter iSAP 311™ and iSAP 311T™

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Cleared for Distribution A:

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**University of Dayton
Research Institute**

Overview

- Problem Statement
- Order of Test
- Coupon Manufacture
- Project Matrix
- Pretreatment Results
- Compare of Pretreatment Results
- Creepage Results
- Optical Profilometry – Surface Roughness and Pit Depth
- Future Evaluations
- Conclusion

Problem Statement

- The Under Secretary of Defense (War) directed military departments to aggressively mitigate risks posed by Hexavalent Chromium (Cr^6) to DoD (DoW) operations
- To reduce and or eliminate the use of Cr^6 where feasible, many product evaluations have been unsuccessful in identifying corrosion inhibited pretreatments and/or non-chrome coatings that perform as well or better than legacy coatings previously utilized on the Outer Mold Line (OML) surfaces of the C-5 aircraft
- The current pretreatment process, known as PreKote[®], is a chrome-free adhesion promoter chosen to replace the legacy chromated Alodine 1200 in 2010; however, its performance has not reduced corrosion

C-5 Legacy Coating

- C-5 Coating Stack-Up
 - Pretreatment – Vantage iSAP 311
 - Primer – Meets MIL-PRF-23377 Type I, Class C2 – PPG 02Y040
 - Top Coat – Meets MIL-PRF-85285 Type IV – PPG 99GY001

Order of Test

- Test Sulfuric Acid Anodize (SAA), Type II, Class II undyed IAW MIL-PRF-8625F, paragraph 4.5.3. for 336 hours in B117 Salt Fog as quality control for panels
- Manufacture test panels (96 test, 12 spare, 12 witness (no fasteners))
 - Drill for fasteners and nutplates
- Coat test panels with test stack-ups
 - Multi-coating process
 - Machine three scribes on each panel
 - Measure scribe depths with Keyence
- Heat-age panels for 96 hours at 210°F



Order of Test

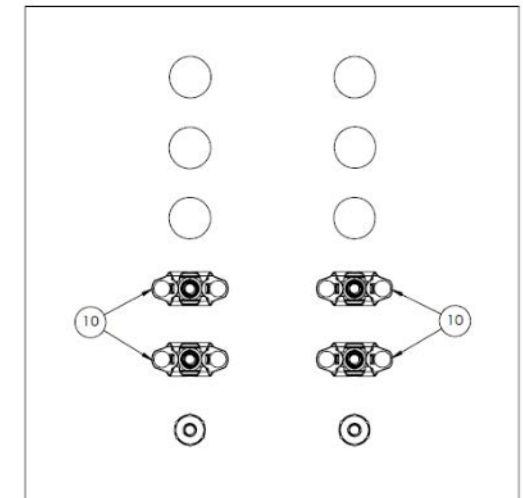
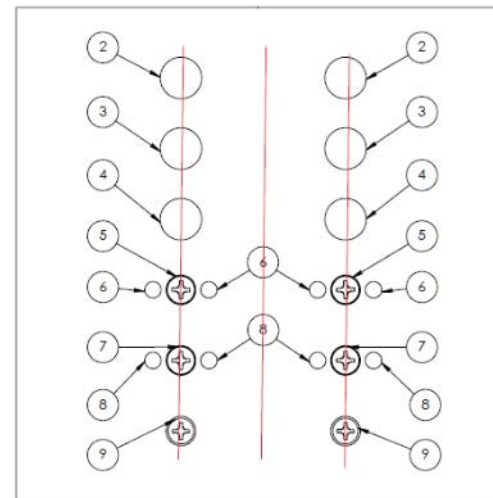
- Subject all panels to 3000 hours of UV in Q-Lab QUV chambers
- Subject all panels to 3000 hours of B-117 Salt Fog in Q-Lab Q-FOG chambers
 - 3 panels of each stack up pulled every 500 hours
 - Pulled panels subject to adhesion testing (one panel for each stage of salt fog pull)
 - Removed coating with chemical paint remover from one panel of each stack up



Coupon – Project Preparation

- 6" X 6" 7075-T6 0.063" Panel
- Manufactured panels from sheet that was sulfuric acid anodized; Type II, Class II (undyed) with dichromate sealer per MIL-PRF-8625
- Two rows of fasteners installed – Left row wet-sealed (MIL-PRF-81733 chromated sealant on top three fasteners and Corban 27L) on bottom three fasteners; Right row row not sealed
- After coatings, three scribes were etched into panel; one through each fastener row and one in the center of the panel

Item No.	Description	Qty.
1	Coupon 6X6	1
2	Aluminum Cherrymax	2
3	Steel Cherrymax	2
4	Cadmium Plated Hi-lok	2
5	Cadmium Plated Screw	2
6	AD Rivet	4
7	Stainless Steel Screw	2
8	Pull through Rivet	4
9	Titanium Screw	2
10	Nutplate	4
11	Washer	4
12	Nut	4



Coupon – Coating Application

- Control 1
 - SAA Anodize->Alodine 1200S->PPG 02Y040->PPG 99GY001+MIL-PRF-81733+Corban 27L
- Control 2
 - SAA Anodize->PreKote->PPG 02Y040 >PPG 99GY001+MIL-PRF-81733+Corban 27L
- Test System 1
 - SAA Anodize->iSAP 311->PPG 02Y040->PPG 99GY001+MIL-PRF-81733+Corban 27L
- Test System 2
 - SAA Anodize->iSAP 311T->PPG 02Y040->PPG 99GY001+MIL-PRF-81733+Corban 27L
- Inner Mold Line
 - To simulate IML, the “backs” of the panels had the following stack-up
 - Anodized->PPG 02Y040 (Panel fronts were masked to protect from overspray)
 - When spraying stack ups, backs (IML) were covered with masking vinyl

Coupon – Coating Application

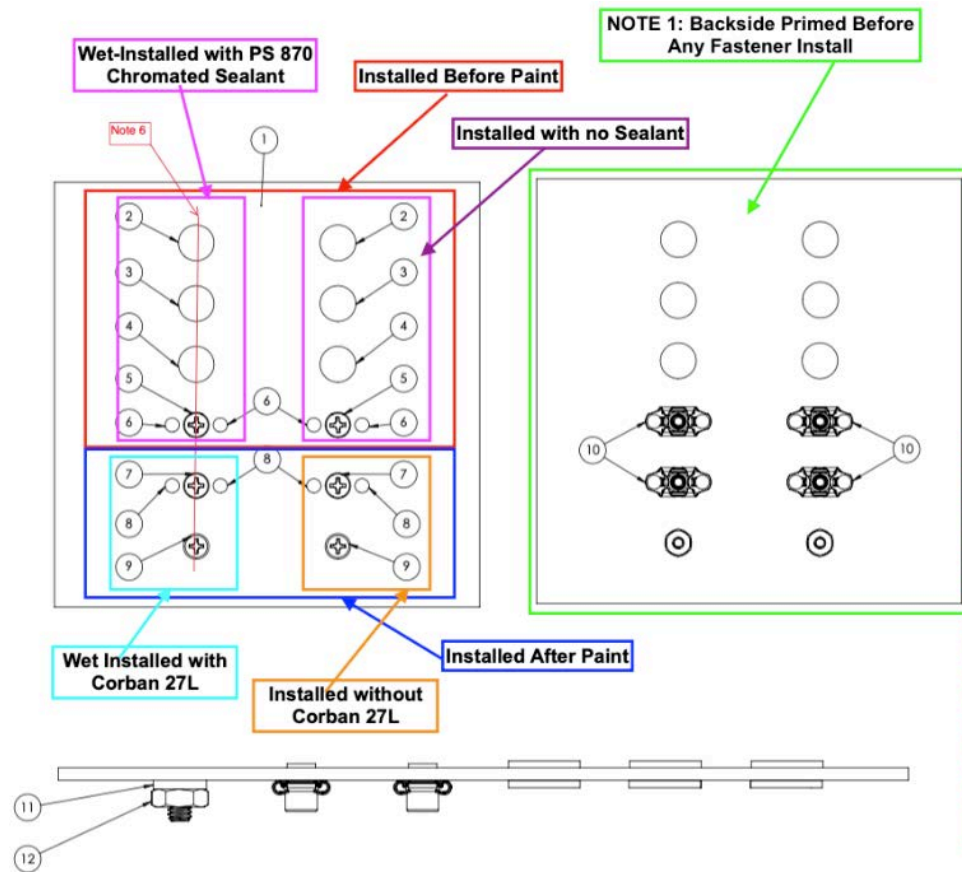
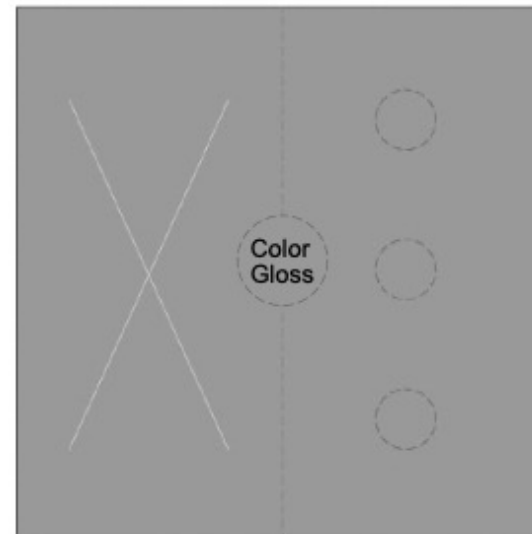


Figure 2. Fastener Installation and Coating Application Process Order of Operation



Coupon – Witness Panels

- Witness Panels were added as a quality assurance measure
 - Also provided additional test data as panels did not have fasteners
 - Test also had three panels of each stack up as spares in case something happened to the test panels; they went through the entire process to 3000 hours B117



ASTM B117 Salt Fog – Chamber Set Up



ASTM B117 Results – Alodine 1200



0 Hours



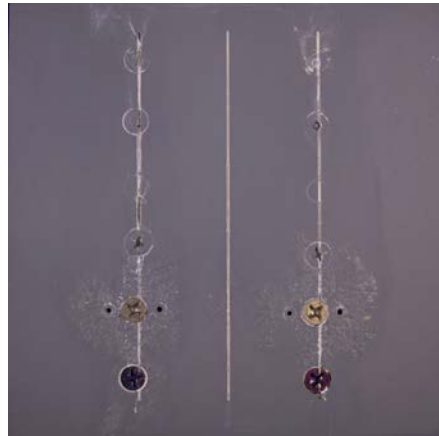
500 Hours



1000 Hours



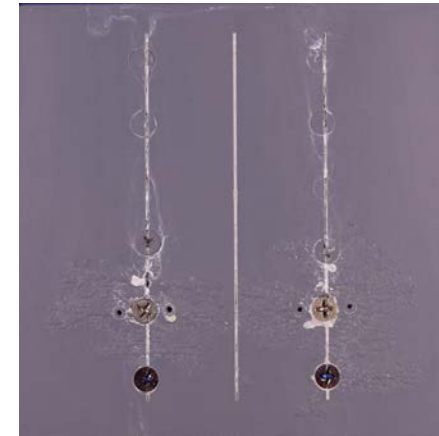
1500 Hours



2000 Hours



2500 Hours



3000 Hours

ASTM B117 Results - PreKote



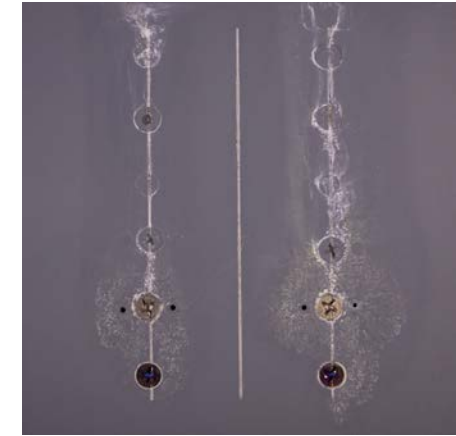
0 Hours



500 Hours



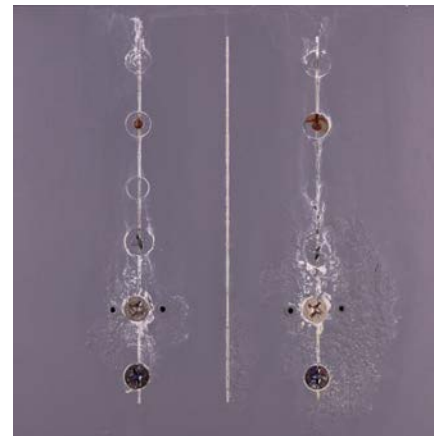
1000 Hours



1500 Hours



2000 Hours



2500 Hours



3000 Hours

ASTM B117 Results – iSAP 311



0 Hours



500 Hours



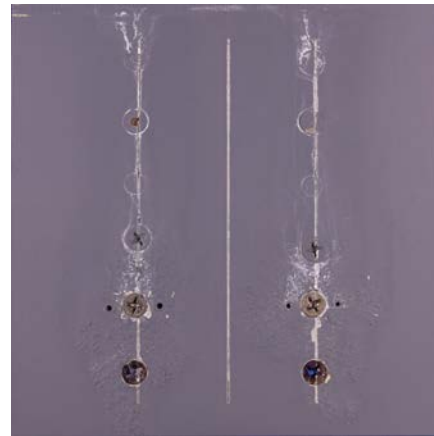
1000 Hours



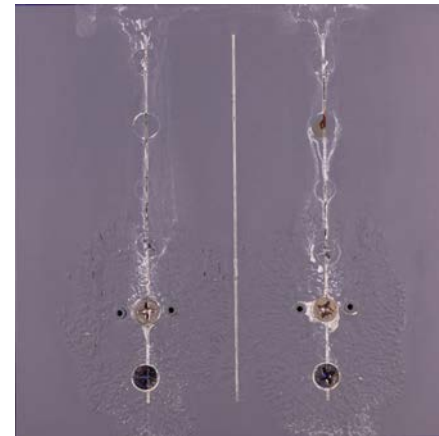
1500 Hours



2000 Hours



2500 Hours



3000 Hours

ASTM B117 Results – iSAP 311T



0 Hours



500 Hours



1000 Hours



1500 Hours



2000 Hours



2500 Hours



3000 Hours

ASTM B117 – 500 Hours



Alodine 1200S



PreKote



iSAP 311



iSAP 311T

ASTM B117 – 1000 Hours



Alodine 1200



PreKote



iSAP 311

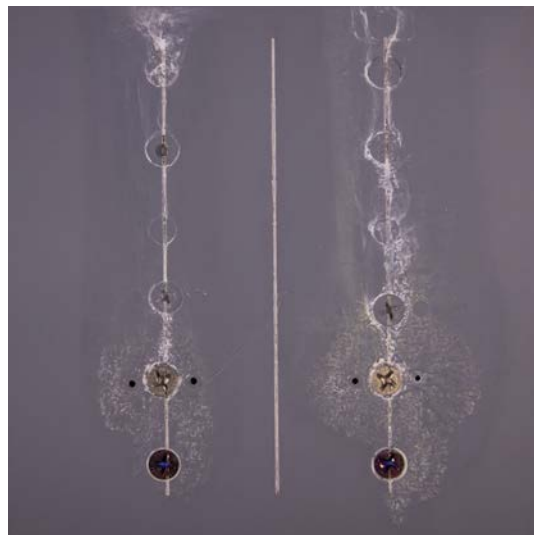


iSAP 311T

ASTM B117 – 1500 Hours



Alodine 1200



PreKote



iSAP 311

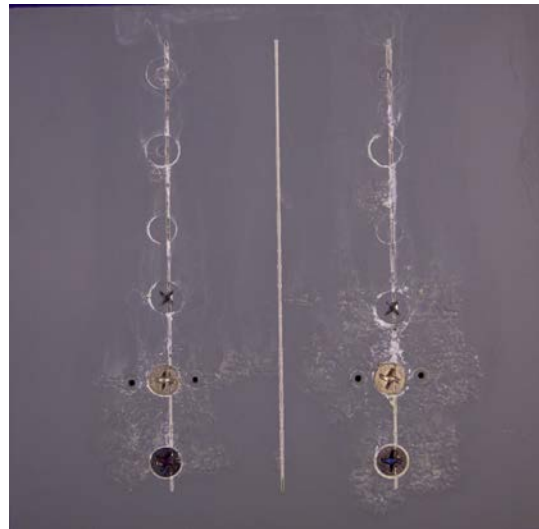


iSAP 311T

ASTM B117 – 2000 Hours



Alodine 1200



PreKote

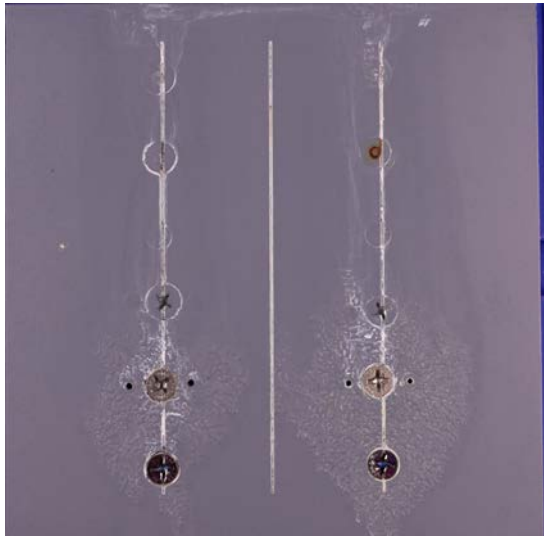


iSAP 311



iSAP 311T

ASTM B117 – 2500 Hours



Alodine 1200



PreKote



iSAP 311

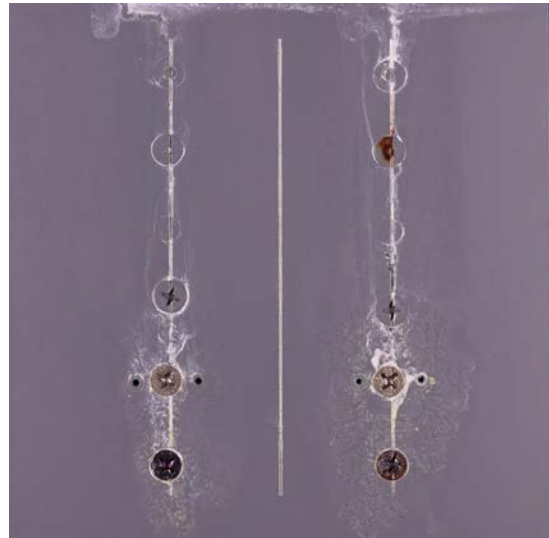


iSAP 311T

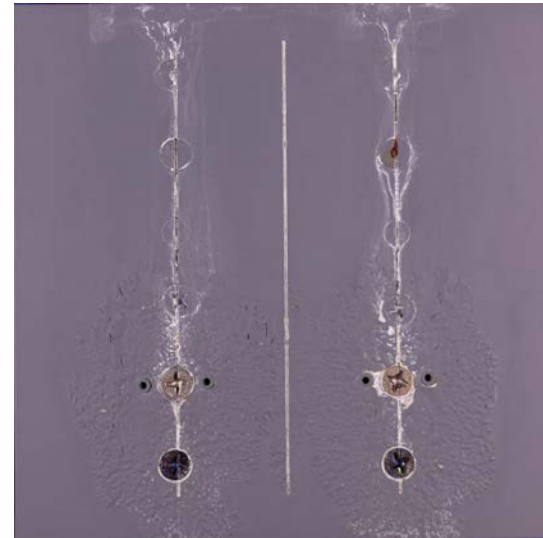
ASTM B117 – 3000 Hours



Alodine 1200



PreKote



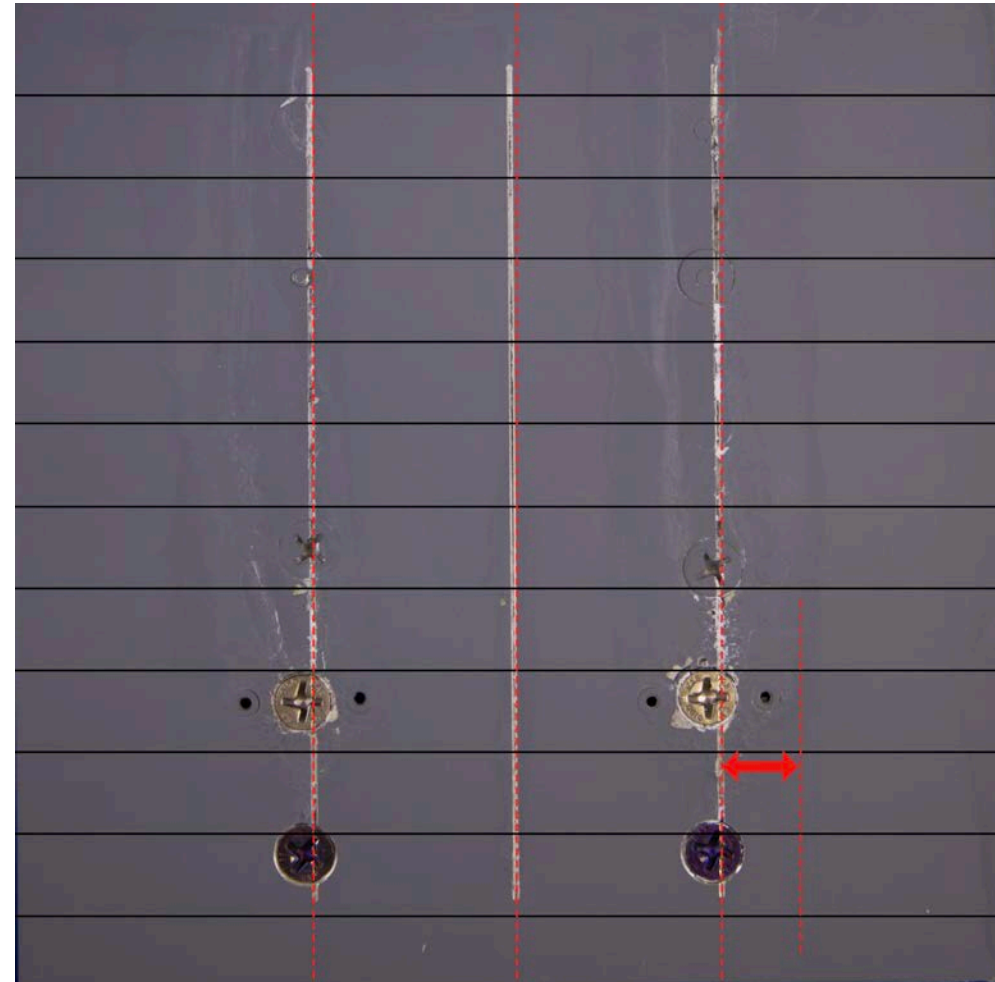
iSAP 311



iSAP 311T

ASTM D1654 – Scribe Creep Measurement

- Starting from top of panel, marks were made at 1/2" increments
- Measurements are taken of corrosion that creeps from the scribe
- Measurements were taken from the scribe to the corrosion that is further from the scribe
- If corrosion creeps out from both sides of the scribe, record measurement of side that has largest creepage value
- Can use true values or rating



Undercutting Values – Alodine 1200

PANEL NUMBER	CREEPAGE (measured every 1/2")											Total Per Scribe	Total Per Panel	Total per hour	When Panels Pulled	
	Scribe	.5"	1"	1.5"	2"	2.5"	3"	3.5"	4"	4.5"	5"					
24004-1-001	Scribe A	0.000	0.000	0.000	0.000	0.130	0.277	0.275	0.330	0.324	0.309	1.645	2.953	4.64	500 hours	
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.108	0.000	0.074	0.182				
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.186	0.474	0.281	0.185				1.126
24004-1-002	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.328	0.117	0.194	0.639	1.687	4.64	500 hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.069	0.000	0.000	0.069			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.252	0.514	0.132	0.081	0.979			
24004-1-004	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.297	0.495	0.208	0.000	1.000	2.314	6.403	1000 Hours	
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000				
	Scribe C	0.000	0.000	0.000	0.000	0.158	0.109	0.140	0.424	0.234	0.249	1.314				
24004-1-005	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.555	0.329	0.564	0.365	0.238	2.051	4.089	6.403	1000 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.150	0.000	0.150				
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.386	0.701	0.451	0.350	1.888				
24004-1-007	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.059	0.450	0.691	0.636	0.403	2.239	4.624	8.549	1500 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.296	0.000	0.000	0.296				
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.058	0.219	0.755	0.612	0.445	2.089				
24004-1-008	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.483	0.631	0.388	0.387	1.889	3.925	8.549	1500 Hours	
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.163	0.000	0.000	0.000	0.163				
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.375	0.758	0.472	0.268	1.873				
24004-1-010	Scribe A	0.000	0.000	0.000	0.000	0.089	0.122	0.809	0.857	0.443	0.312	2.632	5.734	13.532	2000 Hours	
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.156	0.201	0.086	0.000	0.443				
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.327	0.887	0.927	0.518	0.000	2.659				
24004-1-011	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.683	0.919	0.874	0.588	3.064	7.798	13.532	2000 Hours	
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.150	0.285	0.325	0.302	0.139	1.201				
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.402	0.648	1.200	0.755	0.528	3.533				
24004-1-013	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.773	0.843	0.776	0.444	2.836	7.795	20.137	2500 Hours	
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.238	0.436	0.062	0.000	0.736				
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.401	1.200	1.200	0.843	0.579	4.223				
24004-1-014	Scribe A	0.000	0.000	0.000	0.000	0.096	0.817	0.841	0.966	0.779	0.358	3.857	12.342	20.137	2500 Hours	
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	1.200	1.200	1.200	0.000	3.600				
	Scribe C	0.000	0.000	0.000	0.130	0.000	0.346	1.200	1.200	1.200	0.809	4.885				
24004-1-016	Scribe A	0.000	0.000	0.000	0.000	0.000	0.081	0.201	1.200	0.878	0.000	2.360	8.323	24.917	3000 Hours	
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.200	0.000	0.233	1.433				
	Scribe C	0.192	0.000	0.000	0.000	0.000	0.000	1.013	1.200	0.938	1.187	4.530				
24004-1-017	Scribe A	0.000	0.000	0.000	0.000	0.159	0.738	1.103	1.200	1.200	0.511	4.911	16.594	24.917	3000 Hours	
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	1.200	1.200	1.200	0.000	3.600				
	Scribe C	0.000	0.608	0.853	0.633	0.669	0.925	1.200	1.200	1.141	0.854	8.083				
Totals at each Measurement point	Scribe A	0.000	0.000	0.000	0.000	0.474	2.649	6.244	9.024	6.988	3.744	29.123	Total Score	78.178		
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.150	3.242	5.035	3.000	0.446	11.873				
	Scribe C	0.192	0.608	0.853	0.763	0.827	2.568	7.706	10.553	7.577	5.535	37.182				

From	To	Rating Number
0.00000	0.00000	10
0.00001	0.01560	9
0.01561	0.03125	8
0.03126	0.06250	7
0.06501	0.12500	6
0.12501	0.18750	5
0.18751	0.25000	4
0.25001	0.37500	3
0.37501	0.50000	2
0.50001	0.62500	1
0.62500	0.6500+	0

Undercutting Values – Prekote

PANEL NUMBER	CREEPAGE (measured every 1/2")											Total Per Scribe	Total Per Panel	Total per hour	When Panels Pulled
	Scribe	.5"	1"	1.5"	2"	2.5"	3"	3.5"	4"	4.5"	5"				
24004-2-001	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.132	0.221	0.039	0.163	0.555	1.886	3.972	500 hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.740	0.740			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.052	0.078	0.187	0.118	0.156	0.591			
24004-2-002	Scribe A	0.000	0.000	0.000	0.000	0.000	0.133	0.149	0.545	0.147	0.000	0.974	2.086		
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.193	0.121	0.000	0.314			
	Scribe C	0.000	0.000	0.000	0.000	0.043	0.000	0.152	0.236	0.183	0.184	0.798			
24004-2-004	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.126	0.676	0.404	0.380	1.586	3.402	7.14	1000 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.110	0.077	0.000	0.193	0.380			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.223	0.584	0.316	0.313	1.436			
24004-2-005	Scribe A	0.000	0.000	0.000	0.000	0.000	0.228	0.362	0.535	0.326	0.351	1.802	3.738		
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.059	0.000	0.000	0.059			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.090	0.402	0.623	0.356	0.406	1.877			
24004-2-007	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.363	0.694	0.692	0.379	2.128	5.445	10.773	1500 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.160	0.000	0.000	0.160			
	Scribe C	0.000	0.000	0.000	0.107	0.128	0.479	0.620	0.905	0.834	0.084	3.157			
24004-2-008	Scribe A	0.000	0.000	0.000	0.000	0.000	0.185	0.526	0.570	0.396	0.483	2.160	5.328		
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.201	0.000	0.368	0.284	0.086	0.939			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.668	0.771	0.487	0.303	2.229			
24004-2-010	Scribe A	0.000	0.000	0.000	0.168	0.000	0.000	0.000	1.200	0.782	0.715	2.865	8.128	14.246	2000 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.149	0.000	0.000	1.200	0.000	0.094	1.443			
	Scribe C	0.000	0.000	0.000	0.397	0.268	0.000	0.763	0.997	0.736	0.659	3.820			
24004-2-011	Scribe A	0.000	0.000	0.000	0.000	0.000	0.291	0.973	0.951	0.311	0.281	2.807	6.118		
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.082	0.000	0.239	0.000	0.321			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.261	0.823	0.918	0.606	0.382	2.990			
24004-2-013	Scribe A	0.000	0.000	0.000	0.000	0.000	0.154	0.443	0.594	0.477	0.000	1.668	6.511	20.81	2500 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.213	0.343	0.199	0.755			
	Scribe C	0.000	0.000	0.000	0.000	0.104	0.726	0.914	1.056	0.693	0.595	4.088			
24004-2-014	Scribe A	0.000	0.000	0.000	0.000	0.000	0.272	0.700	1.197	1.135	0.923	4.227	14.299		
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	1.200	1.200	1.200	1.290	4.890			
	Scribe C	0.000	0.000	0.174	0.182	0.246	0.455	1.200	1.200	1.200	0.525	5.182			
24004-2-016	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.076	0.461	0.428	0.459	1.424	4.382	10.461	3000 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.138	0.000	0.138			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.860	0.783	0.625	0.552	2.820			
24004-2-017	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.646	0.639	0.353	0.739	2.377	6.079		
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.487	0.686	0.937	0.909	0.683	3.702			
Totals at each Measurement point	Scribe A	0.000	0.000	0.000	0.168	0.000	1.263	4.496	8.283	5.490	4.873	24.573	Total Score	67.402	
	Scribe B	0.000	0.000	0.000	0.000	0.149	0.201	1.392	3.470	2.325	2.602	10.139			
	Scribe C	0.000	0.000	0.174	0.686	0.789	2.550	7.389	9.197	7.063	4.842	32.690			

From	To	Rating Number
0.00000	0.00000	10
0.00001	0.01560	9
0.01561	0.03125	8
0.03126	0.06250	7
0.06501	0.12500	6
0.12501	0.18750	5
0.18751	0.25000	4
0.25001	0.37500	3
0.37501	0.50000	2
0.50001	0.62500	1
0.62500	0.6500+	0

Undercutting Values – iSAP 311

PANEL NUMBER	CREEPAGE (measured every 1/2")											Total Per Scribe	Total Per Panel	Total per hour	When Panels Pulled
	Scribe	.5"	1"	1.5"	2"	2.5"	3"	3.5"	4"	4.5"	5"				
24004-3-001	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.132	0.455	0.058	0.000	0.645	1.421	2.878	500 hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.066	0.054	0.000	0.000	0.000	0.12			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.147	0.471	0.038	0.000	0.656			
24004-3-002	Scribe A	0.000	0.000	0.000	0.000	0.000	0.174	0.165	0.266	0.000	0.000	0.605	1.457	2.878	500 hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.099	0.000	0.099			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.227	0.280	0.246	0.000	0.753			
24004-3-004	Scribe A	0.000	0.000	0.000	0.114	0.159	0.000	0.132	0.666	0.306	0.117	1.494	2.995	5.496	1000 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.188	0.123	0.119	0.000	0.000	0.43			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.091	0.262	0.414	0.304	0.000	1.071			
24004-3-005	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.113	0.506	0.243	0.000	0.862	2.501	5.496	1000 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.610	0.138	0.000	0.748			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.231	0.457	0.203	0.000	0.891			
24004-3-007	Scribe A	0.194	0.000	0.093	0.000	0.000	0.184	0.685	0.735	0.237	0.000	2.128	4.07	8.248	1500 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.157	0.000	0.000	0.000	0.157			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.696	0.701	0.388	0.000	1.785			
24004-3-008	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.453	0.676	0.614	0.603	2.346	4.178	8.248	1500 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.213	0.000	0.213			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.413	0.677	0.380	0.149	1.619			
24004-3-010	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.519	0.945	0.800	0.000	2.264	4.302	8.075	2000 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.111	0.356	0.000	0.467			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.352	0.736	0.483	0.000	1.571			
24004-3-011	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.134	0.419	0.624	0.515	1.692	3.773	8.075	2000 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.421	0.000	0.421			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.128	0.697	0.484	0.351	1.66			
24004-3-013	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.534	0.573	0.809	0.601	2.517	5.819	13.412	2500 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.055	0.000	0.000	0.055			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.743	1.042	0.920	0.542	3.247			
24004-3-014	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.141	0.731	0.655	0.738	2.265	7.593	13.412	2500 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.105	1.200	1.305			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.779	1.035	1.009	1.200	4.023			
24004-3-016	Scribe A	0.044	0.000	0.000	0.000	0.000	0.618	1.135	1.095	1.076	0.905	4.873	14.739	28.216	3000 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.140	1.200	1.200	1.087	0.955	4.582			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.741	1.200	1.200	1.122	1.021	5.284			
24004-3-017	Scribe A	0.000	0.000	0.000	0.000	0.000	0.307	1.200	1.200	1.200	0.654	4.561	13.477	28.216	3000 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.064	1.200	1.200	1.200	0.000	3.664			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.543	0.964	1.791	1.036	0.918	5.252			
Totals at each Measurement point	Scribe A	0.238	0.000	0.093	0.114	0.159	1.283	5.343	8.267	6.622	4.133	26.252	Total Score	66.325	
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.458	2.734	3.295	3.619	2.155	12.261			
	Scribe C	0.000	0.000	0.000	0.000	0.000	1.375	6.142	9.501	6.613	4.181	27.812			

From	To	Rating Number
0.00000	0.00000	10
0.00001	0.01560	9
0.01561	0.03125	8
0.03126	0.06250	7
0.06501	0.12500	6
0.12501	0.18750	5
0.18751	0.25000	4
0.25001	0.37500	3
0.37501	0.50000	2
0.50001	0.62500	1
0.62500	0.6500+	0

Undercutting Values – iSAP 311T

PANEL NUMBER	CREEPAGE (measured every 1/2")											Total Per Scribe	Total Per Panel	Total per hour	When Panels Pulled
	Scribe	.5"	1"	1.5"	2"	2.5"	3"	3.5"	4"	4.5"	5"				
24004-4-001	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.113	0.184	0.000	0.000	0.297	0.455	2.151	500 hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.158	0.000	0.000			
24004-4-002	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.113	0.314	0.000	0.427	1.696	2.151	500 hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.840	0.000	0.000	0.000	0.000	0.840			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.290	0.139	0.000	0.429			
24004-4-004	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.310	0.440	0.323	1.073	2.023	3.313	1000 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.052	0.000	0.064	0.000	0.116			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.210	0.328	0.296	0.834			
24004-4-005	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.138	0.504	0.118	0.000	0.760	1.29	3.313	1000 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.099	0.315	0.116	0.000	0.530			
24004-4-007	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.383	0.789	0.521	0.468	2.161	4.205	8.301	1500 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.127	0.000	0.219	0.346			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.249	0.658	0.333	0.458	1.698			
24004-4-008	Scribe A	0.000	0.000	0.000	0.000	0.000	0.082	0.429	0.673	0.554	0.535	2.273	4.096	8.301	1500 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.089	0.089			
	Scribe C	0.000	0.292	0.273	0.000	0.000	0.000	0.173	0.722	0.274	0.000	1.734			
24004-4-010	Scribe A	0.000	0.000	0.000	0.000	0.000	0.176	0.609	0.752	0.430	0.166	2.133	3.038	5.272	2000 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.174	0.486	0.245	0.905			
24004-4-011	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.196	0.654	0.211	0.000	1.061	2.234	5.272	2000 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.087	0.000	0.087			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.164	0.658	0.104	0.160	1.086			
24004-4-013	Scribe A	0.000	0.000	0.000	0.000	0.000	0.243	0.284	0.747	0.516	0.250	2.040	4.728	10.586	2500 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.092	0.787	0.811	0.542	0.456	2.688			
24004-4-014	Scribe A	0.000	0.000	0.136	0.000	0.000	0.000	0.341	0.994	0.978	0.242	2.691	5.858	10.586	2500 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.118	0.095	0.000	0.000	0.000	0.213			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.584	0.766	1.053	0.551	2.954			
24004-4-016	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.191	0.690	0.763	0.276	1.920	4.617	9.705	3000 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.062	0.060	0.000	0.000	0.122			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.505	0.862	0.744	0.464	2.575			
24004-4-017	Scribe A	0.000	0.000	0.000	0.000	0.000	0.000	0.285	1.198	0.986	0.000	2.469	5.088	9.705	3000 Hours
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.288	0.288			
	Scribe C	0.000	0.000	0.000	0.000	0.000	0.000	0.696	0.956	0.472	0.207	2.331			
Totals at each Measurement Point	Scribe A	0.000	0.000	0.136	0.000	0.000	0.501	2.969	7.608	5.831	2.260	19.305	Total Score	39.328	
	Scribe B	0.000	0.000	0.000	0.000	0.000	0.958	0.209	0.187	0.151	0.596	2.101			
	Scribe C	0.000	0.292	0.273	0.000	0.000	0.092	3.257	6.580	4.591	2.837	17.922			

From	To	Rating Number
0.00000	0.00000	10
0.00001	0.01560	9
0.01561	0.03125	8
0.03126	0.06250	7
0.06501	0.12500	6
0.12501	0.18750	5
0.18751	0.25000	4
0.25001	0.37500	3
0.37501	0.50000	2
0.50001	0.62500	1
0.62500	0.6500+	0

Undercutting Values – All Stack Ups – *Lower Numbers Better*

<i>Scribe A</i>	0.000	0.000	0.000	0.000	0.474	2.649	6.244	9.024	6.988	3.744	29.123		
<i>Scribe B</i>	0.000	0.000	0.000	0.000	0.000	0.150	3.242	5.035	3.000	0.446	11.873		
<i>Scribe C</i>	0.192	0.608	0.853	0.763	0.827	2.568	7.706	10.553	7.577	5.535	37.182	Total Score	78.178

Alodine 1200

<i>Scribe A</i>	0.000	0.000	0.000	0.168	0.000	1.263	4.496	8.283	5.490	4.873	24.573		
<i>Scribe B</i>	0.000	0.000	0.000	0.000	0.149	0.201	1.392	3.470	2.325	2.602	10.139		
<i>Scribe C</i>	0.000	0.000	0.174	0.686	0.789	2.550	7.389	9.197	7.063	4.842	32.690	Total Score	67.402

PreKote

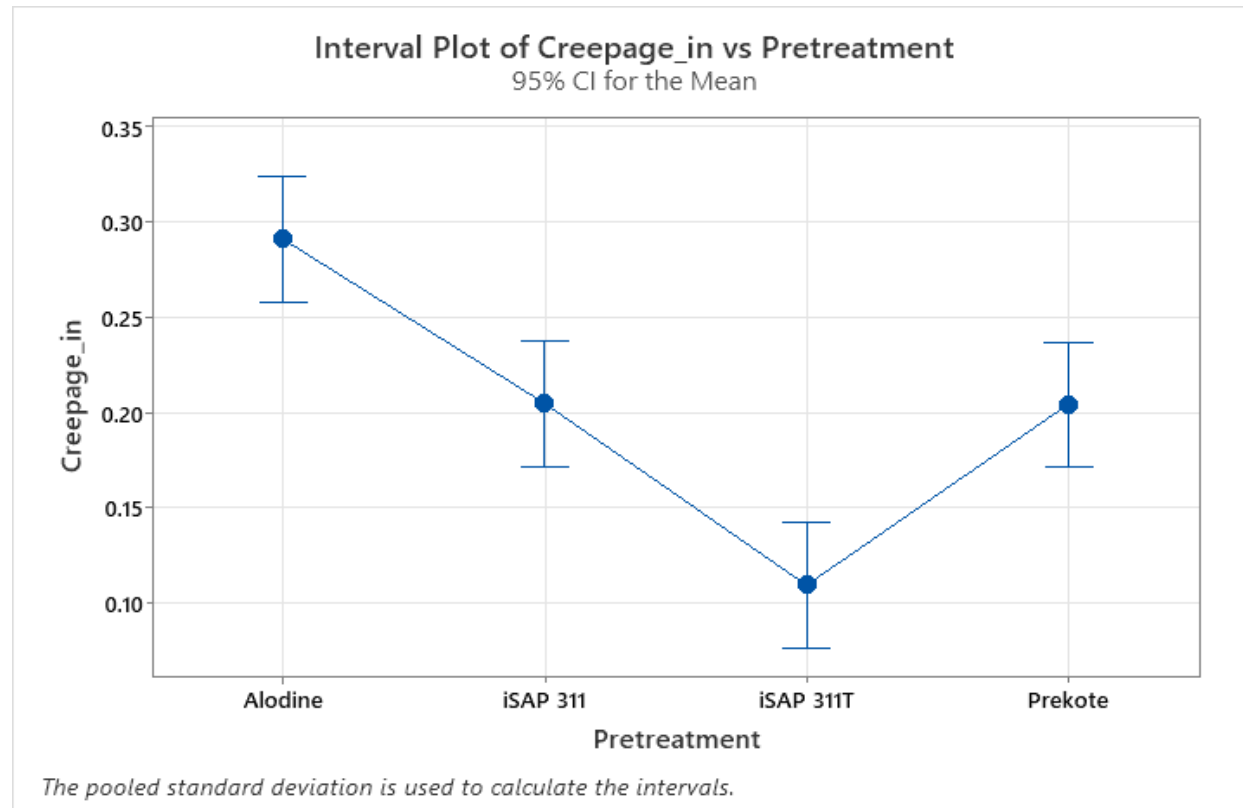
<i>Scribe A</i>	0.238	0.000	0.093	0.114	0.159	1.283	5.343	8.267	6.622	4.133	26.252		
<i>Scribe B</i>	0.000	0.000	0.000	0.000	0.000	0.458	2.734	3.295	3.619	2.155	12.261		
<i>Scribe C</i>	0.000	0.000	0.000	0.000	0.000	1.375	6.142	9.501	6.613	4.181	27.812	Total Score	66.325

iSAP 311

<i>Scribe A</i>	0.000	0.000	0.136	0.000	0.000	0.501	2.969	7.608	5.831	2.260	19.305		
<i>Scribe B</i>	0.000	0.000	0.000	0.000	0.000	0.958	0.209	0.187	0.151	0.596	2.101		
<i>Scribe C</i>	0.000	0.292	0.273	0.000	0.000	0.092	3.257	6.580	4.591	2.837	17.922	Total Score	39.328

iSAP 311T

Undercutting Values – All Stack Ups – *Lower Numbers Better*



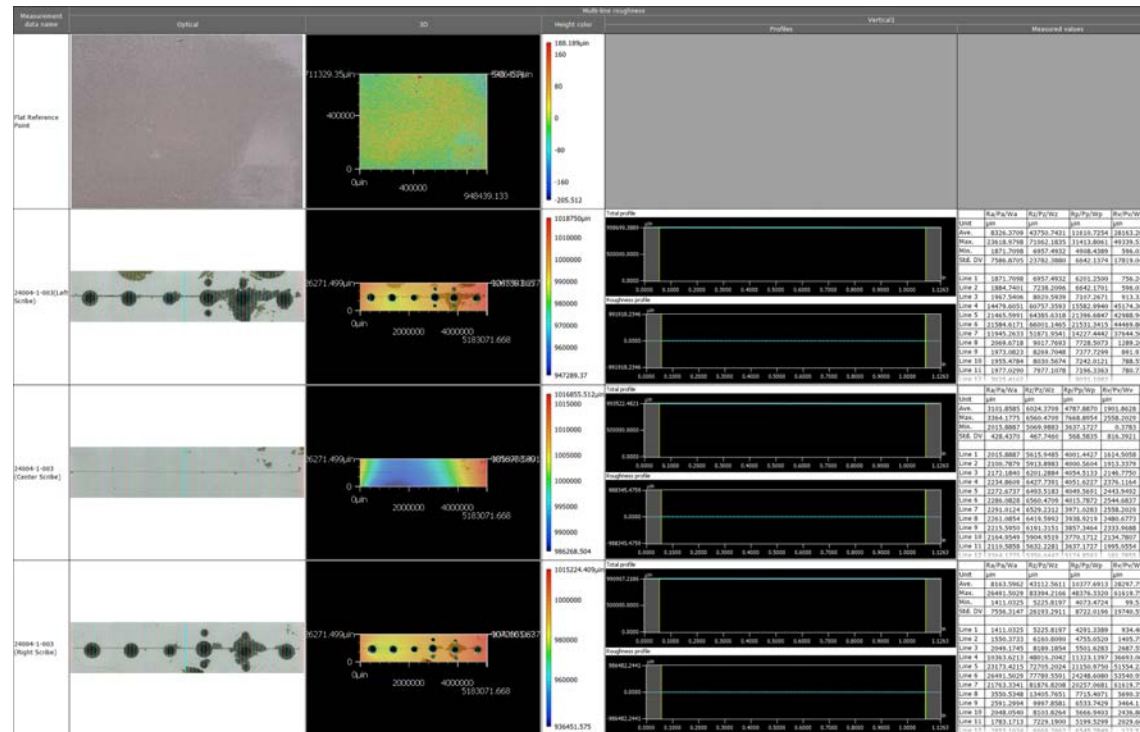
Means				
Pretreatment	N	Mean	StDev	95% CI
Alodine	450	0.2907	0.4368	(0.2579, 0.3235)
iSAP 311	440	0.2045	0.3656	(0.1713, 0.2376)
iSAP 311T	450	0.1091	0.2312	(0.0763, 0.1419)
Prekote	451	0.2040	0.3549	(0.1713, 0.2368)

Pooled StDev = 0.354874

Summary of Mean Creepage Values by Pretreatment from One-Way ANOVA (Post-UV Exposure)

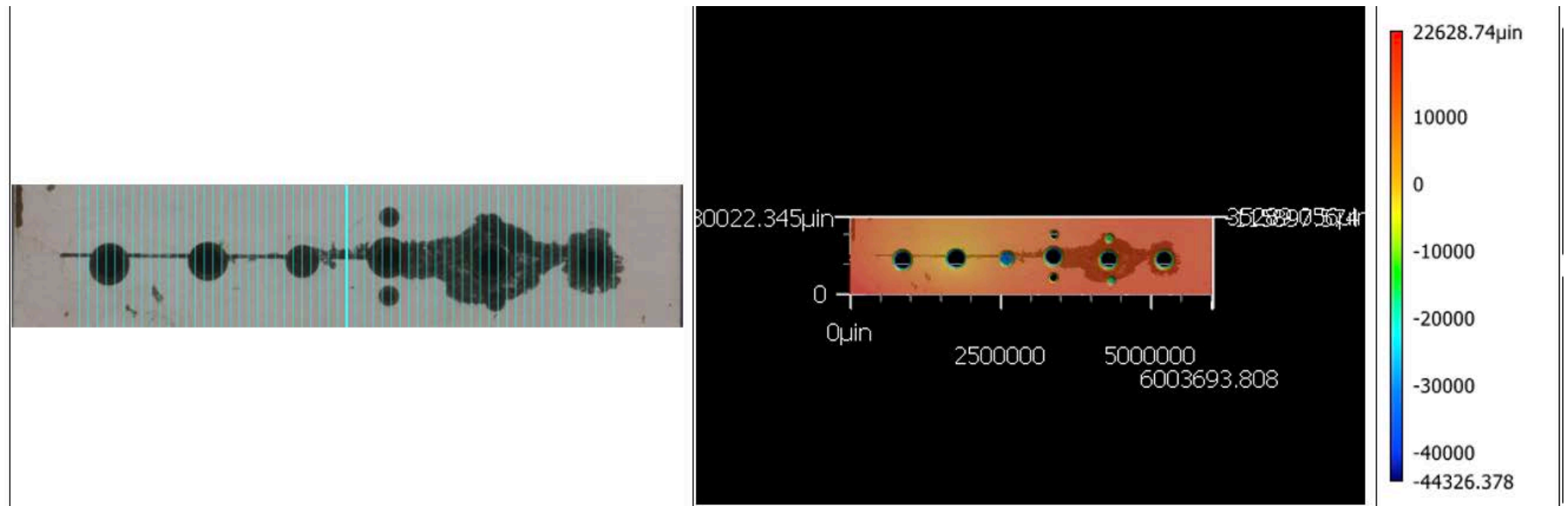
Optical Profilometry

- Keyence 3D Microscope optical profilometry was performed to quantitatively assess surface degradation through high-resolution measurement of average surface roughness (R_a) and maximum pit depth (R_z).



Optical Profilometry

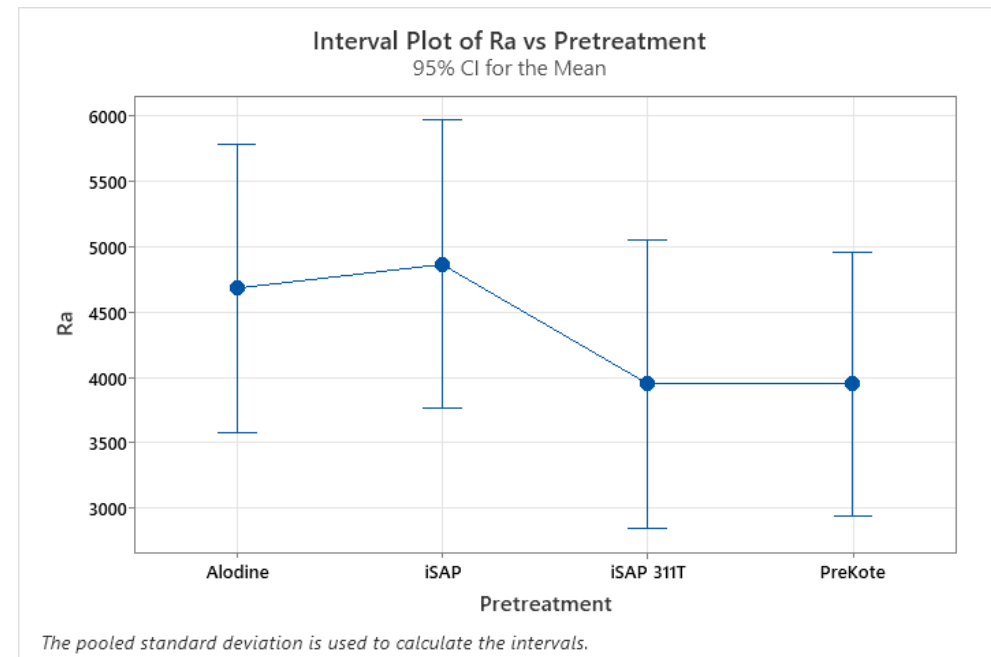
- This method was selected to provide objective, repeatable surface topography data and to quantify localized corrosion features that may not be fully captured through visual inspection alone.



Optical Profilometry – Surface Roughness (Ra)

- Under wet installation, no statistically significant differences were observed among pretreatments ($p=0.513$). Mean Ra values were:
 - Alodine – 4681 μin
 - iSAP 311 – 4862 μin
 - iSAP 311T – 3951 μin
 - PreKote – 3948 μin

Pretreatment	N	Mean	StDev	95% CI
Alodine	153	4681	7043	(3579, 5783)
iSAP	153	4862	7508	(3760, 5965)
iSAP 311T	153	3951	6705	(2849, 5053)
PreKote	183	3948	6551	(2940, 4956)

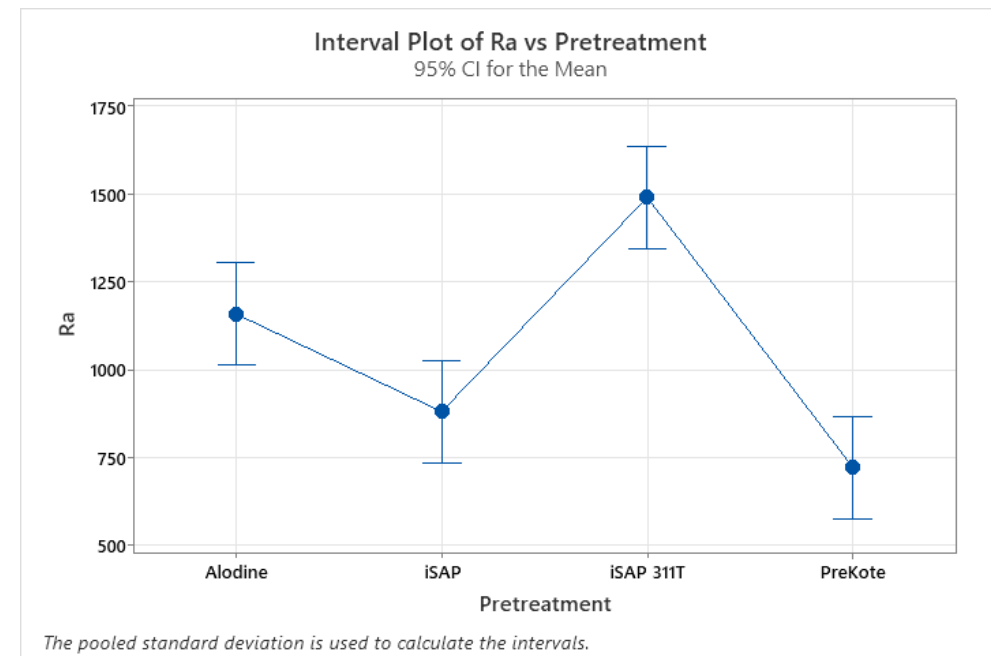


Summary of Mean Surface Roughness (Ra) Values Wet Installed by Pretreatment from One-Way ANOVA (3000 Hours Exposure)

Optical Profilometry – Surface Roughness (Ra)

- Under dry installation, pretreatment had a statistically significant effect on surface roughness ($p < 0.001$). Mean Ra values were:
 - Alodine – 1157 μin
 - iSAP 311 – 879 μin
 - iSAP 311T – 1488 μin
 - PreKote – 721 μin

Pretreatment	N	Mean	StDev	95% CI
Alodine	63	1157.2	359.5	(1012.0, 1302.3)
iSAP	63	879.3	257.8	(734.1, 1024.5)
iSAP 311T	63	1488	1033	(1343, 1634)
PreKote	63	720.9	326.7	(575.7, 866.0)

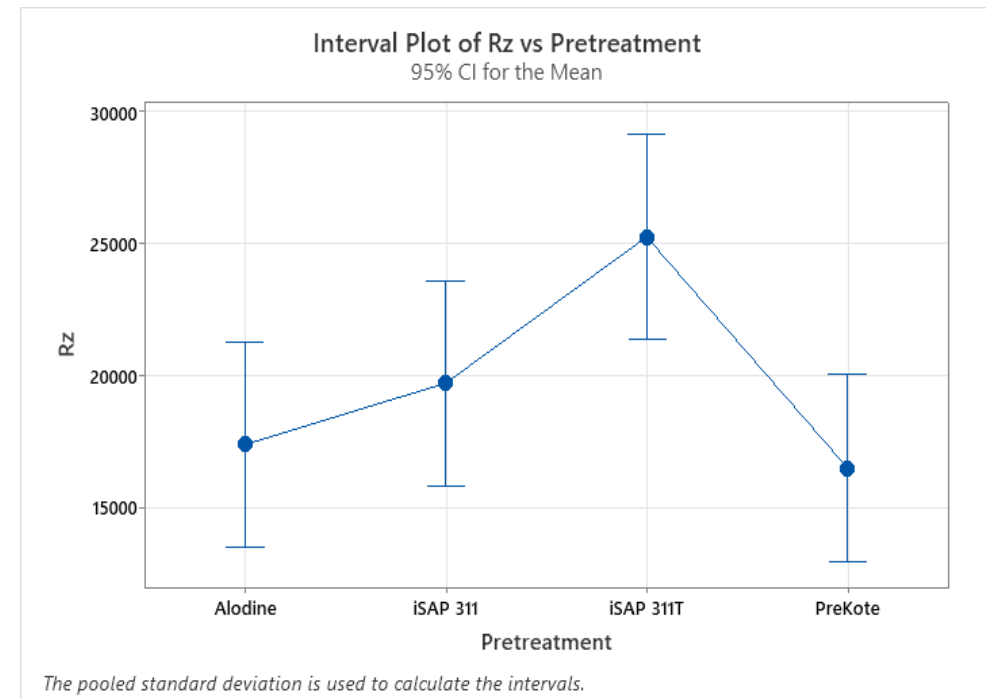


Summary of Mean Surface Roughness (Ra) Values Dry Installed by Pretreatment from One-Way ANOVA (3000 Hours Exposure)

Optical Profilometry – Pit Depth(Rz)

- Pit depth was significantly affected by pretreatment under both installation conditions. *Under dry installation* ($p=.006$), mean Rz values were:
 - Alodine – 17,368 μin
 - iSAP 311 – 19,699 μin
 - iSAP 311T – 25,246 μin
 - PreKote – 16,480 μin

Pretreatment	N	Mean	StDev	95% CI
Alodine	153	17368	23693	(13488, 21249)
iSAP	153	19699	24534	(15818, 23579)
iSAP 311T	153	25246	26615	(21365, 29126)
PreKote	183	16480	23051	(12932, 20029)

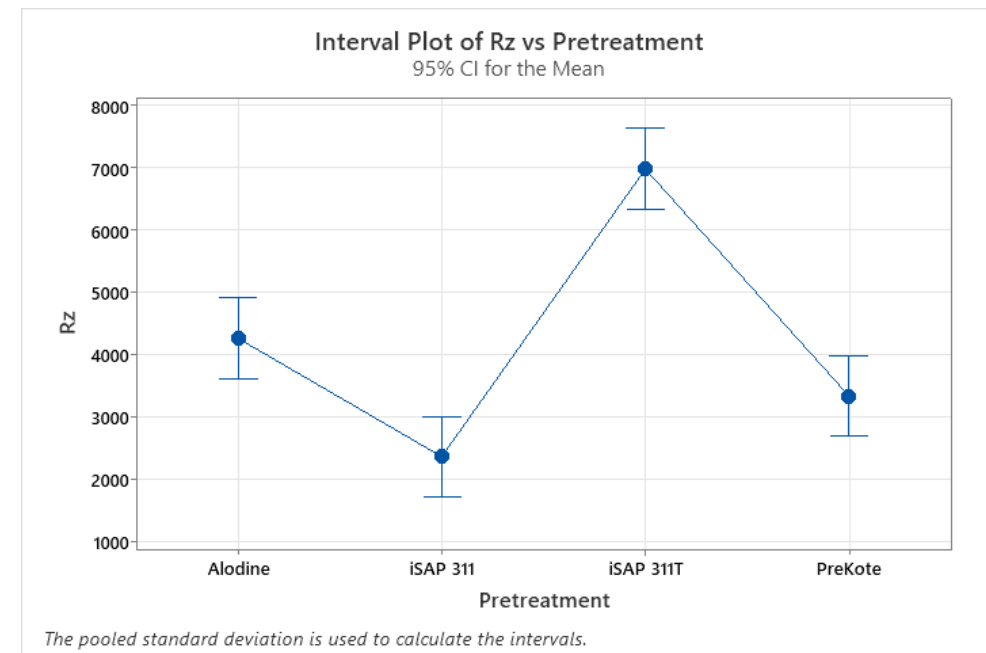


Summary of Mean Pit Depth (Rz) Values Dry Installed by Pretreatment from One-Way ANOVA (3000 Hours Exposure)

Optical Profilometry – Pit Depth(Rz)

- Pit depth was significantly affected by pretreatment under both installation conditions. *Under wet installation* ($p=.006$), mean Rz values were:
 - Alodine – 4,259 μin
 - iSAP 311 – 2,363 μin
 - iSAP 311T – 6,971 μin
 - PreKote – 3,334 μin

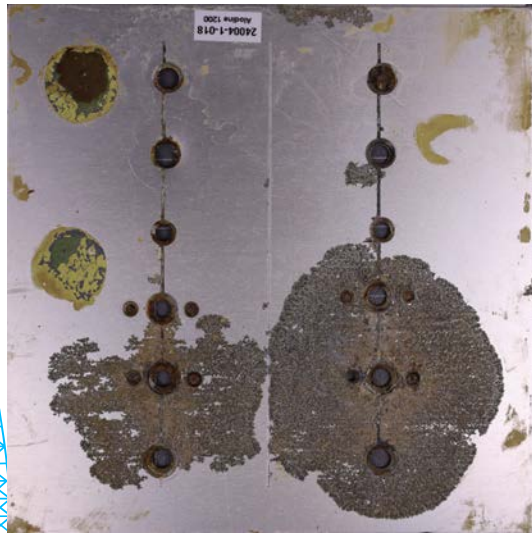
Pretreatment	N	Mean	StDev	95% CI
Alodine	63	4259	2008	(3612, 4907)
iSAP	63	2363.3	4077	(1715.7, 3011.0)
iSAP 311T	63	6971	4409	(6323, 7618)
PreKote	63	3334	1797	(2686, 3982)



Summary of Mean Pit Depth (Rz) Values Dry Installed by Pretreatment from One-Way ANOVA (3000 Hours Exposure)

Chemical Paint Remover

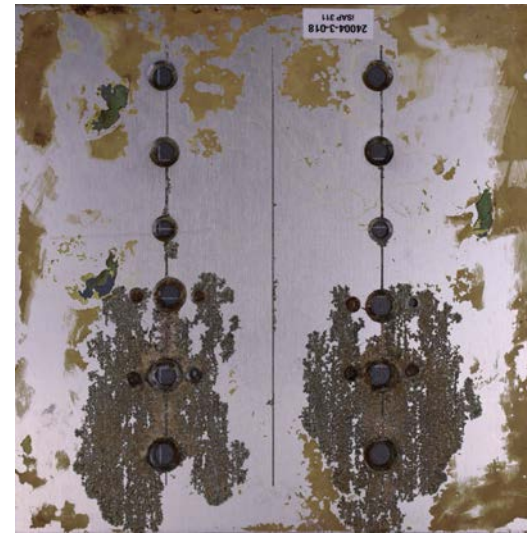
- Coatings were removed about 75- 90 percent with Vantage 9095
 - Due to heat aging and 3000 hours of UV, coatings were very stubborn to remove, even with heated 9095; all coating stack ups presented the same coating removal properties
 - Removed the rest of the coatings with Cee Bee R256 for proper panel inspections



Alodine 1200



PreKote



iSAP 311



iSAP 311T

Tensile Adhesion Testing

- All coating stack ups passed adhesion
 - There were some adhesion pulls that were less than the required pull rating
 - These were at the dolly to adhesive; no failures from pretreatments to primer or primer to the top coat

Tensile Adhesion (PATTI) Test Method E								
PROJECT: C-5 iSAP				PROJECT NUMBER: 24004				
PROJECT MANAGER: Scott Pagenkopf				CHARGE NUMBER:				
TEST DATE: 7/25/2025				REFERENCE: ATTC-ACT-LP-046E				
TECHNICIAN(S): Daniels / Calvert								
Lab Conditions								
Temp: 71.6° f			Relative Humidity: 52.6%			Location: Aging Room		
Panel ID	Substrate	Stack-Up	Adhesive	Fixture Sz	Pull 1	Pull 2	Pull 3	AVG
24004-1-001	7075-T6	Alodine/23377/85285	3M1838	20mm	823	911	730	821.3
24004-1-002	7075-T6	Alodine/23377/85285	3M1838	20mm	2312	1322	1389	1674
24004-1-003	7075-T6	Alodine/23377/85285	3M1838	20mm	688	912	748	782.6
24004-2-001	7075-T6	Prekote/23377/85285	3M1838	20mm	760	861	1838	1153
24004-2-002	7075-T6	Prekote/23377/85285	3M1838	20mm	788	886	1067	913.6
24004-2-003	7075-T6	Prekote/23377/85285	3M1838	20mm	652	1065	1838	1185
24004-3-001	7075-T6	iSAP/23377/85285	3M1838	20mm	744	960	1090	931.3
24004-3-002	7075-T6	iSAP/23377/85285	3M1838	20mm	669	1289	1404	1120.6
24004-3-003	7075-T6	iSAP/23377/85285	3M1838	20mm	482	1039	1047	856
24004-4-001	7075-T6	iSAPT/23377/85285	3M1838	20mm	1104	1081	952	1045.6
24004-4-002	7075-T6	iSAPT/23377/85285	3M1838	20mm	752	615	655	674
24004-4-003	7075-T6	iSAPT/23377/85285	3M1838	20mm	768	551	944	754.3
24004-1-004	7075-T6	Alodine/23377/85285	3M1838	20mm	1125	1184	838	1049
24004-1-005	7075-T6	Alodine/23377/85285	3M1838	20mm	1688	1577	1208	1491
24004-1-006	7075-T6	Alodine/23377/85285	3M1838	20mm	1113	831	1224	1056
24004-2-004	7075-T6	Prekote/23377/85285	3M1838	20mm	706	1009	585	767
24004-2-005	7075-T6	Prekote/23377/85285	3M1838	20mm	741	962	743	815
24004-2-006	7075-T6	Prekote/23377/85285	3M1838	20mm	1104	897	1133	1054
24004-3-004	7075-T6	iSAP/23377/85285	3M1838	20mm	1165	1025	1592	1261
24004-3-005	7075-T6	iSAP/23377/85285	3M1838	20mm	1039	1113	1658	1270
24004-3-006	7075-T6	iSAP/23377/85285	3M1838	20mm	1694	1565	1770	1676
24004-4-004	7075-T6	iSAPT/23377/85285	3M1838	20mm	812	1304	1195	1104
24004-4-005	7075-T6	iSAPT/23377/85285	3M1838	20mm	1044	736	1224	1001
24004-4-006	7075-T6	iSAPT/23377/85285	3M1838	20mm	1779	1492	1411	1561

Future Evaluations

- Future
 - Continue to run multiple statistical models to evaluate performance of stack ups
 - Evaluate the only the top three inches of creepage, surface roughness, and pit depth; leave out lower galvanic cells
 - Run data on only center scribes and X scribe on witness panels
 - Spare panels had similar data to what was presented; add those results to entire project data models

Conclusion

- iSAP 311T gave the best results for creepage; iSAP 311 and PreKote performance were similar
- iSAP 311T had the highest surface roughness and deeper corrosion pits
 - Across all measurements after 3000 hours of exposure, PreKote and iSAP 311 demonstrated the most consistent resistance to surface degradation, producing lower roughness and shallower pit depths.
- Sealing fasteners gives the best protection no matter pretreatment

Questions?

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