

Improvements in Surface Preparation Methods for Adhesive Bonding

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SERDP/ESTCP Workshop

27 February, 2008

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 27 FEB 2008		2. REPORT TYPE		3. DATES COVERED 00-00-2008 to 00-00-2008	
4. TITLE AND SUBTITLE Improvements in Surface Preparation Methods for Adhesive Bonding				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Boeing,Material and Process Technology,P. O. Box 3707,Seattle,WA,98124				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES Surface Finishing and Repair Issues for Sustaining New Military Aircraft Workshop, February 26-28, 2008, Tempe, AZ. Sponsored by SERDP/ESTCP.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 21	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			



DEMONSTRATION/VALIDATION OF SOL-GEL SURFACE PREPARATION FOR METAL ADHESIVE BONDING

Project Description - PP-0204

The purpose of this project is to:

- Demonstrate and validate the laboratory-verified, sol-gel processes developed under SERDP PP-1113 by addressing implementation issues for aluminum, titanium, and steel substrates utilized by tri-service aircraft platforms at the repair (depot and field) and OEM levels.

Dual Use Technology Development

AFRL/MLSA



NAVAIR



TACOM-ARDEC





DEMONSTRATION/VALIDATION OF SOL-GEL SURFACE PREPARATION FOR METAL ADHESIVE BONDING

Team Participants

- ***USAF AFRL/MLSA***
 - ***Naval Air Systems Command, Pax River***
 - ***US Army TACOM-ARDEC***
 - ***USAF WR-ALC/LBRE***
 - ***USAF WR-ALC/EN***
 - ***NAVAIR-NADEP Jacksonville***
 - ***NAVAIR-NADEP Cherry Point***
 - ***NAVAIR-NADEP North Island***
 - ***US Coast Guard***
 - ***The Boeing Company***
 - ***Advanced Chemistry & Technology***
- Mr. Jim Mazza
Mr. Matt Tillman
Mr. Bill De Piero
Mr. Jay Fiebig
Mr. Bill Schweinberg
Dr. Don Knapp
Mr. Bill Alexander
Mr. Doug Perl
LCDR Werner Winz
Dr. Kay Blohowiak
Mr. Stephane Pyrek

AFRL/MLSA



NAVAIR



TACOM-ARDEC



Environmental Reduction Targets

Boeing Technology

- **Aluminum**

- Pasa-Jell 105
 - Hexavalent Chromium, Sulfuric Acid, Contaminated Waste Water
- FPL Etch
 - Hexavalent Chromium, Sulfuric Acid, Contaminated Waste Water

- **Titanium**

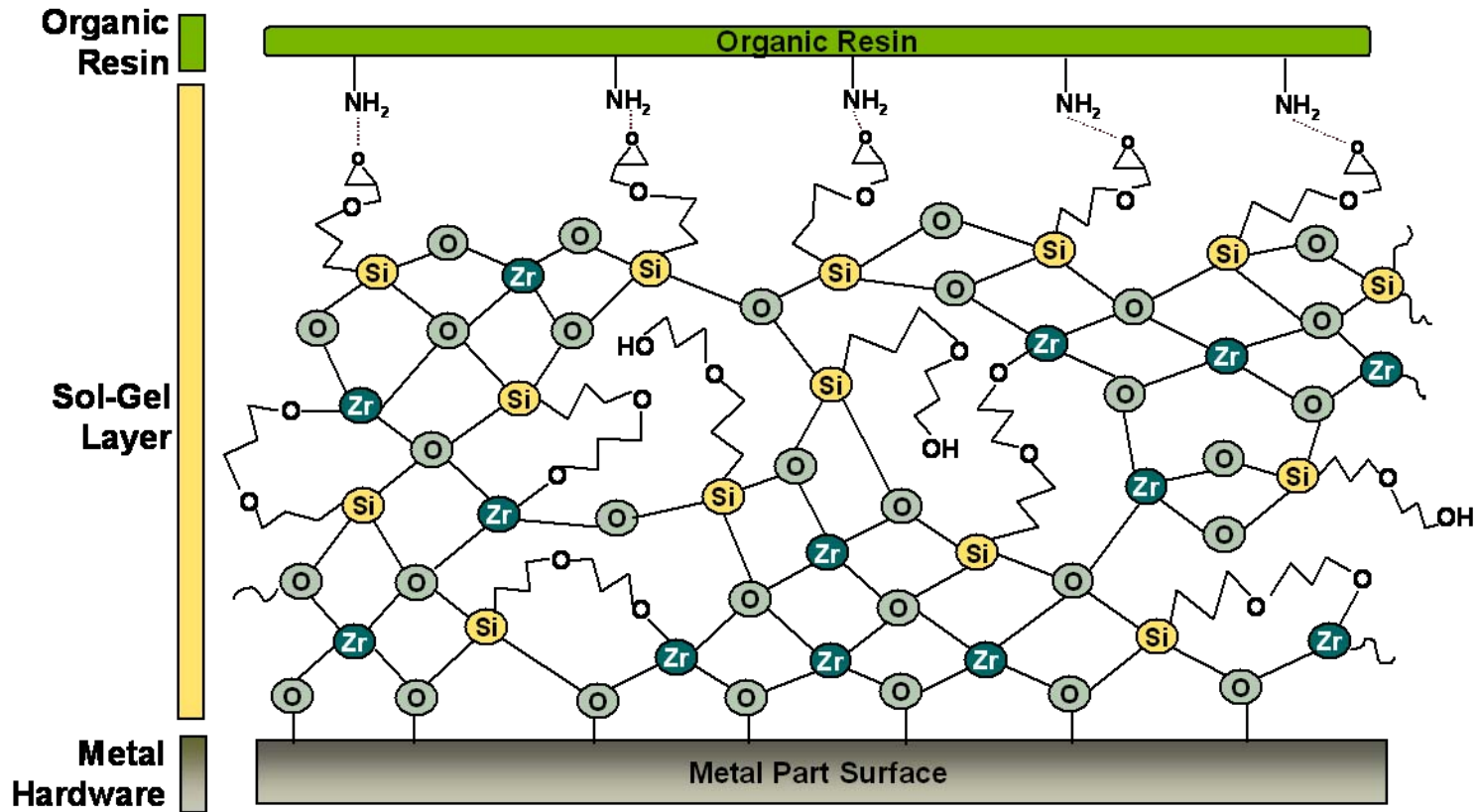
- Chromic Acid Anodizing
 - Hexavalent Chromium, Hydrofluoric Acid, Contaminated Waste Water
- Phosphate Fluoride Etch
 - Hydrofluoric Acid, Phosphoric Acid, Contaminated Waste Water
- Pasa-Jell 107
 - Hexavalent Chromium, Chromic Acid, Nitric Acid, Hydrofluorosilicic Acid, Contaminated Waste Water

- **Steel**

- Ferric Chloride/Hydrochloric Acid Etch
 - Hydrochloric Acid, Sulfuric Acid, Contaminated Waste Water

Designed Sol-Gel Interface

Boeing Technology



- Tailorable to different resin/paint chemistries
- Robust process conditions
- Greater range of properties using inorganic and hybrid polymers than current state-of-the art systems

Repair vs. OEM

Boeing Technology

- Typically better controls at manufacturing level
 - Environmental controls
 - QC/inspection methods
- Fewer tools/materials available in field
- Training/certification
- New clean parts vs. dirty old parts
- Access to repair area
- Potential damage to areas adjacent to repair

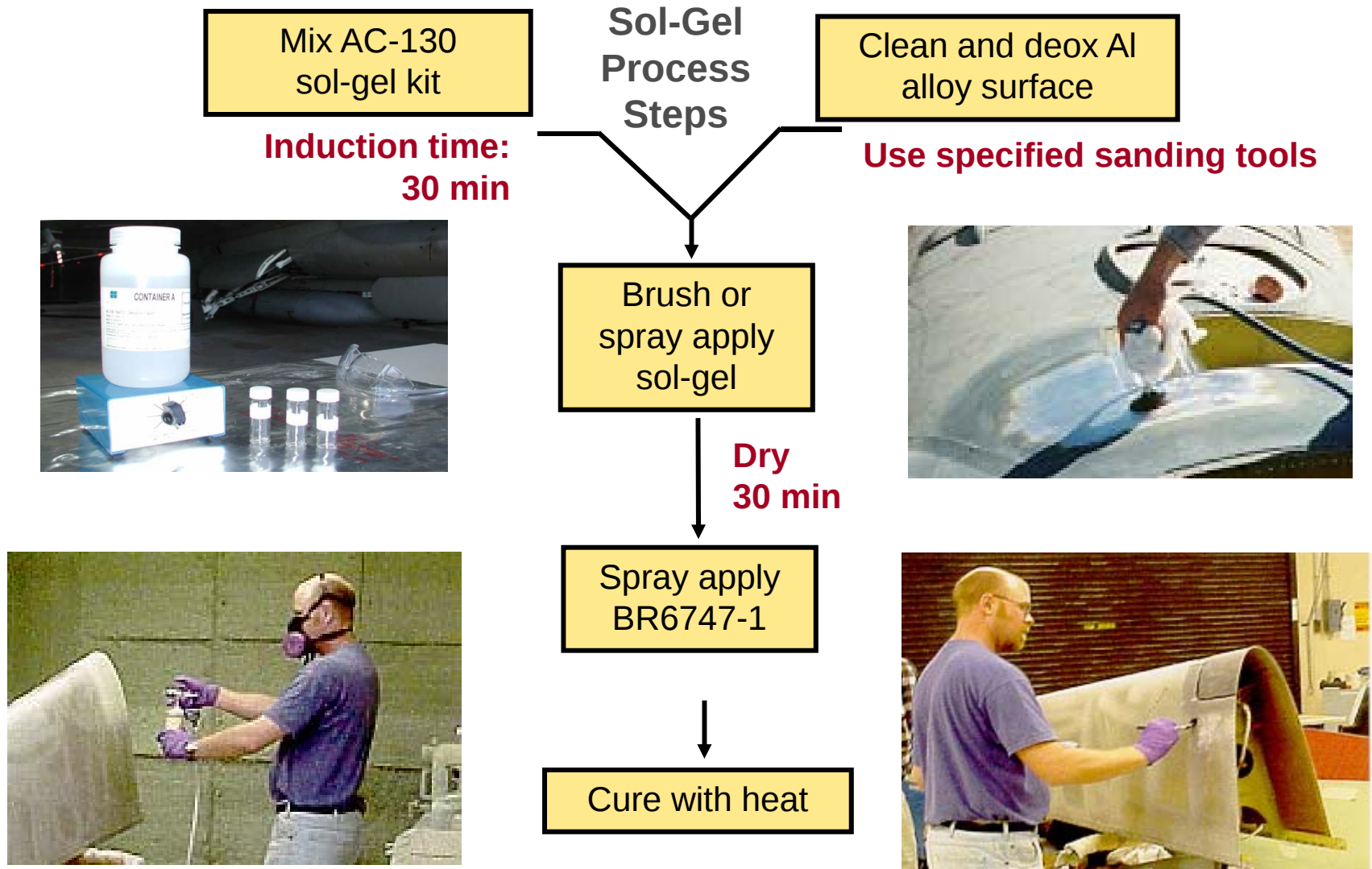


Why we repair...



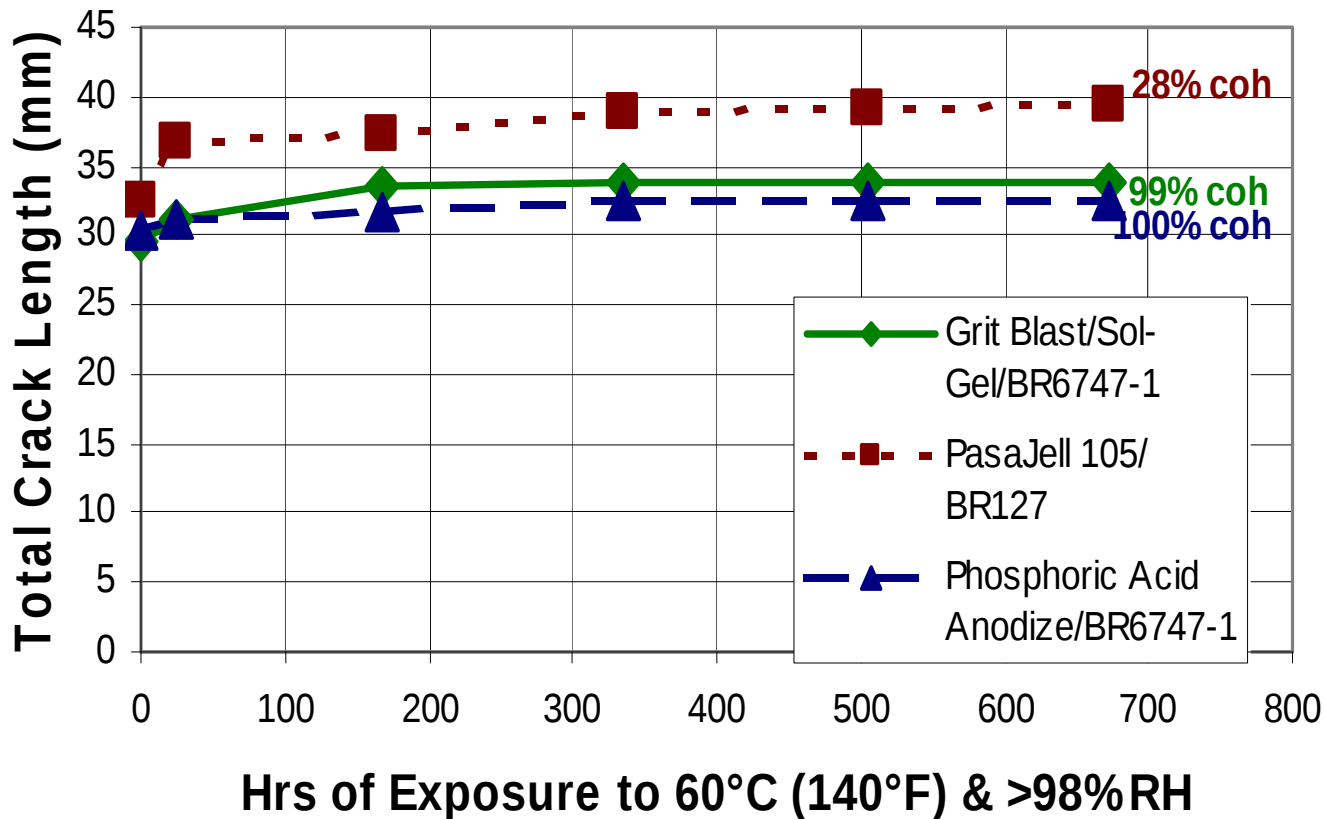


Sol-Gel Process Conditions





Surface Treatment Comparison



Grit blast treatment prior to sol-gel gives a comparable result to PAA pretreatment, but is more difficult than manual abrasion in field repair applications.



WR-ALC TESTING



THERMAL SHOCK



FATIGUE



**STATIC STRESS
DURABILITY**





Examples of Repair Implementations



•C-5 Applications:

- Flaps, Ailerons, Engine Pylon Panels, Floorboards, Torque Deck, Fuselage, Bulkheads, Ramps
- Depot Level, Off-Aircraft Repair



•CH-46 and CH-47 Ti and Al:

- Rotor blade caps, erosion strips, underfloor corrosion repairs



•V-22 Al Repairs



•F-16 Al Repairs



•F-18 Al and Ti Repairs



•C-130 Al Repairs



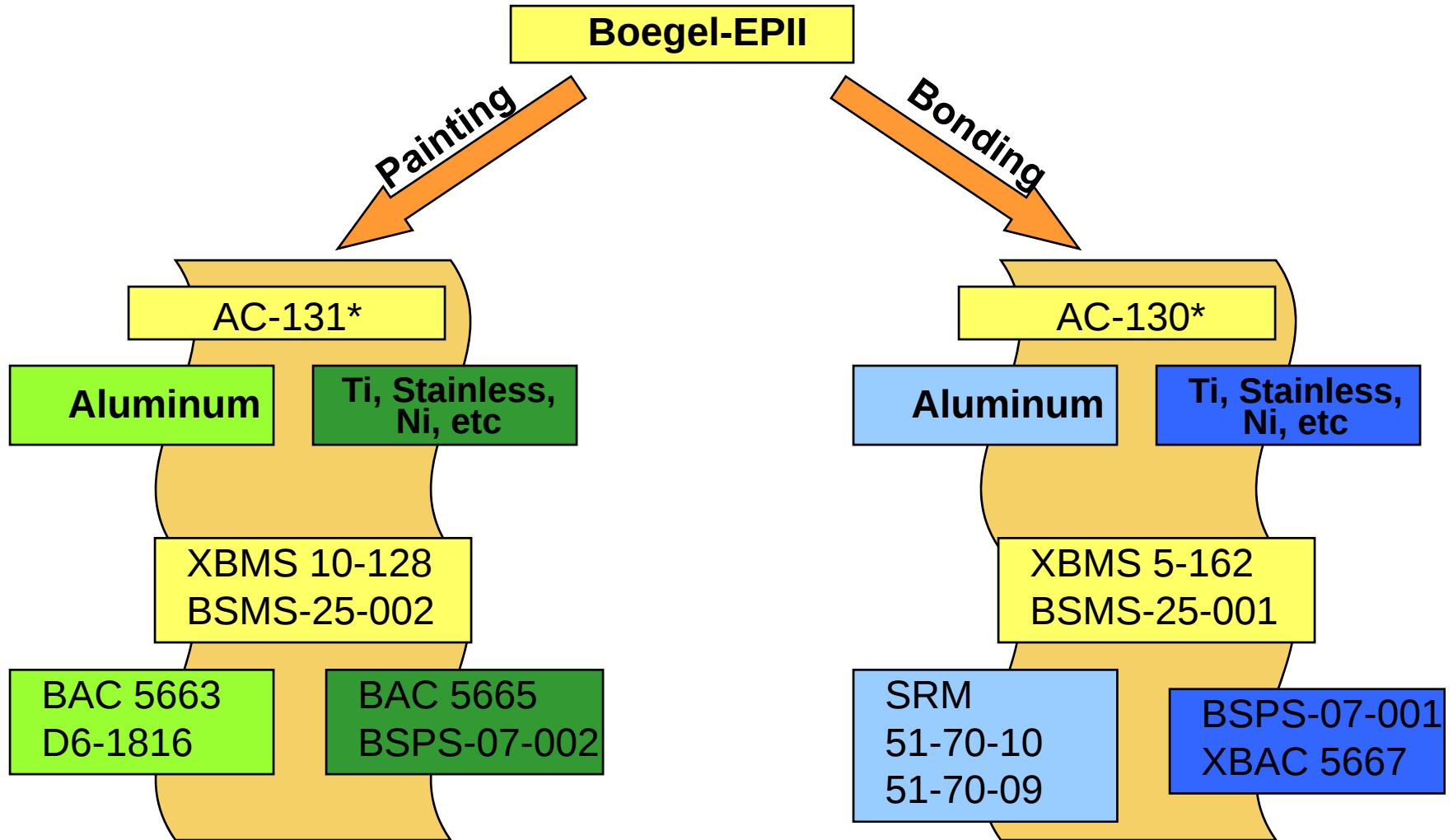
•B-1 Stainless Repair



•F-22 Ti Repairs

OEM Sol-Gel Non-Cr Conversion Coatings

Boeing Technology



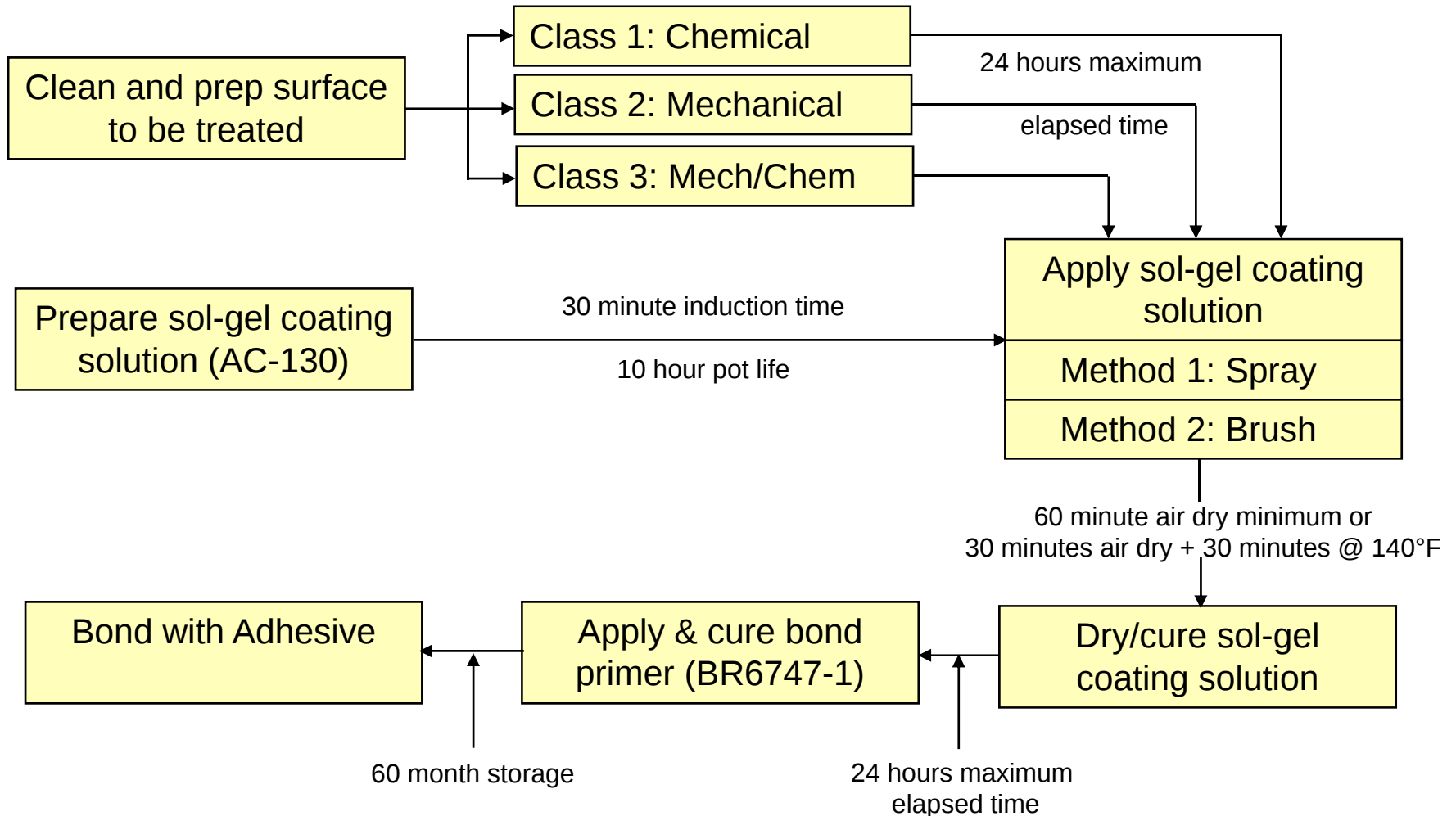
Qualification Test Matrix

Boeing Technology

TEST	TEST METHOD	TEST PROCEDURE	No. of Specimens*	MINIMUM REQUIREMENT
Lap Shear at 75 ± 5°F	BSS7202	BSS7202 Type V	10	4200 psi
Lap Shear at -67 ± 2°F	BSS7202	BSS7202 Type V	10	4200 psi
Lap Shear at 180 ± 5°F	BSS7202	BSS7202 Type V	10	3100 psi
Lap Shear at 250 ± 5°F	BSS7202	BSS7202 Type V	10	650 psi
Lap Shear at 75 ± 5°F after 30 days at 120 ± 5°F and 100% Relative Humidity	BSS7211 BSS7202	BSS7202 Type V	10	4200 psi
Lap Shear at 75 ± 5°F after 30 days salt spray exposure at 95 ± 5°F	BSS7210 BSS7202	BSS7202 Type V	10	3100 psi
Lap Shear at 75 ± 5°F after 7 days immersion in Jet A fuel at 75 ± 5°F	BSS7212 BSS7202	BSS7202 Type V	10	4200 psi
Lap Shear at 75 ± 5°F after 7 days immersion in Reference Fuel B at 75 ± 5°F	BSS7212 BSS7202	BSS7202 Type V	10	4200 psi
Lap Shear at 75 ± 5°F after 7 days immersion in BMS3-11 at 150 ± 5°F	BSS7212 BSS7202	BSS7202 Type V	10	4200 psi
Lap Fatigue at 75 ± 5°F	BSS7201	BSS7202 Type IIIA	3	10 ⁷ cycles at 1500 psi
Sustained Stress Loading at 140 ± 5°F and 100% Relative Humidity	BSS7209	BSS7202 Type V	10	90 days at 900 psi
Metal to Metal Climbing Drum Peel	BSS7206	BSS7206 Type II	10	25 lbf/in width
Wedge Crack after 7 days at 140 ± 5°F and 95% Relative Humidity	BSS7202	ASTM D3762	10	<0.25 inch crack growth >90% cohesive failure

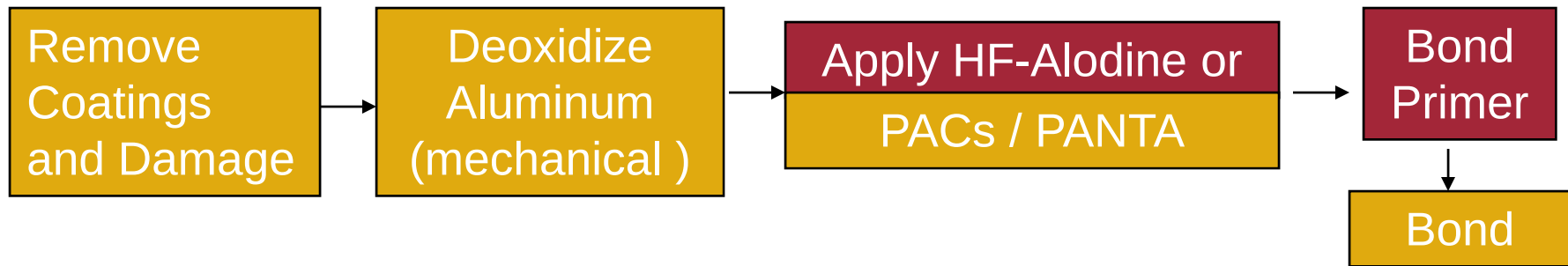
*per batch for three batches for qualification

Sol-Gel Process Steps



BCA Adhesive Bonding Repair Process

Boeing Technology

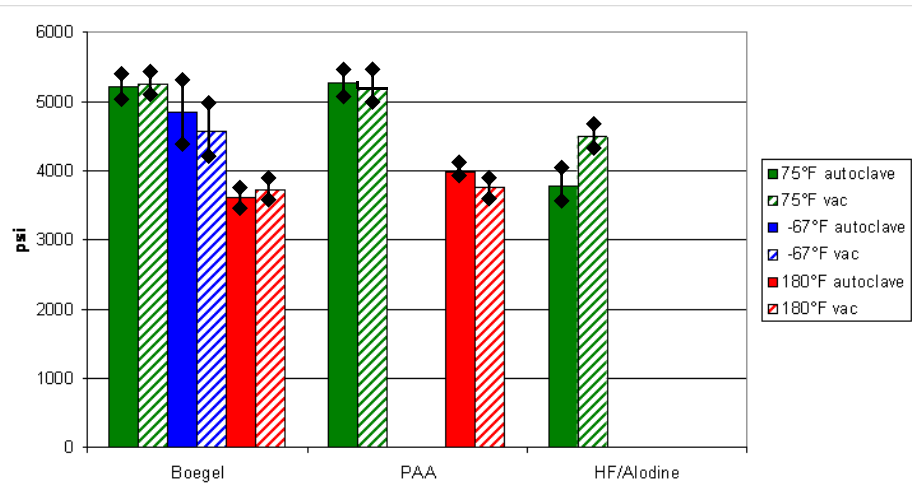


- Added as an option to SRM 51-70-09 and 51-70-10 Implemented 2005-2006
 - Al 250F-cure repairs w/BMS 5-101
 - Al 350F-cure repairs w/BMS 5-137
 - Titanium repairs
- Only BMS 5-89 Ty II (Cytec BR 6747-1) allowed with Boegel-EPII
 - Compatibility of water-based product with sol-gel
- Goal: Replace HF/Alodine in fleet repairs
 - Health/Safety/Hazmat
 - Improved Durability
- Reduce process repair time/cost over anodize repair methods
- Uses specific abrasive materials and tools
- Robust process methods

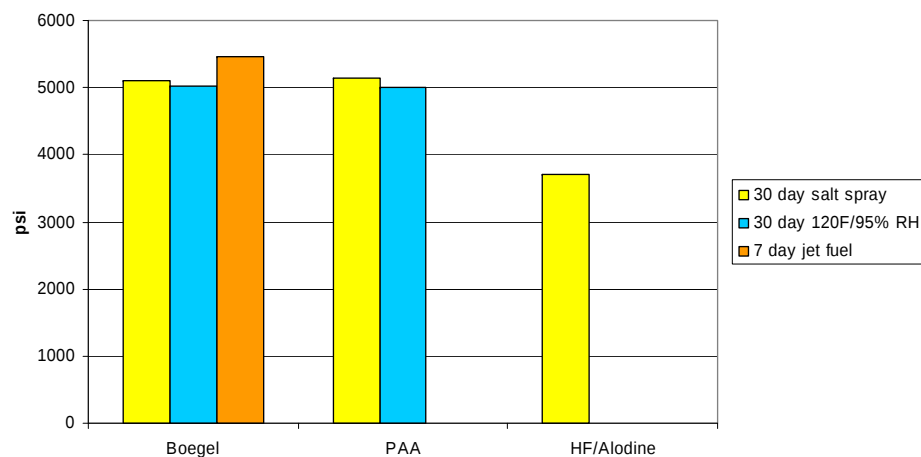
Performance Comparisons

Boeing Technology

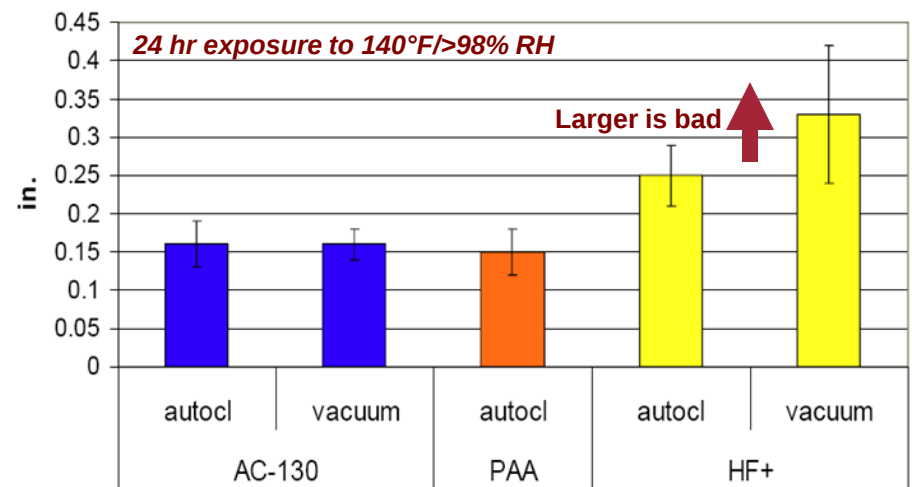
Lap Shear Testing



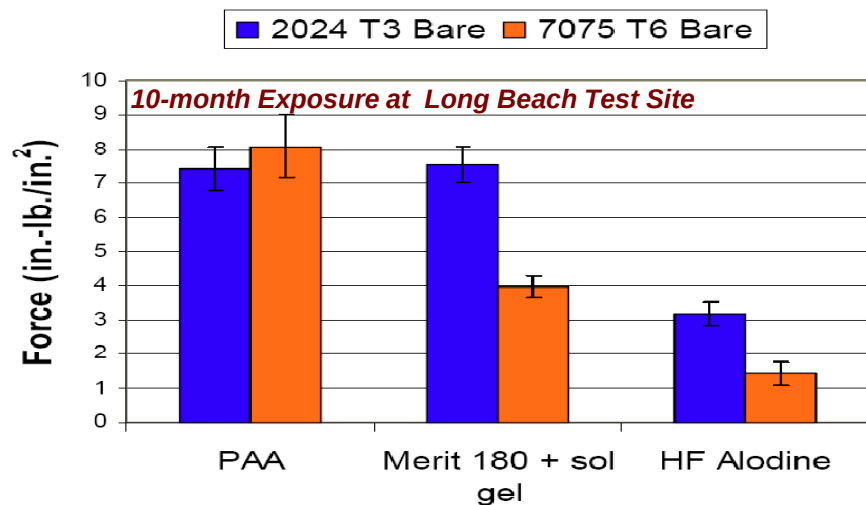
Lap Shear with Environmental Exposure



Wedge Crack Durability



DCB Extended Durability Tests



BCA Repair Implementation

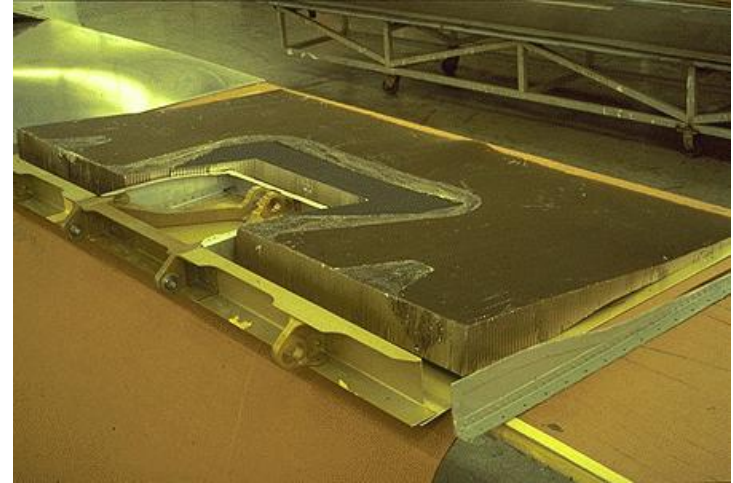
Boeing Technology

- **Implemented in the Boeing Commercial Structural Repair Manuals in 2005**
 - **Metalbond Working Group**
 - Airlines, Boeing R&D, Service Engineering, DERs
- **Aluminum 250F repairs first**
 - Added 350F Al repairs
 - Added Ti repairs
- **Feedback from airline users good**
 - Cost savings
 - Process robustness
 - Wanted some improvements

Boegel-EPII for Al Bonding Updates

Boeing Technology

- Added new sandpaper alternatives for use in Al bonded repairs
 - 3M 361F, 300D, 777F, 900DZ
 - Merit ALO Resin Bond
- Incorporated 2-part Boegel kits (AC-130-2) into BCA SRMs
 - More stable shelf-life
 - Easier shipping to overseas locations
 - More robust, easier to use
 - Equivalent performance and durability
- Working on draft BMS/BAC for internal OEM Al bonding applications
- Testing new nonchromated adhesive bond primers
 - Cytec BR6747-1NC
 - Cytec BR6700-1 (sol-gel compatible)
 - Initial data promising



Adhesive Bond Repair



Composite Patch Repair

Future Work – Deoxidation Methods

Boeing Technology

- **Alternatives to Abrasive Deoxidation Methods**
 - Improve robustness of process
 - Reproducibility over larger areas
 - Evaluate energetic techniques
 - Plasma
 - Laser

Future Work – Bond Primer

Boeing Technology

- **Non-Chromated Adhesive Bond Primers**
 - Preliminary data on 3M and Cytec candidates
 - Compatibility with Multiple Surface Prep Methods
 - PAA
 - Sol-Gel
 - Corrosion Protection within Bondline and Outside of Bondline
 - Non-Aluminum Applications
 - Want one primer for all
 - Industry Team
 - March Telecon; Spring 2008 SAMPE meeting
 - Contact kay.y.blohowiak@boeing.com to get on the distribution list for participation

Future Work – Other Bonded System Improvements

Boeing Technology

- **Composites bonding**
 - **Reduce haz/mats used**
- **Improved Adhesive Systems**
 - **Improved durability – longer life**

