Qualification, Demonstration & Validation of Compliant

Removers for Aircraft Sealants and Specialty Coatings ESTCP WP-0621

NDIA Environment, Energy Security, and Sustainability Symposium and Exhibition Denver, CO, June 14-17, 2010

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PROJECT TEAM

• Air Force

- Mr. Alan Fletcher, PI (AFRL/RXSA)
- Mr. Jeff Kingsley (AFRL/RXSA)
- Mr. David Tanner (OC-ALC)
- Mr. Jerome Jenkins (OO-ALC) DEM/VAL at Hill AFB

Navy

- Ms. Diane Kleinschmidt, Navy Lead (NAVAIR)
- Mr. Brad Youngers (FRC-SE) DEM/VAL at FRC-SE
- Mr. Don Harmston (NADEP North Island)
- Mr. Jack Fennell (NADEP Cherry Point) DEM/VAL at MCAS New River/MCCS Cherry Point

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- Mr. Jim Tankersley, Program Coordinator
- Mr. John Stropki, DEM/VAL Coordinator

• UDRI

- Ms. Susan Saliba
- Mr. John Dues

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TECHNICAL OBJECTIVES

Objective:

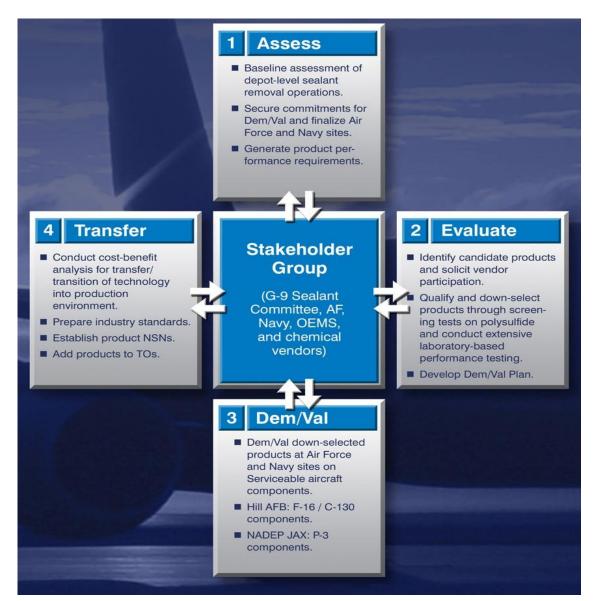
- To demonstrate and validate performance of COTS environmentally friendly *(contains no TRI chemicals, no HAPs, or chlorinated compounds)* chemical strippers for use on MIL-SPEC sealants and specialty coatings
- Conduct a field-level Demonstration/Validation of nonmechanical processes for removing sealants and specialty coatings from metallic aircraft structures
- Reduce Environmental Burdens
- Increase Performance
- Control Costs



TECHNICAL APROACH

- Phase I (FY06, FY07)
 - Polysulfide and silicone sealants
 - Dem/Val 1 at Hill AFB
 - F-16, C-130
 - Dem/Val 2 at FRCSE
 - P-3 OML
- Phase II (FY08, FY09)
 - Polythioether and polyurethane sealants
 - Dem/Val 3 at New River MCAS
 - V-22 Osprey

TECHNICAL APROACH



"Toolbox" Approach:

Provide end users with materials/methods to approach sealant removal tasks consistently and effectively, depending upon situation.



TECHNICAL APROACH

Task 1. Technology Demonstration Plan

- Establish stakeholder team
- Draft technology demonstration plan

Task 2. Technology Qualification

- Establish qualification test plan
- Screening tests for strippers supplied by vendors
- Comprehensive testing for down-selected strippers

Task 3. Technology Validation

- Demonstration on condemned and serviceable parts
- Task 4. Technology Transfer
 - Draft technology transfer plan
 - Assist in writing changes to Tech Orders
 - Establish NSNs for strippers
- Task 5. Regulatory Data/Support



ESTCP approved project expansion in FY08/FY09

- Polythioether/urethane sealants and specialty coatings
- Define materials compatibility with composite structures and specialty coatings
- Goal is to qualify more elements for use in field-level repairs using the "toolbox" approach
- Sealant team benefits from significant input/cooperation from vendor stakeholders

Team capitalizing on "lessons learned" from Phase I efforts to apply to expanded testing and demonstration validation on additional sealants and substrates in FY08/FY09

- Conducted baseline survey/analysis completed by USAF and USN stakeholders (Sept. 06, updated Nov. 08)
- Requirements Definition Drafted (Sept. 06, currently updating for Phase II)
- Selected and Finalized Demonstration Sites (Oct. 06)
 - OO-ALC, UT (Phase I January 2008)
 - NADEP JAX, FL (Phase I April 2008)
 - MCAS New River, NC (Phase II January 2010)
- Completed Phase I Report (November 2008)

- Technology Demonstration Plan (Draft March 07; Final June 07)
- Product Testing to Requirements Definition (Jan. 08)
- Demonstration Validation at OO-ALC (Feb. 08)
 - F-16 Wing Spar/Pylons
 - A-10 Wing IML
 - C-130 Sloping Longeron
- Demonstration/Validation at FRC-SE (Mar. 08)
 - P-3 OML
 - P-3 Wing tank components
 - EA-6B Canopy Structure

Demonstration/Validation at MCAS New River (Jan. 2010)

– V-22 Osprey Wing Components and OML



Phase I Laboratory Demonstration Tests (UDRI)

Sealant Materials

- PR-1422 B-2 (Polysulfide) AMS-S-8802
- PR-1750 B-2 (Polysulfide) AMS 3276
- PR-1826 B-2 (Polythioether) AMS 3277

Coated Substrates

- MIL-C-27725 (Polyurethane)
- MIL-PRF-23377 (Epoxy Primer)
- BMS 10-20 (Epoxy Primer)

Uncoated Substrates

- AMS 2471 (Anodized Aluminum)
- AMS 4911 (Titanium)
- AS-4/3501-6 (Graphite/Epoxy)
- IM-7/5250-4 (Graphite/Bismaleimide)

Laboratory Demonstration Tests (UDRI) - Testing Protocols

Parameter	Test	Test Method
Sealant Removal	Force Measuring Unit	UDRI Proprietary
Substrate Damage Potential	Visual	Fourier Transform Infrared
		Microscopy (FTIR)
	Discoloration (metallic)	ASTM G 1
	Pitting (metallic)	ASTM G-46
	Visual - 100X (composite)	Scanning Electron
		Microscopy (SEM)
	Interlaminar Shear Strength	ASTM D 2344
	Tensile Strength	ASTM E 8
Surface Residue	Pencil Hardness	MIL-C-83286A
	Tape Adhesion	FED STD 141, Method
		6301
Re-Adherence	Peel Strength	AS 5127

Note: Removal methods included application of respective chemical removers w/ and w/o automated (powered) scrapers

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Summary of Phase I Laboratory Results

- Solutia SkyKleen 2000 did not appreciably affect any of the coatings
- Poly-Gone 300 locally damaged the BMS 10-20 topcoat
- Neither paint remover affected the pencil hardness and tape test results after stripping
- AMS-2471 and AMS-4911 tensile and % elongation properties were <u>not</u> affected by either stripper
- The results of the interlaminar shear strength were <u>not</u> affected by either paint remover
- The SEM photos at 100X were inconclusive, therefore, select specimens being evaluated at 500X to determine if there was damage caused by either the paint remover or hand held tool
- Substrates stripped with Solutia SkyKleen 2000 had 100% cohesive failures on all substrates with all sealants, except PR 1750 B-2/AMS-2471 which was 95% cohesive
- Substrates stripped with Poly-Gone 300 did <u>not</u> have 100% cohesive failure on the majority of the substrates with sealants PR 1422 B-2 and PR 1750 B-2
- Both paint removers did <u>not</u> cause a change in lap shear test results

Phase I DEM/VAL Site Locations Air Force Test Site

- Hill AFB (Ogden UT; February 12 14, 2008)
 - C-130 sloping longeron (OML)
 - F-16 and A-10 wing/wing component parts (IML)

Navy Test Sites

- FRC-SE (Jacksonville FL; March 26, 27, 2008)
 - P-3 Aircraft structures (OML)
 - Selection based on end-user application

OO-ALC Demonstration/Validation Summary

• F-16

- When coupled with Cold Jet, both removers showed potential to reduce stripping operations by 50%
- Easier clean-up with SkyKleen 2000

• C-130

 Both products worked adequately, but did not improve the current method (methylene chloride – 2 hr. dwell); however, PPE and evacuation of area is required with current method

• A-10

- Center wing spar tested, but neither stripper was preferred to the current method due to dwell time requirement and methodology
- All
 - Viscosity is key to successful removal of sealant from vertical surfaces and seems to aid in clean-up

FRC-SE JAX Demonstration/Validation Summary

- Applied Poly-Gone 300 to OML of P-3 Aircraft
 - Used varying viscosities (Gel;Liq 2:1, 1:1, 0:1)
 - Dwell time ~4 hrs.
 - Removal using pressurized water not as effective as anticipated
- SkyKleen 2000 applied at later date by USN personnel
 - Dwell time ~5-6 hrs.
 - Greater viscosity than Poly-Gone slurry
 - Removal using pressurized water not as effective as Poly-Gone 300

Lessons Learned

- When possible, apply when longer dwell time can be taken advantage of (possibly overnight)
- Refine viscosities for greater effectiveness
- Refine removal method, possibly with knife edge water jet nozzle, to increase effectiveness of pressurized removal

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Cost Analysis - Phase I

Comparison of P-3 Aircraft Desealing Process Costs (based on 25 aircraft/yr)

		Baseline Scenario Mechanical Desealing	Alternative Scenario Chemical + Mechanical Desealing
Initial Investment Cost			
Capital Equipment		N/A	N/A
Annual Operating Cost			
Direct Labor Direct Materials: Aluminum tape/aircraft (unit \$) Sanding disks/aircraft (unit \$) Plastic and SS wire scrapers (unit \$) Desealant chemical (unit \$)	Total	\$192,000 \$37,500 \$25,000 \$5,000 \$7,500 \$0 \$229,500	\$96,000 \$69,500 \$12,500 \$1,000 \$1,000 \$55,000 \$165,000
Utilities: Electric Steam/Rinse Water	Total	\$2,400	\$2,400
Waste Management: Non-Hazardous Waste Disposal Wastewater Treatment/Disposal Wastewater: Hazardous Waste Wastewater: Sludge	Total	Negligible \$85,200 \$2,936 \$4,607 \$92,743	Negligible \$85,200 \$2,936 \$4,607 \$92,743
Environmental Compliance Recurring Cost		N/A	N/A

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Cost Analysis - Phase I

Comparison of F-16 Aircraft Lower Wing Desealing Process Costs (based on three aircraft wings/month)

		Baseline Scenario Mechanical + CO ₂ Desealing	Alternative Scenario Chemical + CO_2 Desealing
Initial Investment Cost			
Capital Equipment		N/A	N/A
Annual Operating Cost	I		
Direct Labor Direct Materials: Aluminum tape/aircraft (unit \$) Rotary brushes/aircraft (unit \$) Plastic scrapers/aircraft (unit \$) Dry ice pellets/aircraft (unit \$) Desealant chemical/aircraft (unit \$)	Total	\$21,600 \$6,750 \$0 \$0 \$600 \$6,150 \$0 \$28,350	\$12,960 \$8,100 \$0 \$300 \$4,500 \$3,300 \$21,060
Utilities: Rinse Water		\$0	\$0
Waste Management: Non-Hazardous Waste Disposal Wastewater Treatment/Disposal Hazardous Waste/Disposal Sludge/Disposal	Total	Negligible N/A \$375 \$0 \$375	Negligible N/A \$146 \$300 \$581
Environmental Compliance Recurring Cost		N/A	N/A



Cost Analysis - Phase I

Comparison of C-130 Sloping Longeron Desealing Process Costs (based on 4 aircraft/month)

	Baseline Scenario Chemical + Mechanical Desealing	Alternative Scenario Chemical + Mechanical Desealing
Initial Investment Cost		
Capital Equipment	N/A	N/A
Annual Operating Cost		
Direct Labor Direct Materials: Tarping and rags/aircraft (unit \$) Plastic scrapers/aircraft (unit \$) Desealant chemical/aircraft (unit \$) Te	\$3,840 \$1,090 \$400 \$400 \$290 \$4,930	\$3,840 \$2,650 \$1,000 \$400 \$1,250 \$7,450
Utilities: Rinse Water	Negligible	Negligible
Waste Management: Non-Hazardous Waste Disposal Solid Waste Treatment/Disposal Hazardous Liquid Waste/Disposal Sludge/Disposal Te	\$250 N/A \$275 N/A \$475	\$250 N/A \$146 N/A \$396
Environmental Compliance Recurring Cost	N/A	N/A

Cost Analysis - Phase I Summary

- P-3 Outer Moldline
 - Potential to save \$64,500 annually (based on throughput of 25 A/C)
 - Annual savings likely less due to depot scheduling requirements
- F-16 Component Parts (lower wing)
 - Potential annual savings of \$7,046 (based on three aircraft/wings per month)
 - Savings could be significantly greater if throughput is doubled, as data indicate
- C-130 Sloping Longeron
 - Increase in annual cost (~\$7K) can be recovered through manpower efficiency and possible increased throughput

Down-selected candidate sealant removers for Phase II

- Test Panels
 - 4 in. x 6 in. x 0.032 in. unclad 2024-T3 aluminum alloy
- Sealants
 - Polythioether
 - SAE AMS 3277D, PR-1826, CI B
 - Polyurethane
 - SAE AMS 3278A, EFC-100/EF-5992
- Removers Qualified
 - Elixair Sky Restore
 - Solutia SkyKleen 2000

Phase II Laboratory Demonstration Tests (UDRI)

• PR 1826 B-2 polythioether sealant (qualified to AMS 3277)

Coating or Substrate	Туре
MIL-PRF-27725	Polyurethane
AS4/3501	Epoxy Graphite
IM-7/5250-4	BMI

Preliminary Phase II Laboratory Results

- Elixair[®] SkyRestore and Solutia SkyKleen sealant removers did not chemically degrade the MIL-PRF-27725 coating nor either of the two composite substrates
- Neither remover affected the pencil hardness and tape test results after stripping
- Both removers had 100% cohesive failures on AS4/3501 and IM-7/5250-4

Additional laboratory results, and laboratory results on polyurethane sealants, pending

MCAS New River Demonstration/Validation

Summary of Individual Test Areas Along Upper Surfaces of V-22 Wing Section

Test Area Identification	Approximate Length, in.	Condition	Approximate Dwell Time, hr.
	9	Scored	2
Area 1 Skyrestore	9	Unscored	2
	9	Scored	4
Area 2 Skyrestore	9	Unscored	4
Area 3 Skyrestore	12	Unscored	6
	9	Scored	6
Area 1 Skykleen	9	Unscored	6
	9	Scored	22
Area 2 Skykleen	9	Unscored	22

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MCAS New River Demonstration/Validation

Sealant Removal Times for Sealants Processed with Skykleen Remover

Test Area Identification	Approximate Surface Area, in ² .		Approximate Dwell Time, hrs.	Approximate Removal Rate, in ² / min.
		Condition		
	2.25	Scored	6	0.520
Area 1	2.25	Unscored	6	0.562
	2.25	Scored	22	0.843
Area 2	2.25	Unscored	22	1.25
Control	2.25	Unscored	N/A	1.58

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MCAS New River Demonstration/Validation

Sealant Removal Times for Sealants Processed with SkyRestore Remover

Test Area Identification	Approximate Surface Area, in ² .	Condition	Approximate Dwell Time, hrs.	Approximate Removal Rate, in ² /min.
	2.25	Scored	2	.225
Area 1	2.25	Unscored	2	.225
	2.25	Scored	4	2.25
Area 2	2.25	Unscored	4	.900
Area 3	3.00	Unscored	6	.901

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MCAS New River Demonstration/Validation Summary

Dem/Val conducted at MCAS New River, NC (January 26, 27, 2010)

- Elixair Sky Restore and Solutia SkyKleen 2000 demonstrated on V-22 Osprey components
 - Fixed Wing Structure
 - Outer Mold Line Elements
- Dem/Val conditions affected outcomes
 - Unheated hangar resulted in dwell temperatures <40°F, possibly effecting remover efficiency
 - Sky Restore exceeded performance of SkyKleen 2000 at more desirable dwell times

Controlled Temperature Test

Test Matrix and Sample Specifications

Sample #	Sealant	Sealant Surface Area (in²)	Sealant Thickness (mils)	Chemical Remover	Remover (grams)	Remover Dwell (hrs)	Temp. (°F)	Coverage (grams/in²)
1	PR1826, Class B	7.1875	66.10	Skykleen	11.34	20	35	1.58
2	PR1826, Class B	7.1875	65.87	Skyrestore	11.26	6	35	1.57
3	PR1826, Class B	7.1875	60.33	Skykleen	11.69	20	50	1.63
4	PR1826, Class B	7.1875	65.23	Skyrestore	11.76	6	50	1.64
5	PR1826, Class B	7.1875	65.60	Skykleen	11.67	20	70	1.62
6	PR1826, Class B	7.1875	64.13	Skyrestore	11.75	6	70	1.63

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Controlled Temperature Test

Removal rates for each test sample according to the subjected temperature

Sample #	Chemical Remover	Remover Dwell (hours)	Temperature (°F)	Removal Time (min:sec)	Strip Rate (in²/min)
1	Claddaan	20	25	10.52	0.20
1	Skykleen	20	35	19:53	0.36
2	Skyrestore	6	35	15:41	0.46
3	Skykleen	20	50	5:52	1.23
4	Skyrestore	6	50	5:25	1.33
5	Skykleen	20	70	2:22	3.04
6	Skyrestore	6	70	9:41	0.74



MCCS Cherry Point Demonstration/Validation Summary

Dem/Val conducted at MCCS Cherry Point, NC (June 3, 4, 2010)

- Elixair Sky Restore and Solutia SkyKleen 2000 demonstrated on AV-* Harrier components
 - Fixed Wing Structure

Results pending at time of briefing submission

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TECHNOLOGY TRANSFER

- Prepare Industry Standard for Removers
- Establish NSNs for Removers
- Add Removers to Tech Orders
 - TO 1-1-3 fuel tank repair
 - TO 1-1-8 coating application
 - TO 1-1-691 cleaning/coating application
- Communication of DEM/VAL Results Across DoD and Industry
 - Quarterly and final reports
 - Preparation of draft Process Order
 - Presentations at conferences and meetings
 - Life-Cycle Cost Analysis
- Approach for obtaining DoD and regulatory acceptance
 - Air Force and Navy Materials Safety Organizations
 - Chemical company chemical registration



PolyGone 310 AG Corrosion Testing

- Concerns with sandwich corrosion testing on PolyGone 300 AG (Phase I)
 - RPM technology responded by modifying COTS formula
 - Submitted new formulation to NAVAIR for additional testing (PAX River)

PolyGone 310 AG Corrosion Testing Results

- <u>Sandwich Corrosion</u>: No corrosion observed on 2024 and 7075 coupons
- <u>Hydrogen Embrittlement</u>: Four test specimens exceeded 75% NFS sustained load for 200 hours
- <u>Effects on Painted Surfaces</u>: Product performed complete coating removal within 30 minutes
- <u>Total Immersion Corrosion</u>: Product met corrosion limits as specified

Test	Specification	Results			
Sandwich Corrosion	ASTM F1110	*			
Hydrogen Embrittlement	ASTM F519	V			
Effects on Painted Surfaces	ASTM F502	\sim			
Total Immersion Corrosion	ASTM F484	\checkmark			
PolyGone 310 AG now being considered as compliant coating remover by USAF					

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UPCOMING ACTIVITIES

Complete remaining laboratory testing (UDRI)

- Remaining polythioether data
- Polysulfide data
- Assess and report on MCCS Cherry Point dem/val for polythioether sealants
 - Schedule of dem/val reports dictated by remedial action plan

Complete Draft Final Report

- Submission dependent on schedule for additional dem/val
- Incorporate Phase I/Phase II activities