



# HVOF TECHNOLOGY INSERTION



# ADVANCED COATING REMOVAL

**DemVal, Inc. & Aeromet Technologies, Inc.**

**HCAT**

San Diego, CA 25 January 2006

**DemVal, Inc.**

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17 Richard Place, Suite 2475 • Ronkonkoma, NY 11779

Phone/Fax: 202-521-4060

[www.demval.com](http://www.demval.com) • [info@demval.com](mailto:info@demval.com)

# Report Documentation Page

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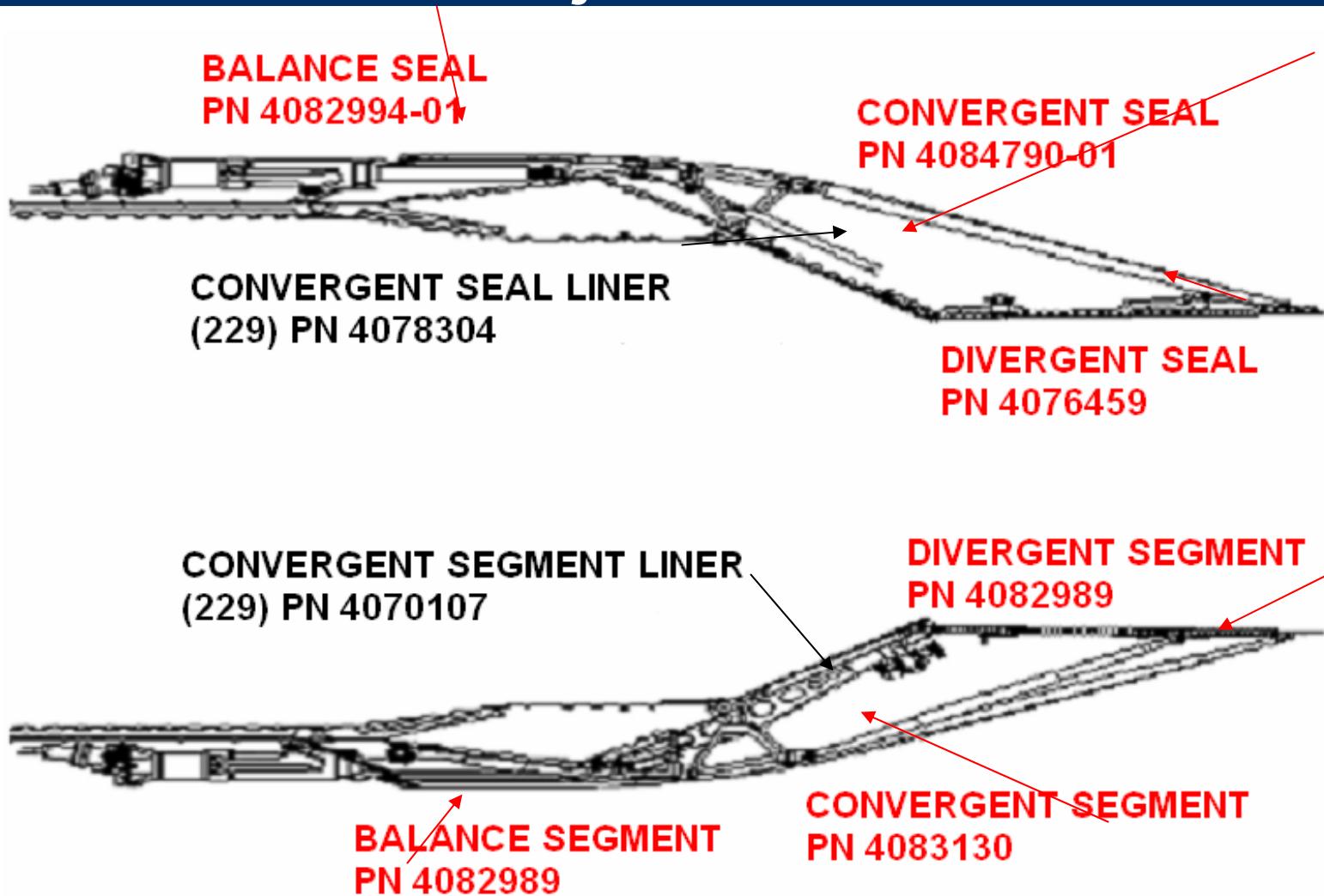
# HVOF Technology Insertion

- Life Extension For P&W F100 Components
- Upgrade existing wear coatings
  - Meet new 4300 TAC target
  - Qualify non-proprietary alternatives
- Project Partners
  - OC-ALC Tinker AFB
  - Anteon Corporation
  - Hitemco

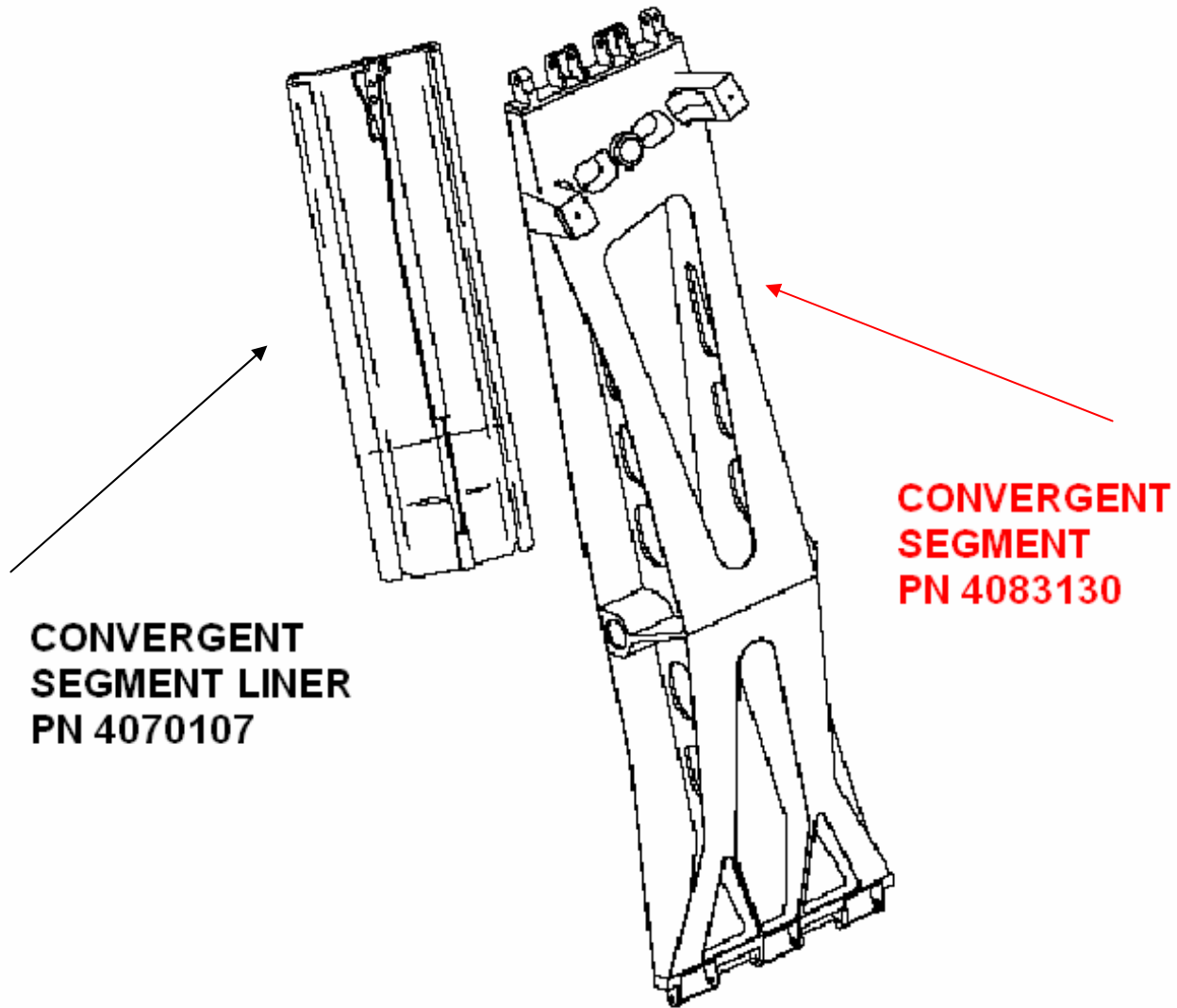
# HVOF Technology Insertion

- Qualify alternative wear coatings for
  - PWA 53-1 (WC-Co), PWA 53-5 (CrCNiCr)
    - Old technology plasma, disallowed by OC-ALC
  - PWA 256-1,(WC-Co), PWA 256-2 (CrCNiCr)
    - Preferred coating(s) however proprietary to Pratt: few qualified vendors
- Replace with
  - 701HE (WC-Co), 702HE (CrCNiCr)
    - Developed by Hitemco, agreed to transfer rights to Government
  - HVOF - AMS 2447-8 (WC-Co), AMS 2447-3 (CrCNiCr)
    - Non-proprietary, better performance than any of the above

# Project Parts



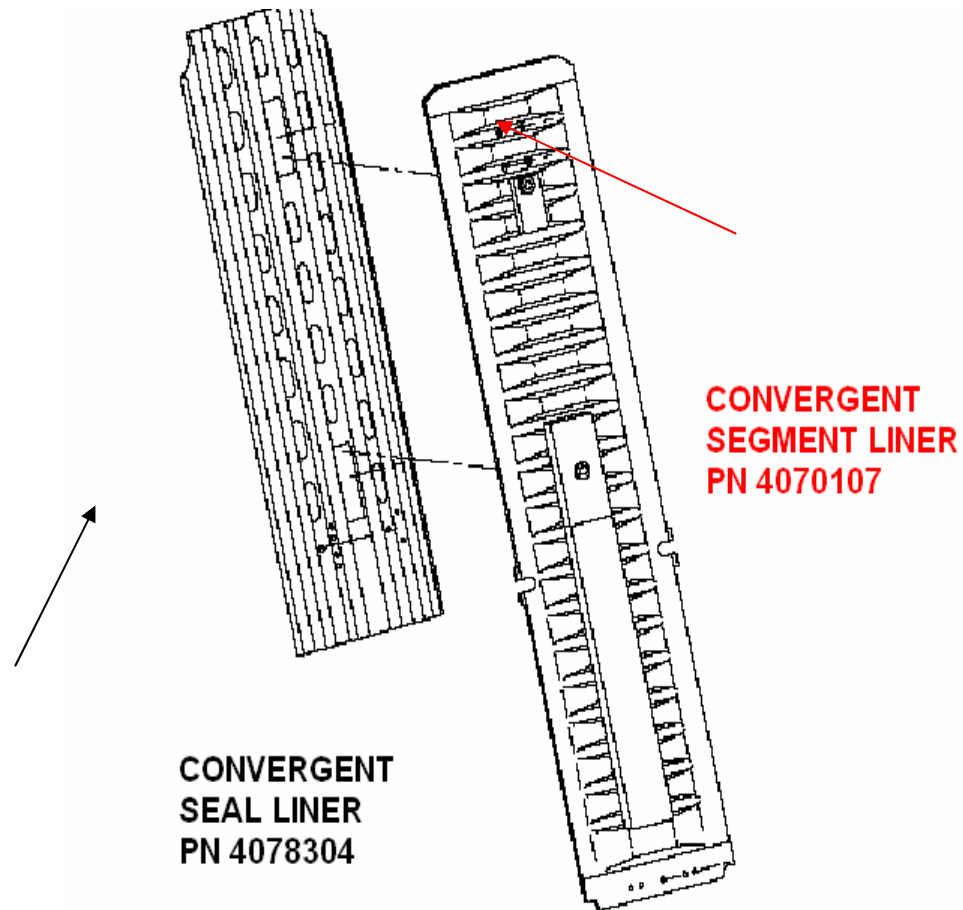
# Project Parts



**CONVERGENT  
SEGMENT LINER  
PN 4070107**

**CONVERGENT  
SEGMENT  
PN 4083130**

# Project Parts



# Current Situation

- Convergent Segment & Seal Liners

P/N 4070107 Segment Liner

P/N 4078304 Seal Liner

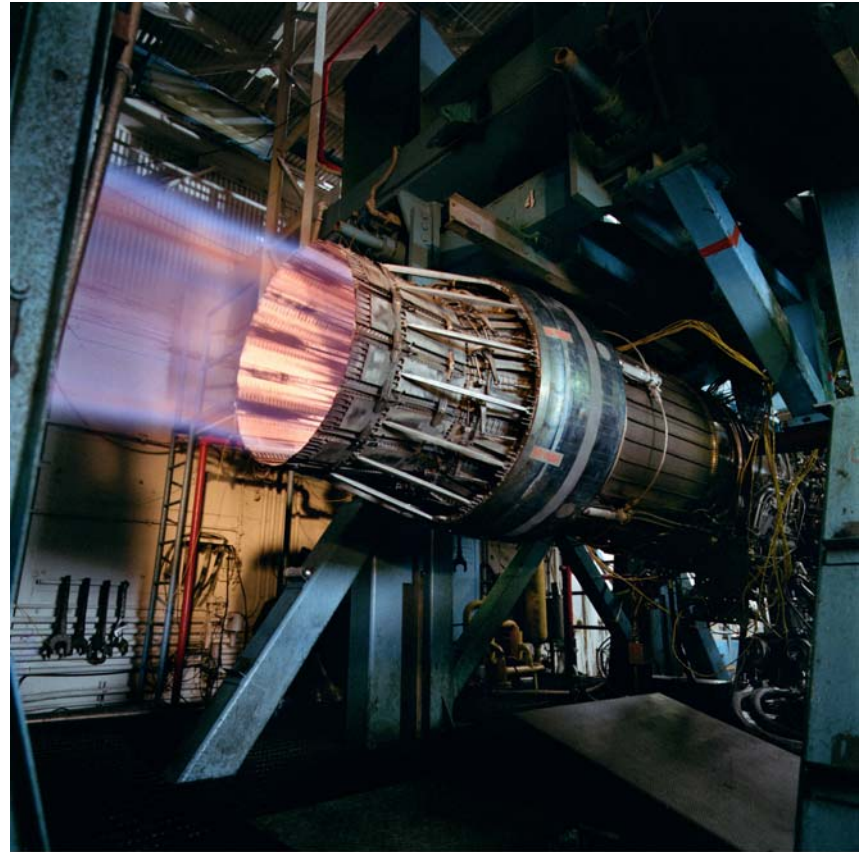
Manufactured with

Columbium Alloy C-103

Columbium

Titanium

Hafnia





# Current Situation

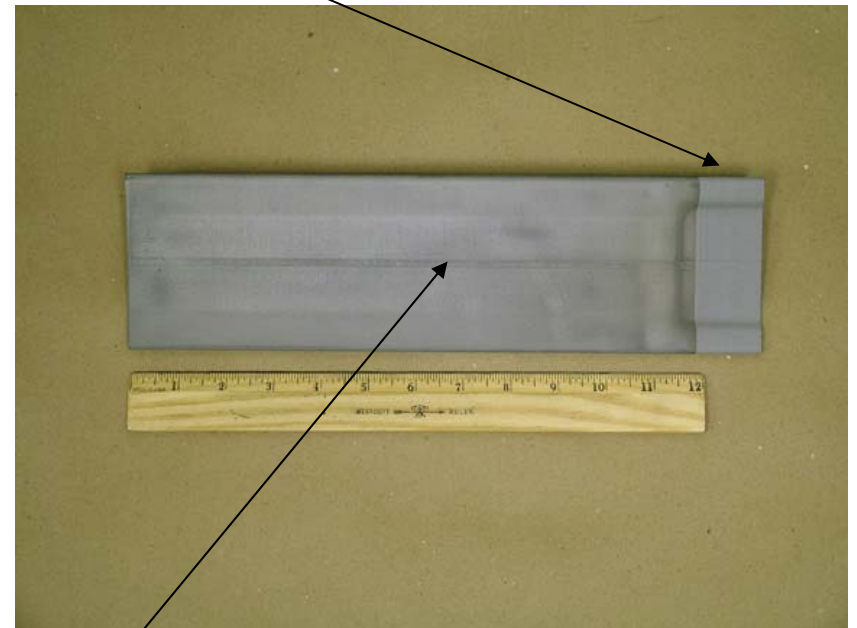
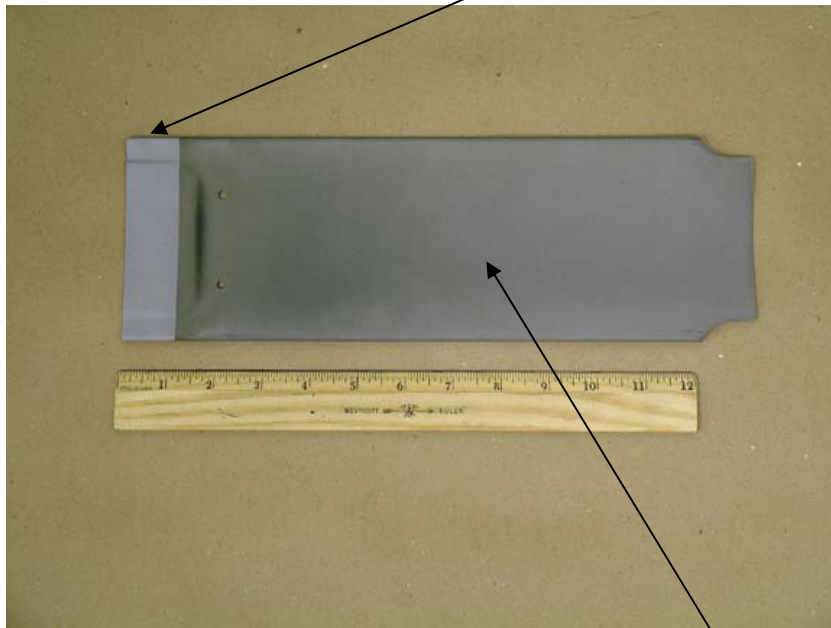
- Columbium liners: before coating



# Current Situation

- Columbium liners: after coating

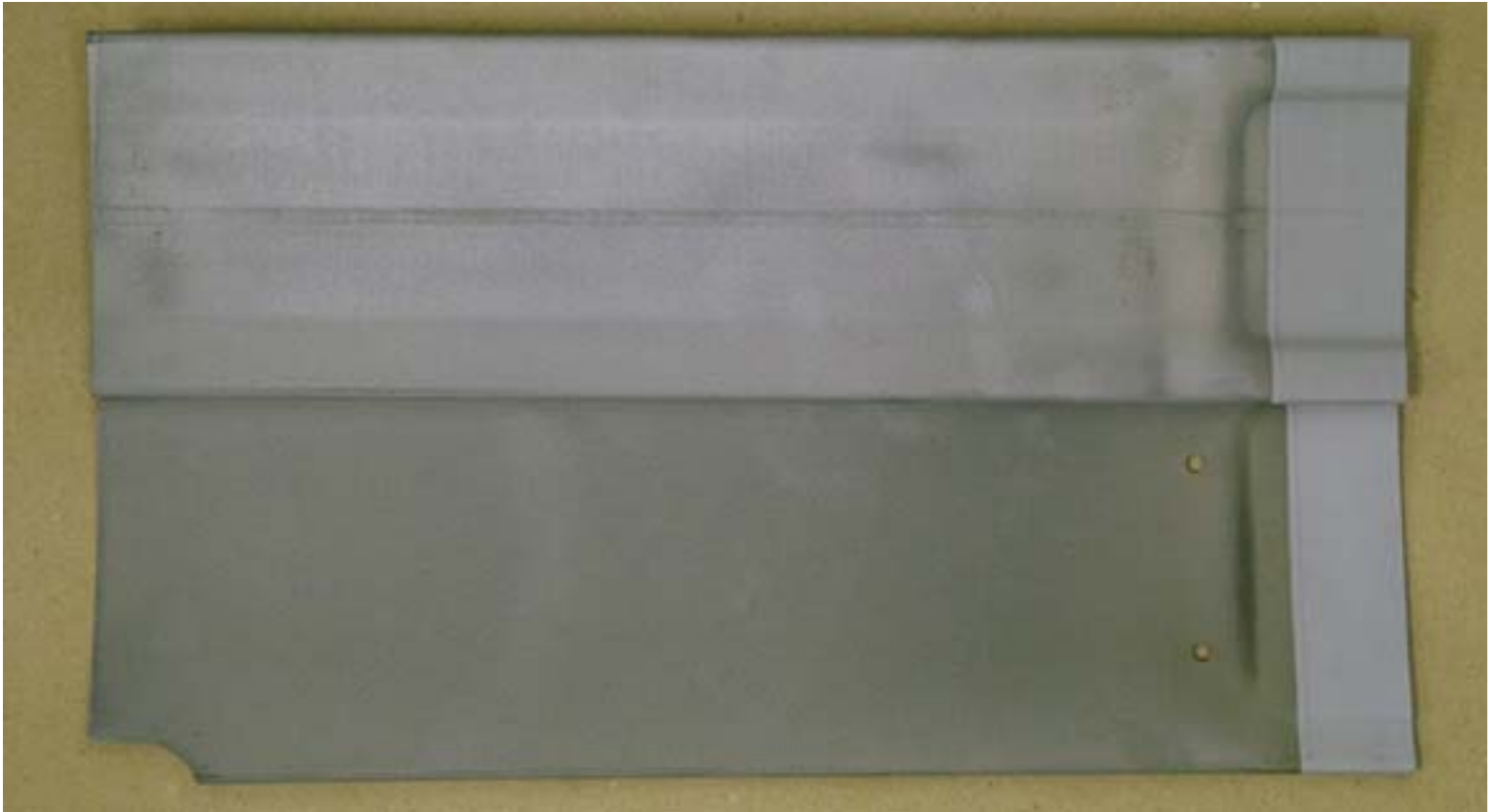
88/12  
WC/Co



PWA 295 (R512)

# Current Situation

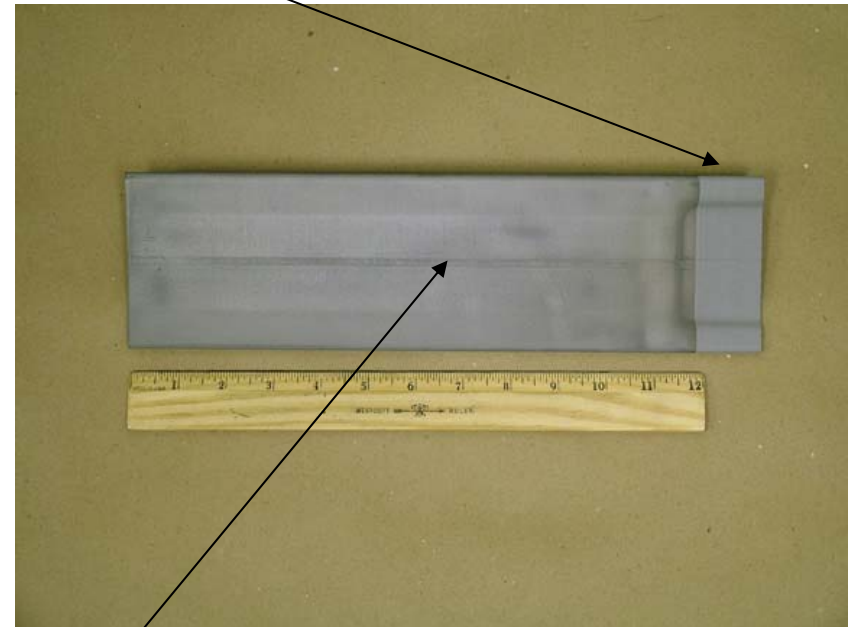
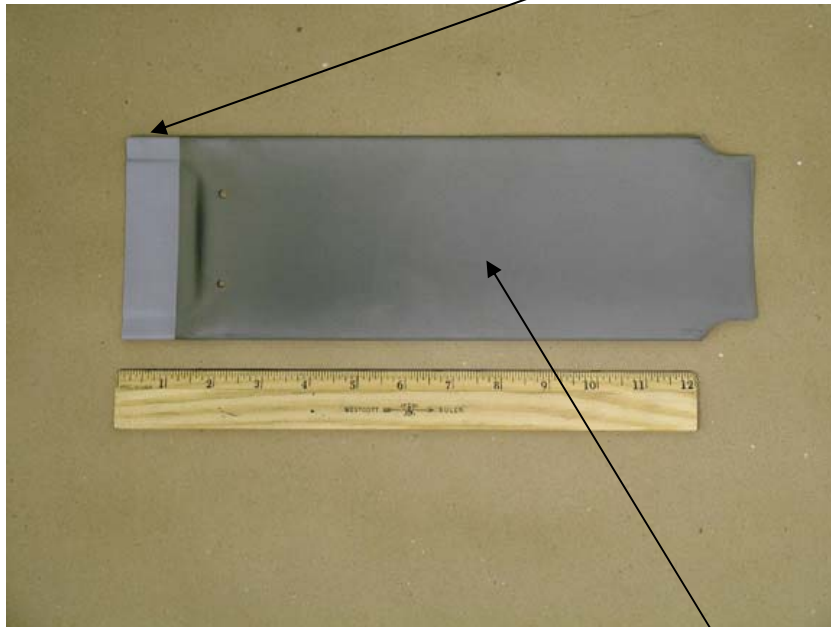
- Columbium liners: mated



# The Project

- 5 (ea) PWA 53-1; 5 (ea) 701HE; 5 (ea) HVOF

88/12 WC/Co



R522

# Project Definition

## Project Coatings

DESIGNATION	COATING DESCRIPTION	PURPOSE
PWA 53-1	A Tungsten Carbide / Cobalt coating applied by the Plasma Spray process.	A baseline coating
PWA 53-5	A Chrome Carbide / Nickel Chrome coating applied by the Plasma Spray process.	A baseline coating
PWA 255	An Aluminum Silicon Polyester coating applied by the Plasma Spray process.	A baseline coating
PWA 256-1	A Tungsten Carbide / Cobalt coating applied by a proprietary P&W Plasma Spray process.	A baseline coating
PWA 256-2	A Chrome Carbide / Nickel Chrome coating applied by a proprietary P&W Plasma Spray process.	A baseline coating
AMS 2447-3	A Chrome Carbide / Nickel Chrome coating applied by the High Velocity Oxy-Fuel coating process as defined within AMS 2447.	Intended to replace PWA 53-5 and PWA 256-2
AMS 2447-8	A Tungsten Carbide / Cobalt coating applied by the High Velocity Oxy-Fuel coating process as defined within AMS 2447.	Intended to replace PWA 53-1 and PWA 256-1
A962 / 1271	A duplex coating: Nickel Chrome Aluminum base, Zirconia Oxide top, per USAF T.O 2-1-111	A baseline coating
HITEMCO SC701HE	A Tungsten Carbide / Cobalt coating applied by a non-proprietary Hitemco High Velocity Plasma Spray process.	Intended to replace PWA 53-1 and PWA 256-1
PWA 295	A Diffused Silicide coating designed to protect refractory metals from high temperature oxidation. Developed by Hitemco pre-1975.	A baseline coating
HITEMCO R522	An upgraded version of PWA 295, also developed at Hitemco, designed to provide increased longevity.	Intended to replace PWA 295

# Project Parts

ITEM	DESCRIPTION	IDENT	QTY	SMITHS PO	HTC J/N	NON-GASPATH	GASPATH
1	4076459 Div Seal Segment Rowboat						
		SK-17	8	F012021	72121-2	AMS 2447-3	A962 / 1271
2	4082986 Div Segment Honeycomb	Base	7	F012012	72121-3	N/A	265
		SK-01	8	F012011	72121-4	N/A	A962 / 1271
3	4082989 Balance Segment Apple	SK-03	5	F012016	72121-5	N/A	AMS 2447-8
		SK-04	5	F012017	72121-6	N/A	SC701HE
4	4082994 Balance Seal Eve	SK-02	5	N/A	72121-7	AMS 2447-8	PWA 255
		SK-03	5	N/A	72121-8	SC701HE	PWA 255
5	4083130 Convergent Segment Cast Flap	SK-06	3	F012006	72121-9	N/A	AMS 2447-8
		SK-07	3	F012007	72121-10	N/A	SC701HE
6	4084790 Convergent Seal Adam	SK-01	5	F012009	72121-11	AMS 2447-8	PWA 255
		SK-02	5	F012010	72121-12	SC701HE	PWA 255
7	4083170 Augmentor CC Liner Screech Liner	SK-02	1	F012013	72121-13	N/A	A962 / 1271
8	4077809 Convergent Segment Fabricated Flap	Base	3	N/A	N/A	N/A	256-1
		SK-01	2	N/A	72121-15	N/A	AMS 2447-8
		SK-02	2	N/A	72121-16	N/A	SC701HE
9	4070107 Liner, Convergent Segment	Base	5	N/A	72121-1	N/A	BOM
		SK-01	5	N/A	72121-1	N/A	R522/SC701
		SK-02	5	N/A	72121-1	N/A	R522/HVOF
10	4078304 Liner, Convergent Seal	Base	5	N/A	72121-1	N/A	BOM
		SK-01	5	N/A	72121-1	N/A	R522/SC701
		SK-02	5	N/A	72121-1	N/A	R522/HVOF

# Test Plan

- Coat AMT Augmentor Parts
  - Coat 5 each balance and convergent section parts.
    - PWA 256-1
    - AMS 2447-8
    - 701HE
  - Coat 7 each divergent section parts.
    - PWA 256-2
  - Coat 8 each divergent section parts.
    - AMS 2447-3

# Test Plan

- Install parts May 04
- Build AMT Module FX-231
- Begin AMT Test mid June 04
- Complete AMT Testing Ending December 04



# Testing Issues

- Sketch Print Mark-ups were required by PW configuration Management.
  - Furnished sketch print mark-ups April 04.
  - Received approval for PEWG funding to pay for sketch print markups.
  - Received sketch print mark-ups July 04
- Parts sprayed September 04
- Module built & Installed October 04.
- Test program delayed

# Accelerated Test Plan

- Approved by F100 Cognizant Engineering Branch Chief.
- Parts have 1516 cycles on them when the AMT engine completed 4000 cycle test.
- Upon completion of the ACI on FX-231 two each of all configurations were removed from each section of the module. Then sent to OC-ALC lab for comparative analysis test coatings to PWA 256.
- Test coatings met or exceeded the performance of PWA 256.
- Action being taken for T. O. implementation.

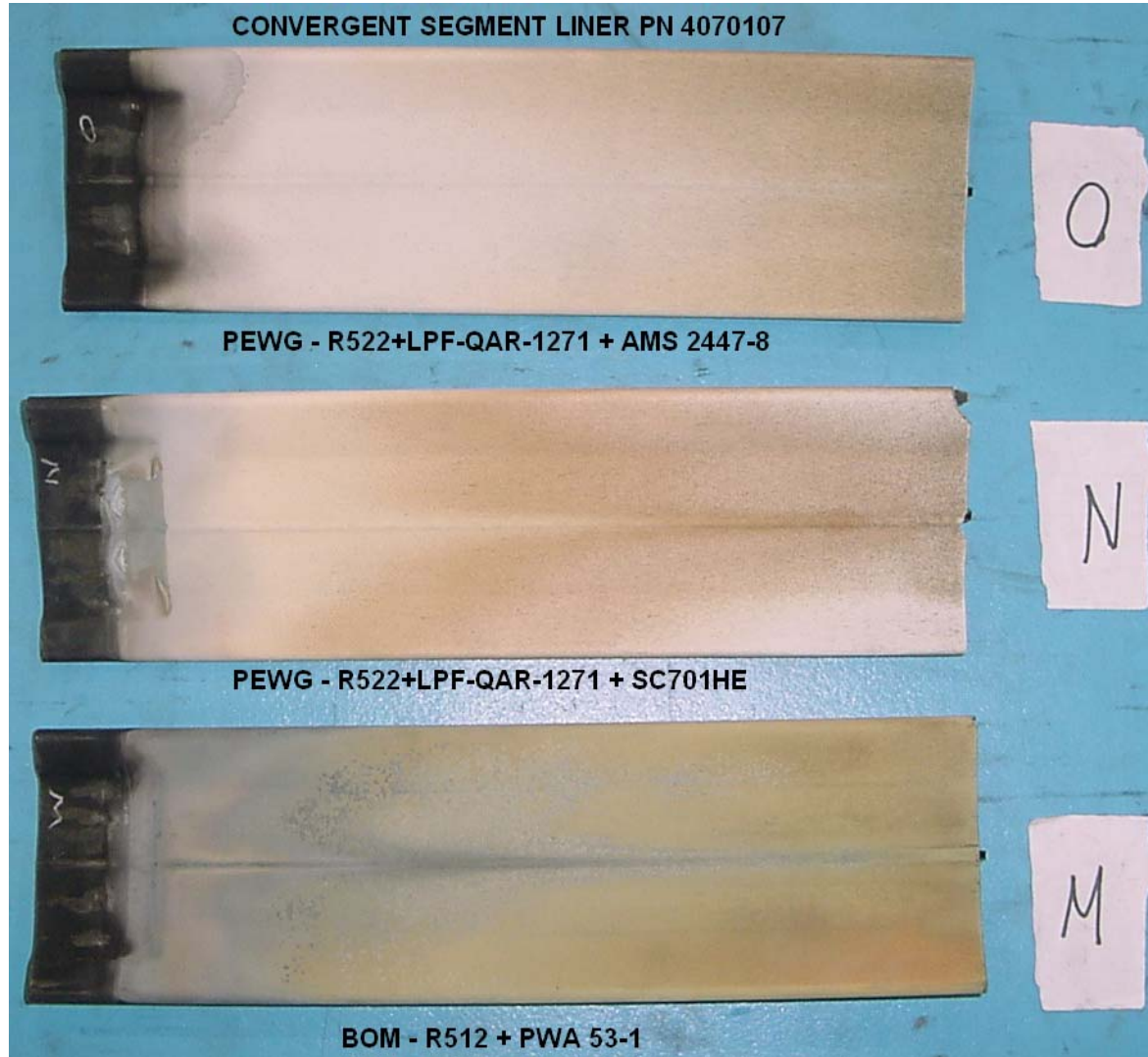
# Accelerated Test Plan - Continued

- New (“0” time) parts will be used in place of removed test parts and the module rebuilt.
  - The module will be installed on AMT FX-231 for a scheduled maintenance interval of 4000 cycles.
  - Test parts will be flown to failure or have 5516 cycles at the next scheduled maintenance interval.
- The remaining test parts will be sent to the OC-ALC lab for comparative analysis to justify the first set of test results.

# Testing

- Testing accomplished on AMT
  - FX-394
  - FX-231
    - Due to other component test requirements this engine ran with higher than normal EGTs.
- ACI accomplished at Pratt & Whitney SA
- No Condemnations
- Parts installed on AMT P264 for additional experience

# ACI Documentation



# Current Status

- All parts passed all inspections
  - By TO authority, all new coatings approved for use on F100 components during repair / overhaul.
- P&W tasked to revise drawings to allow use of HVOF coatings on newly manufactured parts.
  - New drawings to reference only non-proprietary specifications
  - New drawings to reference AMS 2447 as opposed to P&W HVOF specifications.
- Project complete success!
- Questions to Tim Terhune ([leo.terhune@tinker.af.mil](mailto:leo.terhune@tinker.af.mil)) 405-734-8788

# Advanced Coating Removal

- Dave Fairbourn - Aeromet Technologies, Inc.

# Aeromet Technologies

- Small Utah Company, partners with Meyer Tool in MTCoatings, LLC
- Products: Small CVD coatings systems, platinum plating systems, special stripping systems, working to develop Si, Y, Hf additions and new bond coats for TBC's
- Holder of 25 US and Foreign Patents, 15 more in the hopper
- Clients: Chromalloy, Meyer Tool, P-W, numerous others



# The technology

- Derived from a Russian discovery.
  - peroxide dissolves tungsten
- LeChatelier's Principle: use of chelating agent to drive reaction.
- Leads to Consumptive Stripping Concepts
- Unique vulnerability of Tungsten has led to a breakthrough in removal of WC/Co.

# The invention

- Addition of graphite plates
  - increases driving force
  - for reaction.
- Unique susceptibility of
  - Tungsten to Peroxide.
- Control of peroxide
  - concentration.
- US Patent 6294072B1



# Simple, safe, effective

- Completely removes coatings in 30-45 minutes
- Dilute solutions of peroxide and chelating agent
- Does not remove Magic Marker ID on samples
- Government Report OC-ALC (results to follow)

# The environment

- Tungsten is in short supply in Europe and Asia.
- Want to save every bit.
- Distillation will concentrate solution.
- Heating will drive off chelating agent or leave Tungsten Citrate for reuse.
- Take even the squeal!

# The equipment



# Progress to date

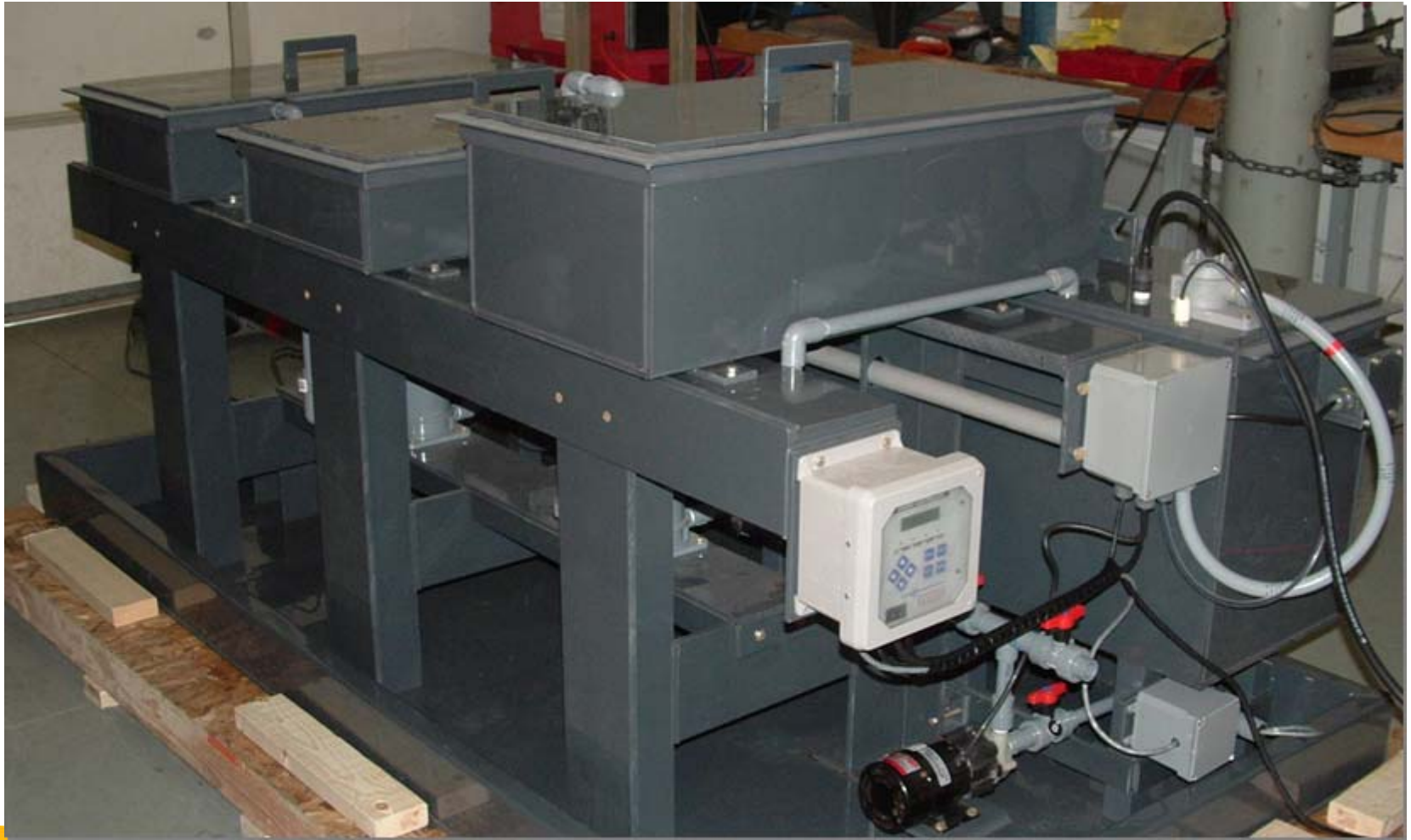
- Tinker test parts.



# Progress to date

- Prototype system installed Tinker Air Force Base
  - Tested / evaluated on GE & PWA augmentor components, fan and compressor blades, various other components.
- USAF performed exhaustive analysis: effects on substrate, effectiveness vs. Rochelle Salts, dilute nitric acid, molten salt, etc.
- Based on results, OC-ALC purchased second larger system to include equipment improvements.

# Larger system





# System improvements

- Versatility of tanks boosts production capability of prototype.
- Addition of ORP Sensing and Automatic Dosing reduces analytical operating burden, increases safety / productivity.
- Small change makes big results.
- Capable of six F110 exhaust augmentor segments.
- Removes coating in 30-45 minutes.

# OC-ALC Evaluation

- OC-ALC Tinker AFB - Materials Engineering Report - Metallurgical Analysis Section - Report Number 05-034 - Analysis of Several Thermal Spray Test Coupons Processed by AeroMet Technologies
  - “...to evaluate the efficacy and viability of this proposed new stripping procedure on coupons made from materials representing the four components listed above. The F100 propulsion engineering office had two primary concerns: 1) did the new procedure actually strip the coating, 2) did the new stripping process damage the parent material.”

# Technology criteria

- Test Protocol
  - The criteria for acceptable stripping solution performance was defined as:
  - The stripper shall not etch or otherwise damage the material substrate
  - The stripping rate should be as high as possible
  - The stripper should remove the coating as uniformly as possible; it should not cause galvanic corrosion between the coating and substrate
  - The chemicals should not be harmful or hazardous to the environment

# Reference parts

- Applicable F100 Components:
  - Liner, Convergent Segment P/N: 4057394 Columbium PWA 1095
  - Seal, Convergent Nozzle P/N: 4084790 Inco 718 AMS 5596
  - External Flap Ti-6AL-4V AMS 4911
  - Segment, Convergent Nozzle P/N: 4077809 Ti-6AL-4V
- Conclusions: “The proposed new procedure effectively stripped the WC-Co thermal spray coating from the various coupons. There was no significant loss of mass, surface damage, or measurable dimensional changes observed as a result of the new stripping process.”

# Photographic documentation

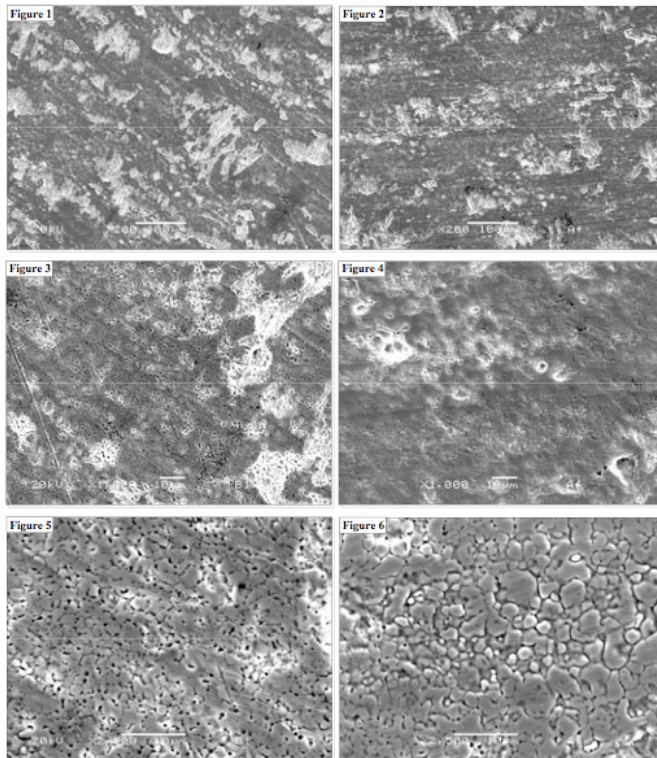
05-03

05-034

## PHOTOGRAPHIC DOCUMENTATION

### SEM Examination:

Surface images of an uncoated Inconel 718 coupon (In-Un-1) taken at 200X, 1,000X, and 2,500X both before (left) and after (right) exposure to the proposed stripping procedure.

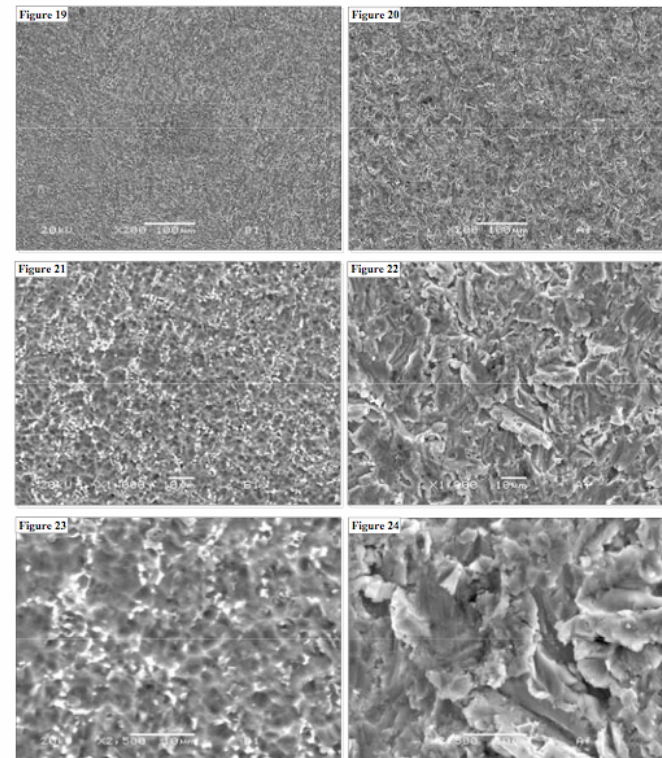


6 of 31

## PHOTOGRAPHIC DOCUMENTATION

### SEM Examination:

Surface images of an uncoated Titanium coupon (Ti-Un-1) taken at 200X, 1,000X, and 2,500X both before (left) and after (right) exposure to the proposed stripping procedure.



10 of 31

# Weight loss

**TABLE II**

Weight Documentation Chart to Assess both the Stripping of the Thermal Coatings and any Possible Attack from the Strip Bath

	Met Lab ** Specimen ID #	Parent Material	Component Associated with the Specimen	Weight prior to Grit Blasting (grams)	Weight after Grit Blasting (grams)	Weight after Thermal Spray Coating (grams)	Weight after Strip (grams)
1.	In-Un-1	Inconel 718	Seal, Convergent Nozzle	21.2461	-----	-----	21.2458
2.	In-C-1	" "	Seal, Convergent Nozzle	16.5382	16.5311	18.9562	16.5197
3.	Nb-Un	Columbium	Liner, Convergent Segment	6.5989	-----	-----	6.5988
4.	Nb-C	" "	" "	7.7017	7.6985	8.9658	7.6949
5.	Ti-Un-1	Ti-6Al-4V	External Flap	11.9224	-----	-----	11.8788
6.	Ti-Un-2	" "	Segment, Convergent Nozzle	12.2748	-----	-----	12.2739
7.	Ti-C-1	" "	External Flap	12.9895	12.9789	15.3733	12.9283
8.	Ti-C-2	" "	Segment, Convergent Nozzle	14.4069	14.3927	15.5134	14.3750

\*\*Specimen Legend – the “Un” designation indicates an uncoated or “control” sample. The “C” designates a sample that was prepared, coated, and then stripped. See appendices “A1” through “A6” (pages 26 to 31) for a complete listing and description of all the various laboratory samples.

# Weight loss

**Table III**  
**Material Lost During the Proposed “New” Stripping Procedure**

	Met Lab Specimen ID #	Parent Material	Component Associated with the Specimen	Weight Lost (grams)	% Weight Lost
1.	In-Un-1	Inconel 718	Seal, Convergent Nozzle	0.0003	0.0014
2.	In-C-1	“ ”	Seal, Convergent Nozzle	0.0114	0.0690
3.	Nb-Un	Columbium	Liner, Convergent Segment	0.0001	0.0015
4.	Nb-C	“ ”	“ ”	0.0036	0.0468
5.	Ti-Un-1	Ti-6Al-4V	External Flap	0.0436	0.3657
6.	Ti-Un-2	“ ”	Segment, Convergent Nozzle	0.0009	0.0073
7.	Ti-C-1	“ ”	External Flap	0.0506	0.3899
8.	Ti-C-2	“ ”	Segment, Convergent Nozzle	0.0177	0.1230

# Current status

- Tinker AFB testing expanded range of components and substrates.
- Technical Order being amended to permit AND PREFER this technology as opposed to others.
  - Will effect vendor base, I.e. Smiths Aerospace, AAR, etc.
  - Form 202 issued December 2005
  - TO to be modified
- Favorable results communicated to Pratt and GE.



# Work continues

- To date, developments have focused on WC/Co on non-ferrous alloys, i.e, titanium, columbium, inconel.
  - Opened project to address coatings on high-strength steels (landing gear) applications.
  - Expanding development to include WC/Co/Cr and Cr/C/NiCr.
  - Recent interest by US Gov't to expand further, i.e. CuAl (Aluminum Bronze) and CuNiIn (Copper Nickel Indium) from blade roots, various substrates.
  - TBC duplex coatings, Ni or NiCr bondcoats / YSZ topcoats.
  - Commercial approvals

# Summary

- We found a safe and economical process that works effectively.
- Tinker AFB is moving rapidly to integrate it into their production facility.
  - Hoping for full approval later this year by modification of F100, TF33 Tech Orders.
- OEMs very interested.
- Very Successful project to date.
- Licensing opportunities available.
- Thanks to OC-ALC Tinker AFB and PEWG.

# DemVal, Inc. & Aeromet Technologies, Inc.

Thank you for your time and attention.

Dave Fairbourn

Aeromet Technologies, Inc.

[dfairbourn@aeromettech.com](mailto:dfairbourn@aeromettech.com)

[www.aeromettech.com](http://www.aeromettech.com)

801-568-0227

Bruce Bodger

Demval, Inc.

[bruce.bodger@demval.com](mailto:bruce.bodger@demval.com)

[www.demval.com](http://www.demval.com)

631-835-8400

