

# 84th Combat Sustainment Wing



**U.S. AIR FORCE**

## Hill AFB HVOF Implementation

**HCAT  
27 Feb 08**

**Ryan Josephson / Brad Martin  
Hill AFB**

**[ryan.josephson@hill.af.mil](mailto:ryan.josephson@hill.af.mil)  
[brad.martin@hill.af.mil](mailto:brad.martin@hill.af.mil)**

**Richard Vander Straten  
ES3, Inc. Aerospace Division  
[richard.vanderstraten@es3inc.com](mailto:richard.vanderstraten@es3inc.com)**

# Report Documentation Page

*Form Approved*  
*OMB No. 0704-0188*

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1. REPORT DATE <b>27 FEB 2008</b>	2. REPORT TYPE	3. DATES COVERED <b>00-00-2008 to 00-00-2008</b>			
4. TITLE AND SUBTITLE <b>Hill AFB HVOF Implementation</b>		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) <b>84th Combat Sustainment Wing, Hill AFB, UT, 84056</b>		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 <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>Surface Finishing and Repair Issues for Sustaining New Military Aircraft Workshop, February 26-28, 2008, Tempe, AZ. Sponsored by SERDP/ESTCP.</b>					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>29</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			



# HILL AFB HVOF PROGRAM



84TH COMBAT SUSTAINMENT WING

- Key Personnel in attendance today from Hill AFB
  - Ryan Josephson- Landing Gear Lead Engineering PM
  - Brian Kemp- HVOF Process Engineer, HAFB
  - Ben Smith- HVOF Program Manager, HAFB 309 CMXG
  - Preston Miller- Process Engineer- Grinding, HAFB
  - Dave Web- HVOF Engineer, ES3
  - Richard Vander Straten- HVOF Manager, ES3
  
- Subcontractor support to Hill AFB/ES3
  - Metcut
  - 3M
  - Abbott Machine



# AGENDA



84TH COMBAT SUSTAINMENT WING

- HVOF Implementation – Phase I, II, III
- Qualification Spec
- Diamond Belt Grinding
- Duplex Coating
- Narrow Groove Super Finishing Technique
- C-5 Lower Metering Tube
- B-1 MLG Axle Evaluation
- Questions



# HVOF IMPLEMENTATION



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## ■ Aircraft currently flying with HVOF components

- A-10
- F-16 LW
- F-16 HW
- B-1
- T-38
- F-15 C/D
- F-15E
- KC-135
- C-130
- C-5
- B-52



# HVOF IMPLEMENTATION



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## ■ HVOF implementation at Hill AFB

- Program to convert all line of sight chrome plate to HVOF WC-Co coatings on landing gear components
- Approximately 400 parts with an average of 4 surfaces per part = 1600 surfaces being converted to HVOF coatings

## ■ Combined Effort Between

- Hill AFB LG Engineering
- Hill AFB Process Engineering
- Hill AFB Production
- ES3 and Support Contractors



# HVOF IMPLEMENTATION



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## ■ HVOF Implementation Program Workflow

- Component selection
- Initiate System Safety Evaluation (SSE)
  - Unique to this program
    - Review part function
    - Review stress level
- 3D Model Part using Pro-E software
- Design and manufacture HVOF application tools/fixtures
- HVOF Prototype Spray
  - Program robot
  - Confirm dimensional attributes are met
  - Document and create HVOF Process Order, route and publish
- Prototype Grind/Super Finish
  - Design/Purchase diamond wheels and super finish equipment, create methods
  - Document and create HVOF Grind Process Orders, route and publish
- Create Tech Order changes, submit for publication
- Production spraying begins (46 parts in production at this time)



# HVOF IMPLEMENTATION



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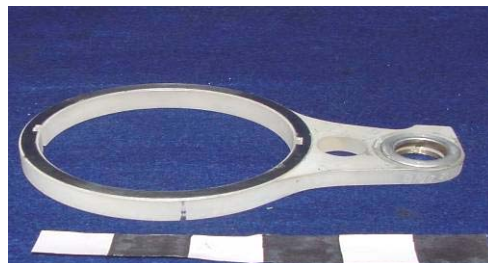
- Phase I - Converted 38 components (1-06 to 4-07)
- Phase II- Converting 128 components (1-07 to 6-08)
- Phase III- 238 parts identified, work commencing



# HVOF IMPLEMENTATION



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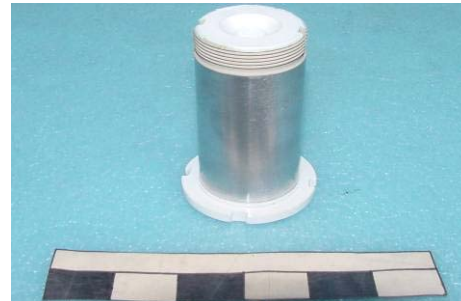




# HVOF IMPLEMENTATION



84TH COMBAT SUSTAINMENT WING





# HVOF IMPLEMENTATION



84TH COMBAT SUSTAINMENT WING





# HVOF IMPLEMENTATION



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- **Hill AFB currently has five HVOF booths**
  - Three additional booths installed in 07
    - Gantry robot, vertical, large swing
    - Gantry robot, horizontal, large swing
    - Gantry robot, multiple turntables, vertical
    - New Booth qualifications began Winter 08
      - Bonds
      - Porosity
      - Hardness
      - Fatigue as required
      - Coating integrity as required
  - C-17 Booth installation scheduled for Summer 08



# ADDITIONAL HVOF WORK



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- In addition to the implementation program, the following projects were worked in 2007
  - Qualification specification
  - Diamond Belt Grinding
  - Duplex coating development
  - Narrow Groove Super Finishing
  - C-5 Elimination of scratch induced N<sub>2</sub> leak



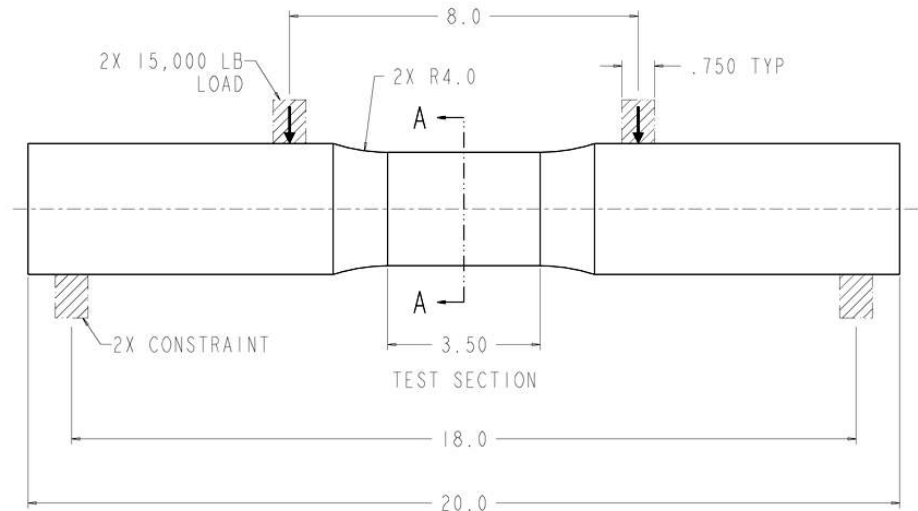
# Qualification Specification



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## ■ Qualification specification

- Establish a standard for USAF system qualification
  - Long term goal to qualify vendors for manufacture of spare parts
    - Criteria for HVOF vendors and suppliers to become qualified to spray Air Force LG components
- Air Force specification drawing
  - Process qualification
  - Powder qualification
  - ECD May 08



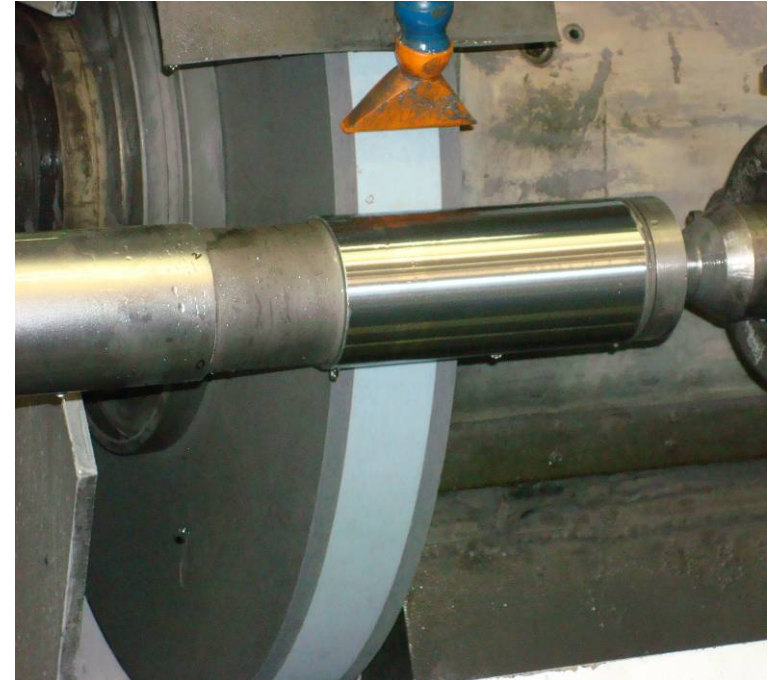


# Diamond Belt Grinding



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- 3M introduced data during the 2007 HCAT meeting indicating a significant reduction in diamond grinding times associated with finishing of HVOF applied WC/Co coatings
- 3M and ES3 worked with HAFB personnel to evaluate 3M Trizact™ Diamond Belt grinding of HVOF WC/Co coatings.
  - **Initial Tests Evaluated:**
    - **Diamond belt grinding efficiency (Speed)**
    - **The reduced grinding burn potential on 300M substrates.**
    - **Ease of surface finish attainment**
    - **Effectiveness of correcting induced out of round conditions.**
- Base metal preparation and Hard Chrome stripping, grinding and finishing methods were also evaluated with 3M Trizact™ Ceramic belt technology.



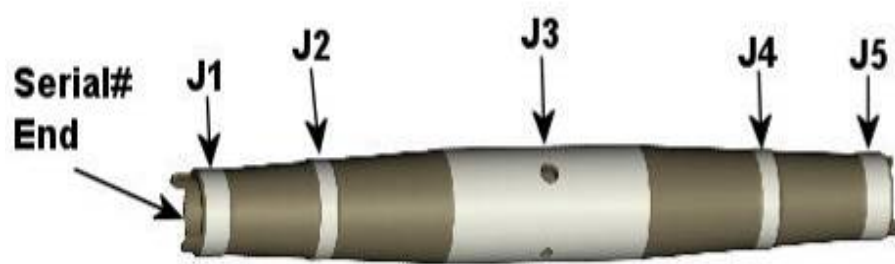


# Diamond Belt Grinding

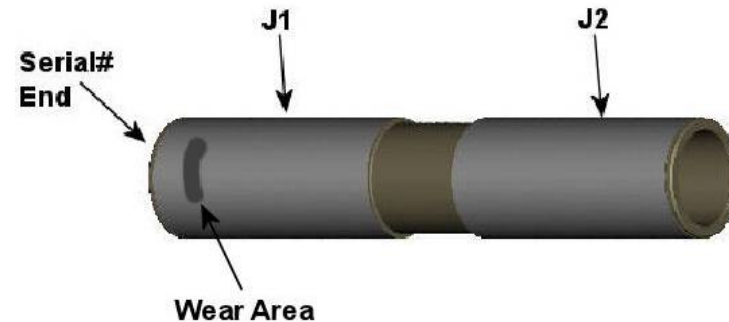


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Two condemned parts were diamond belt finished to determine cutting efficiency and quality of surface finish



B1-B Nose Landing Gear Axle Journal Locations



C-5 Upper Shaft #1 Journal Locations

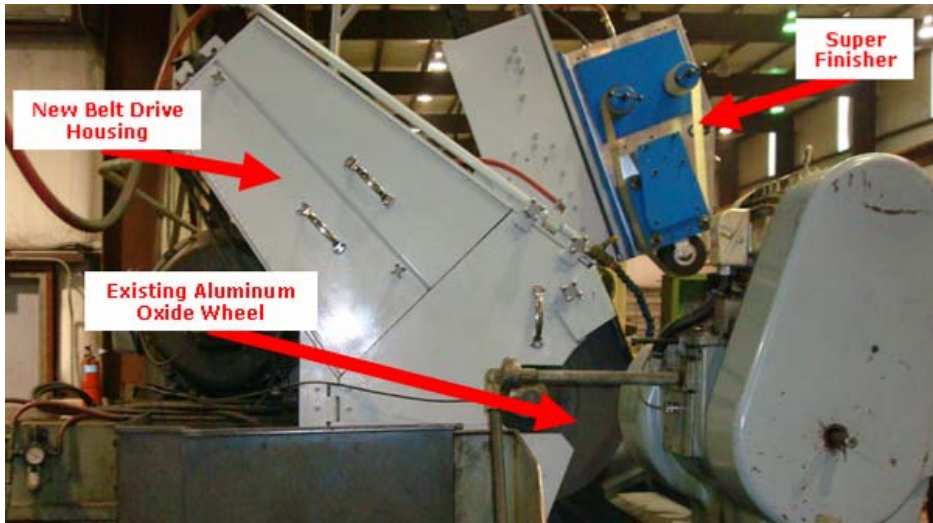


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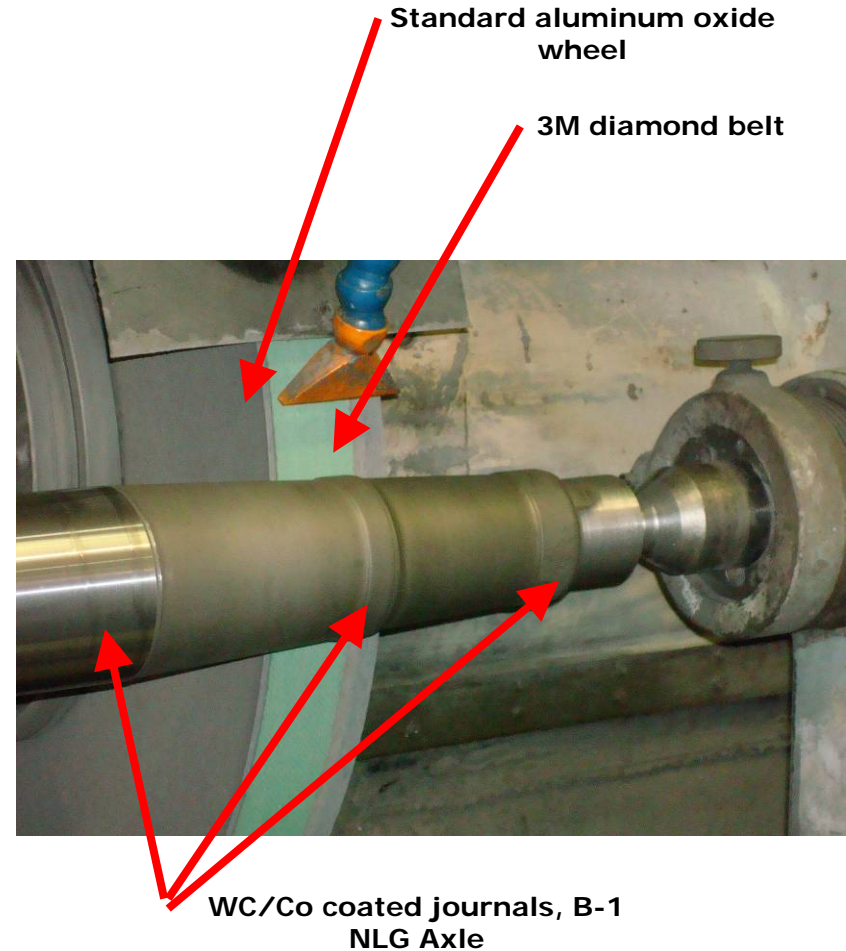


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## ■ Equipment configuration



Abbot Machine Belt Grinding Housing Attachment for 3M Belts  
Side View



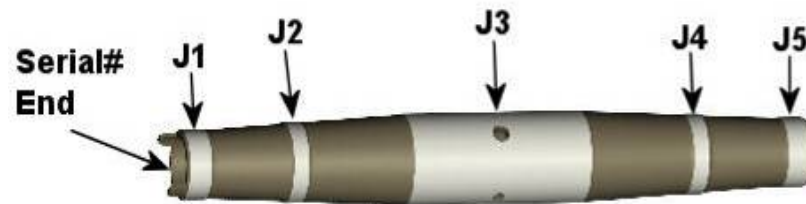


# Diamond Belt Grinding

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## ■ Results-

Time Comparison		
B-1B N Axle P/N 3002306		
Journal #	HAFB Operator Actual Grind Time on Part	Test Diamond Belt Grinding Time
J1	30 min	2 min
J2	30 min	2 min
J3 (center)	2 hrs	5.4 min



Estimated time saved per part is 3.75 hours  
(actual time on part)



# Diamond Belt Grinding



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## ■ Conclusion of results

- Dramatic reduction of grinding times with belt compared to standard wheel
- Surface finishes were very good without great degree of optimization
- Burns were not found where most aggressive grinding took place
- Belt change took approximately 2.5 minutes

## ■ Next steps

- Determination of optimized methods to ensure grinding burns will not occur
- Limited fatigue testing
- Write specification
- Install for use



# HVOF Duplex Coating



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- **Duplex coating to be used to replace chrome/nickel repair use in landing gear**
  - Phase I showed promising results
    - Briefed in Spring 04 HCAT
    - On HCAT web page
  - Phase II to investigate a variety of powders for the build-up coat
    - Top coat to be WC-Co
    - Initial testing to include
      - Bond plugs
      - Porosity
      - Hardness
    - Qualification testing to include
      - Fatigue
      - Coating integrity
      - Corrosion
      - Stripping

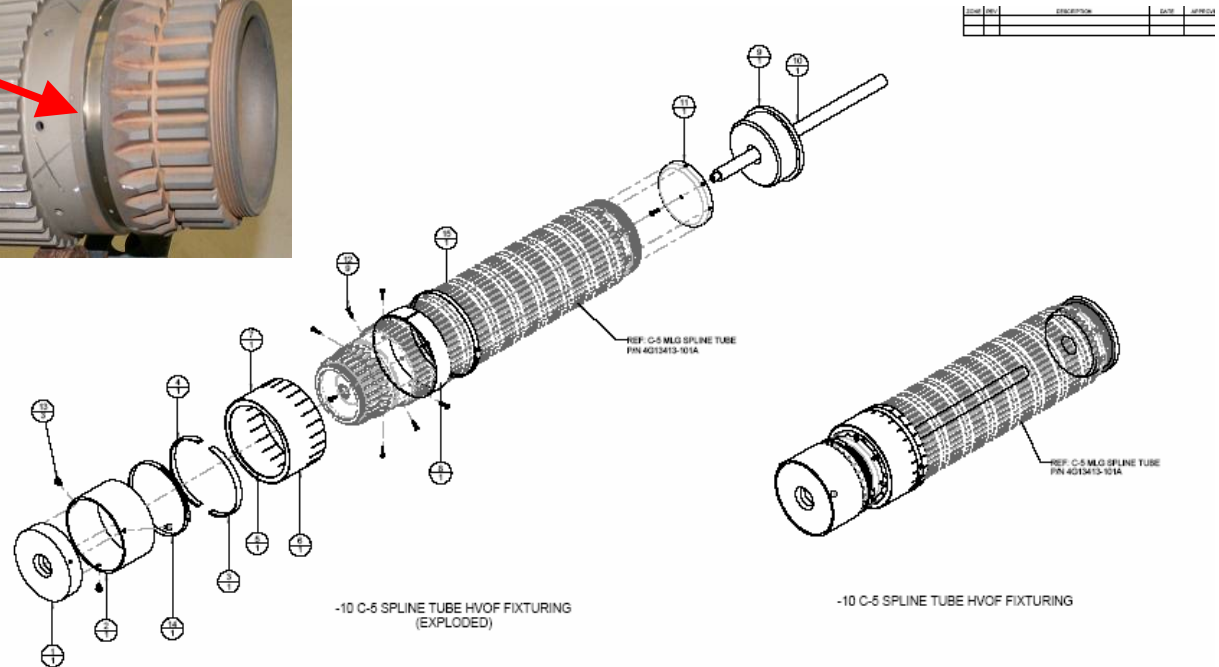


# Narrow Groove Super Finishing



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- Testing to investigate interface wear of landing gear components using different finishing techniques



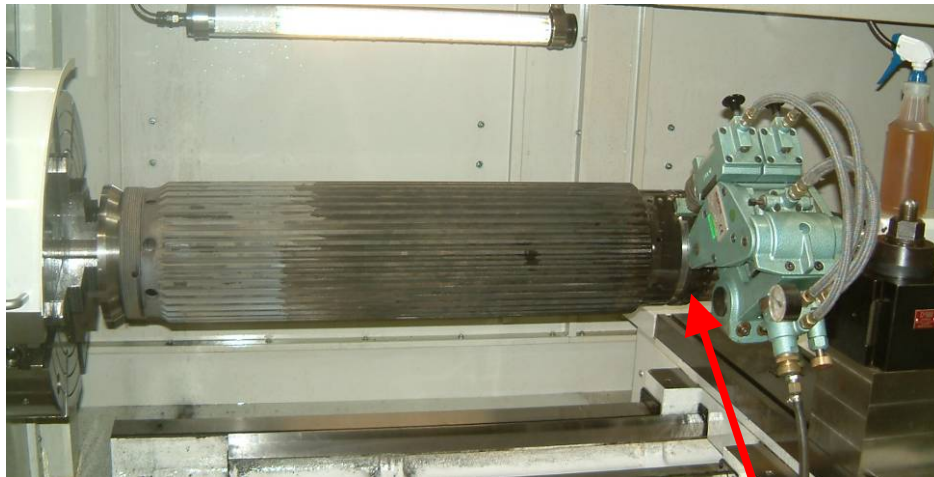


# Narrow Groove Super Finishing



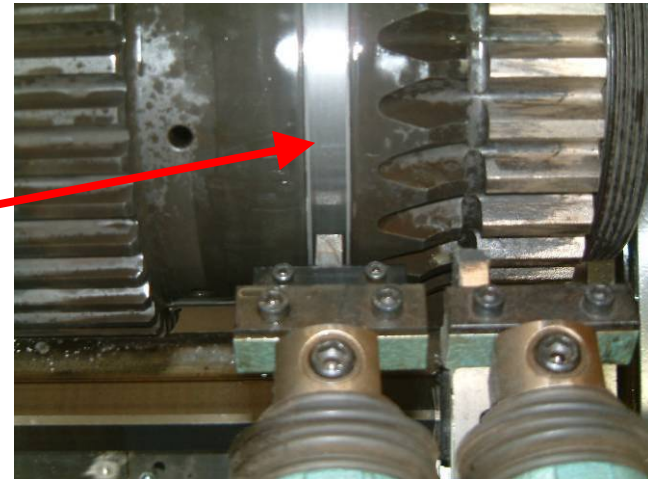
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## ■ Super Finishing of Narrow Groove



C-5 Spline Tube Narrow Groove  
Super Finished

Surface Finish Parameters for seal surfaces Per Air Force Drawing 200310642 Rev A	
Ra	4 micro-inch Max
Rp	8 micro-inch Max
Rz	40 micro-inch Max
Tp	10-90% at c=5% and 0.25 Rz





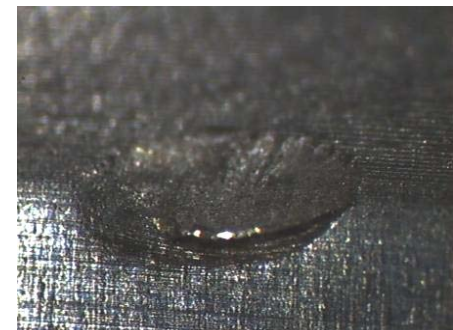
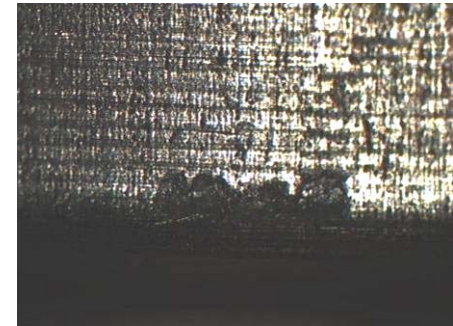
# C-5 Lower Metering Tube



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## ■ Problem Description

- The C-5 Lower Metering Tube is part of a high pressure nitrogen system which utilizes the C-5 Floating Carrier Piston (P/N 4G13514-101) an anodized aluminum sleeve, which slides up and down the length of the C-5 Lower Metering Tube.
- The C-5 Lower Metering Tube (P/N 4G13518-101) has a history of leaks due to longitudinal scratches. The Lower Metering Tube develops scratches on its working surfaces both during new part assembly and during use in the field.
- The scratches are created by imbedded particles in the seals of the C-5 Floating Carrier Piston and/or anodize defects in the surface of the C-5 Floating Carrier Piston. The Lower Metering Tube is stainless steel or flash chrome and both surfaces have become scratched in service.
- To prevent constant field rework and frequent part condemnation ES3 was asked to determine cause of scratches and to evaluate the use of High Velocity Oxygen Fuel (HVOF) applied coatings to eliminate them. Cost was a consideration so three materials were considered.



Three images (35X) of damage on mating surface, creating fine line scratches



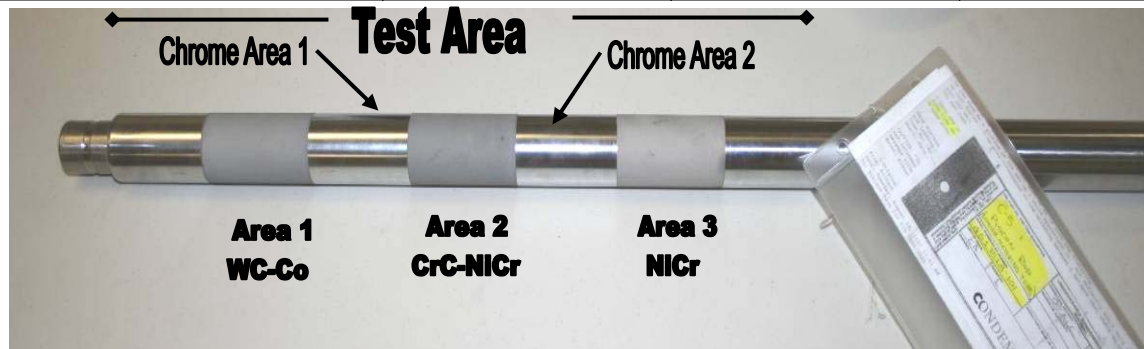
# C-5 Lower Metering Tube



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## ■ HVOF Processing Parameters (JP-8000 System)

	WC-Co	CrC-NiCr	NiCr
Powder Composition	83% WC-17% Co	75% CrC-25% NiCr	Ni-Bal, 14.5% Cr, 4.5% Fe, 4.5% Si, 3.2% B
Spray Rate	10.5 lbs/hr	10 lbs/hr	10 lbs/hr
Carrier Gas Flow Rate	20 scfh	21 scfh	26 scfh
Fuel Flow Rate	5.3 gph	6 gph	8.8 gph
Oxygen Flow Rate	1900 scfh	1850 scfh	1950 scfh
Oxygen Supply Pressure	128 psi	136 psi	133.4 psi
Traverse Rate	4 mm/s	4 mm/s	4 mm/s
Nozzle Length	6 in	6 in	4 in
Stand off distance	15.5 in	14 in	15 in
Max Part Temperature	350 °F	350 °F	350 °F
Total coating thickness	.0092 inch	.0083 inch	.0088 inch



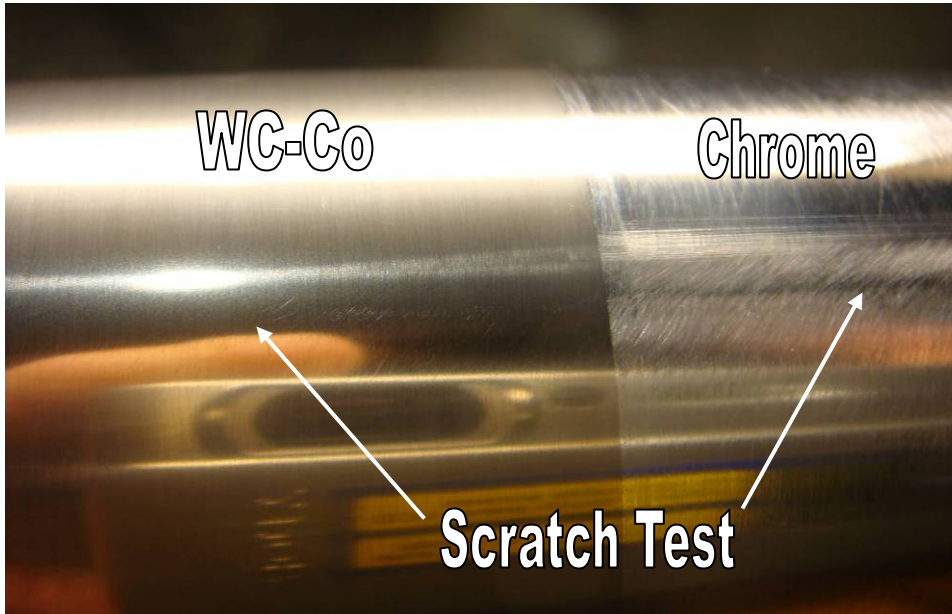


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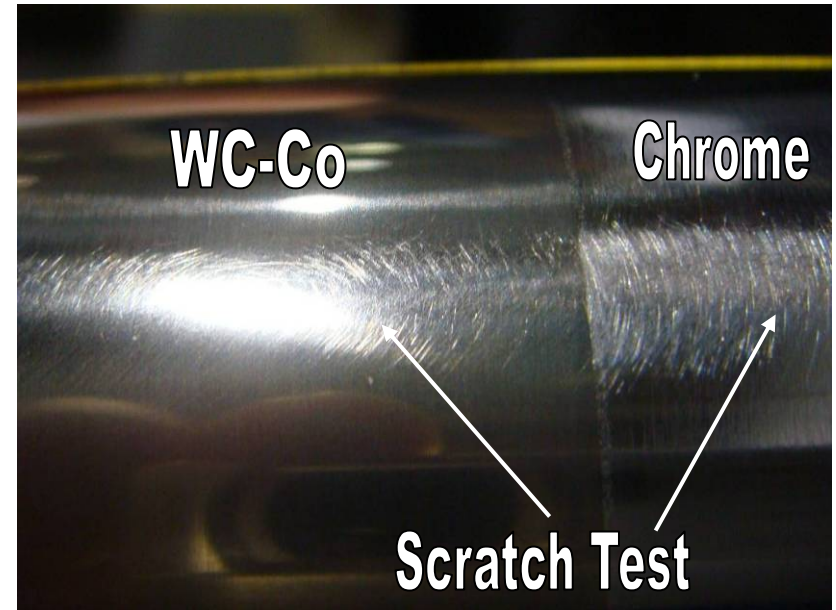


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## ■ Scratch Test WC/Co vs EHC



400 Grit: WC-Co



240 Grit: WC-Co

	Chrome	WC-Co
Super Finish		.96 Ra
400 Grit	5.8 Ra	1.72 Ra
240 Grit	7.18 Ra	2.4 Ra

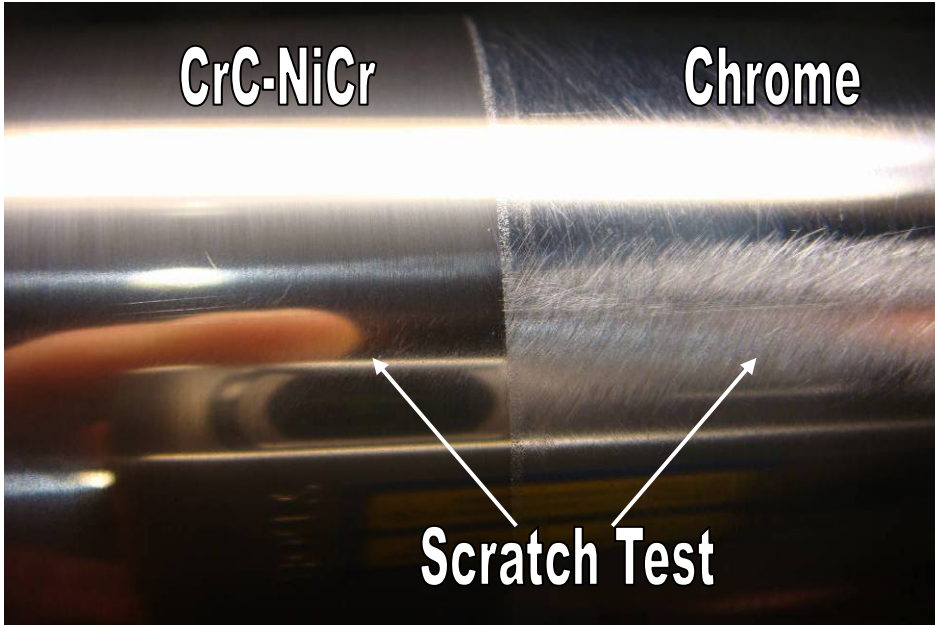


# C-5 Lower Metering Tube

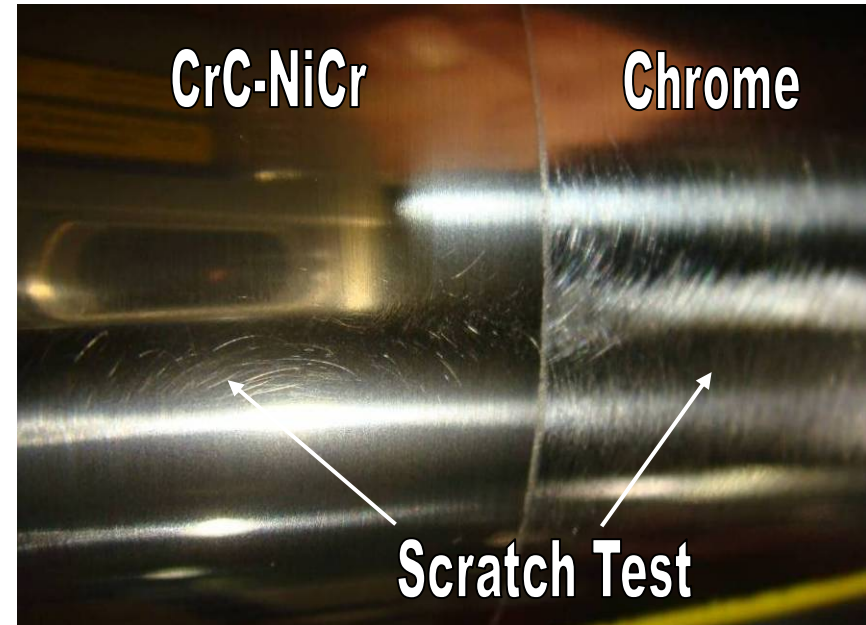


84TH COMBAT SUSTAINMENT WING

## ■ Scratch Test CrC/NiCr vs EHC



400 Grit: CrC-NiCr



240 Grit: CrC-NiCr

	Chrome	CrC-NiCr
Super Finish		1.03 Ra
400 Grit	5.8 Ra	2.04 Ra
240 Grit	7.18 Ra	3.79 Ra

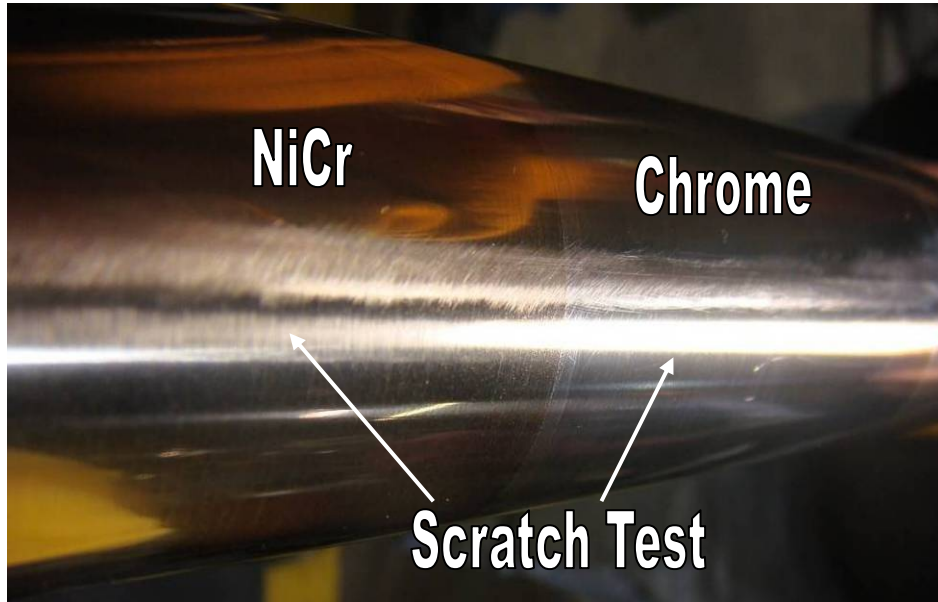


# C-5 Lower Metering Tube

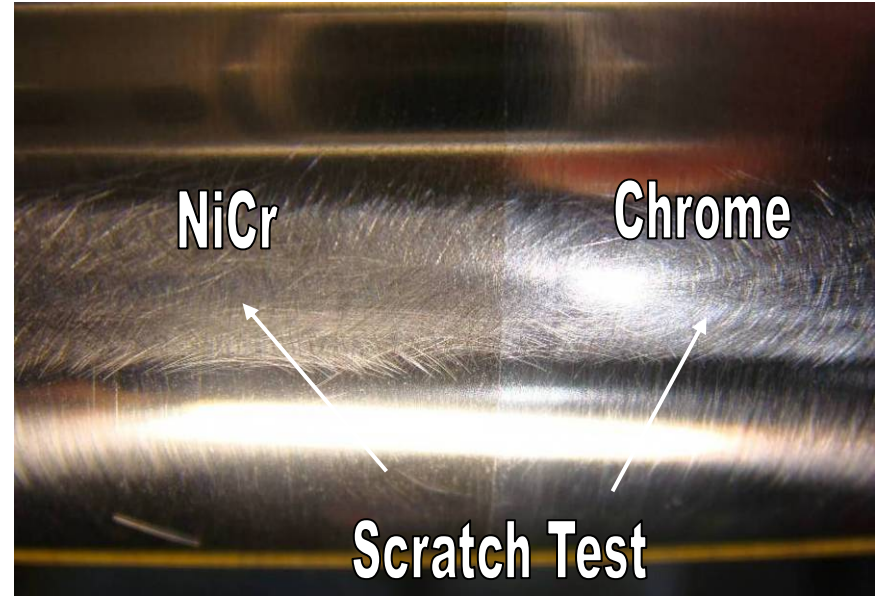


84TH COMBAT SUSTAINMENT WING

## ■ Scratch Test NiCr vs EHC



400 Grit: NiCr



240 Grit: NiCr

	Chrome	NiCr
Super Finish		1.36 Ra
400 Grit	5.8 Ra	7.47 Ra
240 Grit	7.18 Ra	14.4 Ra



# C-5 Lower Metering Tube



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## ■ Scratch Test conclusions

- The cause of the initial scratches could not be determined. Damage was noted on the mating part, imbedded particles in the seal were not found. As a result both 240 and 400 grit aluminum oxide cloth was used to create a controlled, worst case test.
- As expected, the WC/Co performed better than the CrC/NiCr and NiCr coatings
- The application cost differences between the three coatings was relatively insignificant based on performance levels
- Currently both the Lower Metering Tube and its corresponding part on the C-5 Nose Landing Gear are being converted from Chrome to an HVOF applied WC/Co eliminating the in-service failures.



# B-1 MLG Axle Evaluation



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- The axles (P/N 1881B85) were installed in Dec 06. They have performed great while in service, due to the high brake removal costs, the axles have not been removed for further inspection to date
- The axles will be inspected during the next major Phase inspection for AC 134
- The most notable item is the axle beam bushings had to be resealed before the installation of HVOF axles in 06.
- In every past case, the axle beam bushings migrate with chrome axles and they re-migrate in service very shortly after being resealed.
- The HVOF axles, in service since Dec 06, have not encountered axle beam bushing migration.
- When the axle bushings migrate, the brake swivels in a direction it was not designed for and may be cause of failures which may have led to major fire mishaps.
- This is very important, and a major reason for switching to HVOF 100% at both Depot and for new axles spare buys.
- An Engineering Change Order was recently created, new parts will have HVOF coatings only, no chrome.





# HILL AFB HVOF PROGRAM



*84TH COMBAT SUSTAINMENT WING*

■ **Questions??**