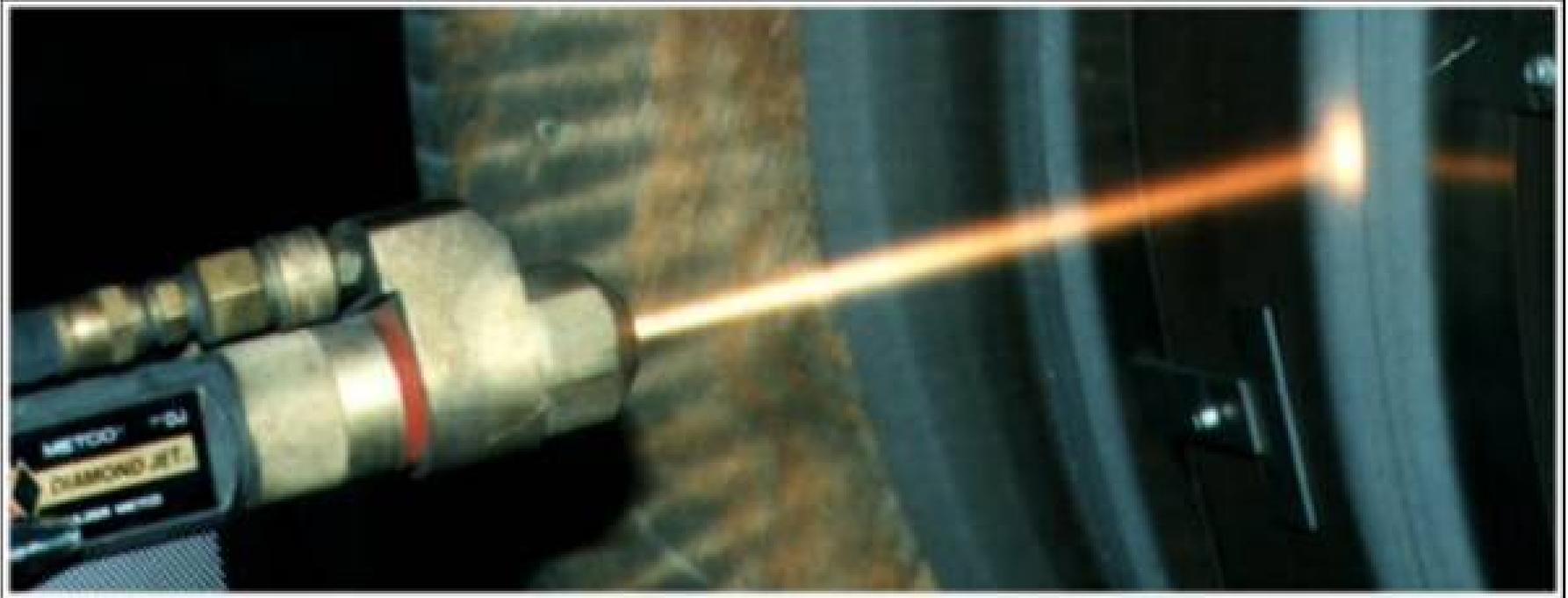


Hard Chrome Alternatives for Hydraulic Components



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Report Documentation Page

Form Approved
OMB No. 0704-0188

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1. REPORT DATE JUL 2004		2. REPORT TYPE		3. DATES COVERED 00-00-2004 to 00-00-2004	
4. TITLE AND SUBTITLE Hard Chrome Alternatives for Hydraulic Components				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) Oklahoma City Air Logistics Center, Tinker AFB, OK, 73145				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 24th Replacement of Hard Chrome Plating Program Review Meeting, July 20-21, 2004, Park City, UT. Sponsored by SERDP/ESTCP.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	unclassified	unclassified	Same as Report (SAR)	63	

Hard Chrome Alternatives for Hydraulic Components

- Program established to assist Oklahoma City Air logistics Center Airborne Accessories Directorate Avionics and Accessories Division (OC-ALC/LGERC) in development and implementations of replacement, repair, and overhaul procedures for hydraulic actuators across multiple weapon systems.



Hard Chrome Alternatives for Hydraulic Components

- Phase 1 – TO and Drawing Review, Database Development, Test Requirement Development
- Phase 2 – Delta-Qualification and Service Testing
- Phase 3 – Data Evaluation
- Phase 4 - Implementation



Hard Chrome Alternatives for Hydraulic Components

- Phase 1 – TO and Drawing Review, Database Development, Test Requirement Development
 - 100% Complete
 - 124 Air Force Technical Orders Reviewed.
 - 729 Engineering Drawings Reviewed.
 - 276 Chrome plated parts and 195 potentially chrome plated parts have been identified



Hard Chrome Alternatives for Hydraulic Components

- Phase 2 – Delta-Qualification and Service Testing
 - Delta-Qualification Testing
 - Flight Control Actuators
 - 87 distinct part numbers
 - 10 estimated to require delta-qualification
 - Utility Actuators
 - 73 distinct part numbers
 - 10 estimated to require delta-qualification
 - Snubbers/Other
 - 12 distinct part numbers
 - 3 estimated to require delta-qualification



Hard Chrome Alternatives for Hydraulic Components

- Flight Control Candidates
 - B-1 Horizontal Stabilizer
 - B-1 Pitch/Roll SCAS
 - C-130 Rudder Booster Actuator
 - A-10 Aileron
 - F-15 Pitch/Roll Channel Assembly (PRCA)
 - T-38 Aileron Actuator



Hard Chrome Alternatives for Hydraulic Components

- Utility Candidates
 - C-130 Ramp Actuator
 - C/KC-135 Main Landing Gear Actuator
 - C/KC-135 Main Landing Gear Door Actuator



Hard Chrome Alternatives for Hydraulic Components

- Snubber/Other Candidates
 - C-135 Aileron Control Surface Snubber
 - KC-135 Ruddevator



Hard Chrome Alternatives for Hydraulic Components

- Service Testing
 - A two year service test is planned for all actuators and their similar components.
 - C/KC-135 Service Test to include: Snubbers, MLG, MLG Door, and Ruddevator actuators
 - C-130 Service Test to include: Rudder, Elevator, Aileron, Ramp, and Aft Cargo Door actuators
 - A-10 Service Test to include: Aileron, Rudder, and Elevator actuators
 - C-130, C/KC-135 and A-10 service test plans have been completed and delivered to OC-ALC/LGERC
 - Coordination with the SPOs, Using Commands, and Center Test Authority is awaiting completion of rig tests



Hard Chrome Alternatives for Hydraulic Components

- Phase 3 – Data Evaluation
 - Results of testing thus far will be discussed with each unit breakdown



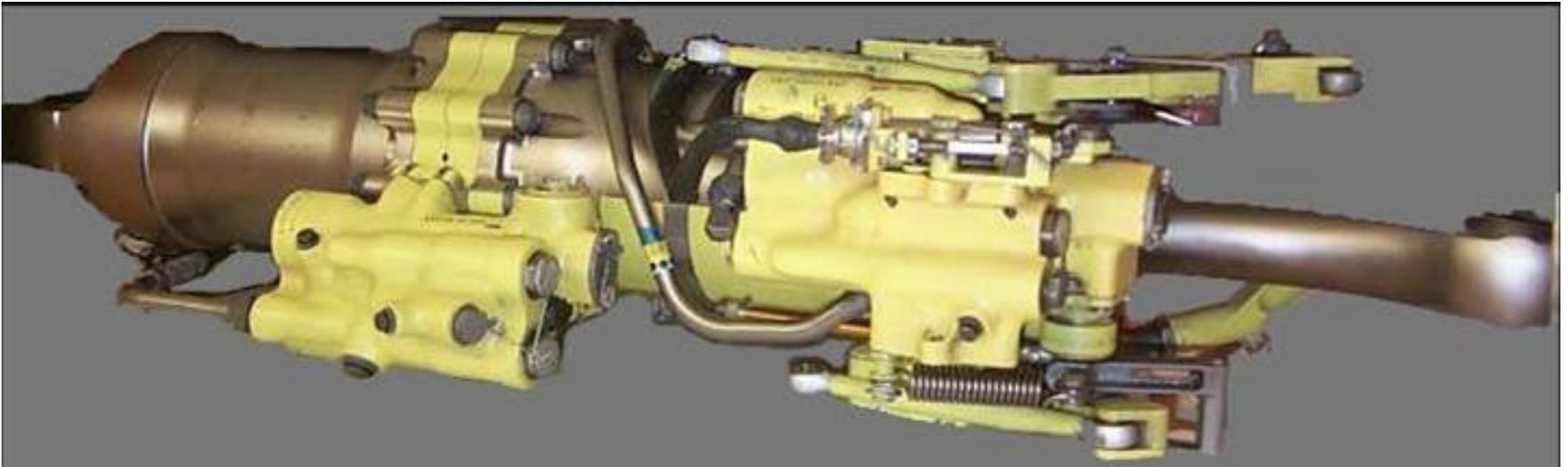
Hard Chrome Alternatives for Hydraulic Components

- Phase 4 – Implementation
 - The solutions developed during evaluation will be implemented.
 - One actuator has reached this phase; OC-ALC/LGERC is working with Boeing to provide updated configuration documents (drawings, specs) to allow production to commence



Hard Chrome Alternatives for Hydraulic Components

- B-1 Horizontal Stabilizer
 - Drives horizontal stab surfaces for pitch and roll control



Hard Chrome Alternatives for Hydraulic Components

- B-1 Horizontal Stabilizer
 - Specifications
 - P/N: L5873400-051/052/061/062
 - Stroke: 6.843 in.
 - Operating Pressure: 4000 psi
 - Fwd Piston OD: 2.4 in.; Fwd Head OD: 4.8 in.
 - Aft Piston OD: 3.1 in.; Aft Head OD: 5.2 in.
 - Piston Rod Material: HP9-4-30
 - Coating Material: WC-CoCr – Piston Rod and Head
 - Seals: Enercap II HP (G-T)



Hard Chrome Alternatives for Hydraulic Components

- B-1 Horizontal Stabilizer
 - Background
 - Forward piston required redesign to eliminate fatigue failures (not related to chrome)
 - Design qualification required endurance testing
 - Opportunity to include alternatives and new seals in test
 - HVOF coatings replace chrome on forward and aft pistons



Hard Chrome Alternatives for Hydraulic Components

- B-1 Horizontal Stabilizer
 - Coating
 - Forward Piston coated by Southwest United Industries
 - Aft Piston coated by PTI



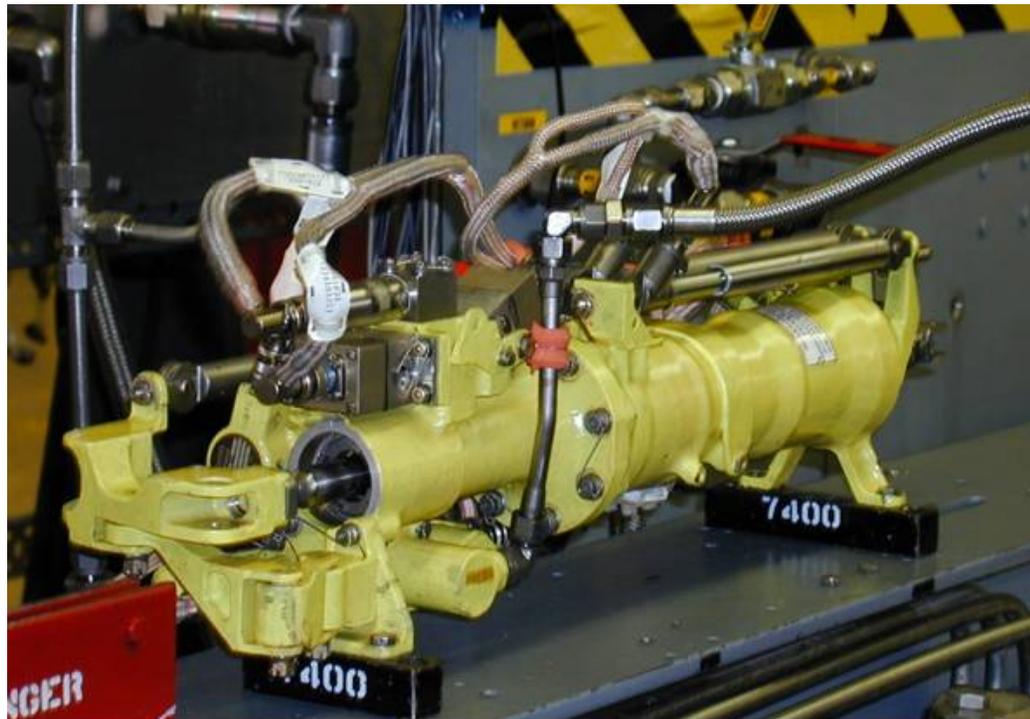
Hard Chrome Alternatives for Hydraulic Components

- B-1 Horizontal Stabilizer
 - Testing
 - Performed by Boeing
 - Endurance
 - 750,000 Cycles
 - Results
 - Endurance Testing
 - Completed 750,000 cycles, no unallowable leakage
 - Similarity Arguments
 - Other B-1 flight control actuators



Hard Chrome Alternatives for Hydraulic Components

- B-1 Pitch/Roll SCAS
 - Provides pitch and roll input to mixers and on to horizontal stab surfaces for added stability and for autoflight



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Hard Chrome Alternatives for Hydraulic Components

- B-1 Pitch/Roll SCAS
 - Specifications
 - P/N: L5877400-071
 - Stroke: 3.5 in.
 - hOperating Pressure: 4000 psi
 - Primary Piston OD: .7 in.; Secondary Piston OD: .5 in.; Head OD 1.2 in.; Groove OD: .9 in
 - Numerous other components (sleeves, pistons) will also be coated
 - Piston Rod Material: HP9-4-30
 - Coating Material: WC-CoCr – Piston Rod and Head
 - Seals:



Hard Chrome Alternatives for Hydraulic Components

- B-1 Pitch/Roll SCAS
 - On contract with Boeing
 - Multiple improvements are planned.
 - Parts have been shipped to Boeing for coating.



Hard Chrome Alternatives for Hydraulic Components

- C-130 Rudder Booster Actuator
 - Used to operate the rudder in the C-130 aircraft



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Hard Chrome Alternatives for Hydraulic Components

- C-130 Rudder Booster

- Specifications

- P/N: 5C5792-1
- Stroke: 8.312 in.
- Operating Pressure: 3000 psi
- Piston OD: .9 in.; Head OD 1.5 in.
- Piston Rod Material: 4130
- Coating Material: WC-CoCr – Piston Rod; T-400 Head; WC-CoCr – Trunnion OD and ID
- Seals: Original O-ring with Backups, Enercap II (G-T) and Plus Seal II (S)



Hard Chrome Alternatives for Hydraulic Components

- C-130 Rudder Booster
 - Specifications Cont'd
 - Surface Finish for HVOF rods
 - Ra – 4 or better
 - Rp – 8 maximum (+4 tolerance)
 - Rz – 40 maximum (+5 tolerance)
 - Tp – 60-90% @ a depth of 25% Rz ($\pm 5\%$ tolerance)



Hard Chrome Alternatives for Hydraulic Components

- C-130 Rudder Booster Actuator
 - Background
 - Rudder booster actuator delta-qualification was contracted to OEM in September 2001.
 - OEM was acquired by new company in March 2002.
 - New OEM was terminated in March 2004, due to lack of progress.
 - ARINC subcontracted coating/grinding of parts to Southwest United and subcontracted endurance/temperature testing to Smiths Aerospace.



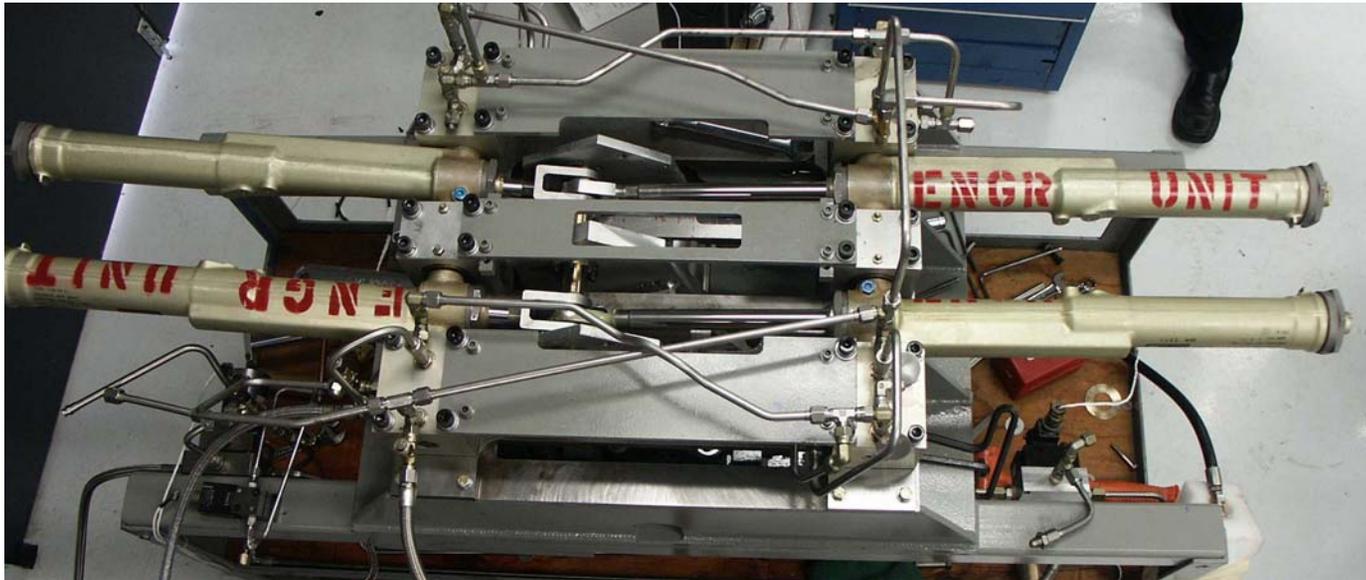
Hard Chrome Alternatives for Hydraulic Components

- C-130 Rudder Booster Actuator
 - Coating
 - Performed by Southwest United in Tulsa, Oklahoma during week of May 5, 2004
 - Assembly/ATP
 - Performed by OO-ALC during week of May 10, 2004
 - Testing
 - Performed by Smiths Aerospace in Duarte, California; July 2004
 - Endurance
 - 1,000,000 Cycles
 - Temperature
 - -65° F to +160° F



Hard Chrome Alternatives for Hydraulic Components

- C-130 Rudder Booster Actuator
 - Endurance Testing Results
 - 3 HVOF coated piston rods completed 1,000,000 cycles
 - Three sets of seals, passed endurance testing; Original Elastomeric T-Seal, Enercap II (G-T) and Plus Seal II (S)



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Hard Chrome Alternatives for Hydraulic Components

- C-130 Rudder Booster Actuator
 - Endurance Testing Results
 - Chrome baseline actuator failed after 415,145 cycles
 - No data currently as to what caused failure.



Hard Chrome Alternatives for Hydraulic Components

- C-130 Rudder Booster Actuator
 - Temperature Testing Results
 - All 4 actuators failed low temperature testing (due to excessive leakage).
 - Further testing is planned.
 - Rapid warm-up and high temperature tests were passed successfully.
 - Similarity Arguments
 - C-130 Aileron and Elevator actuators



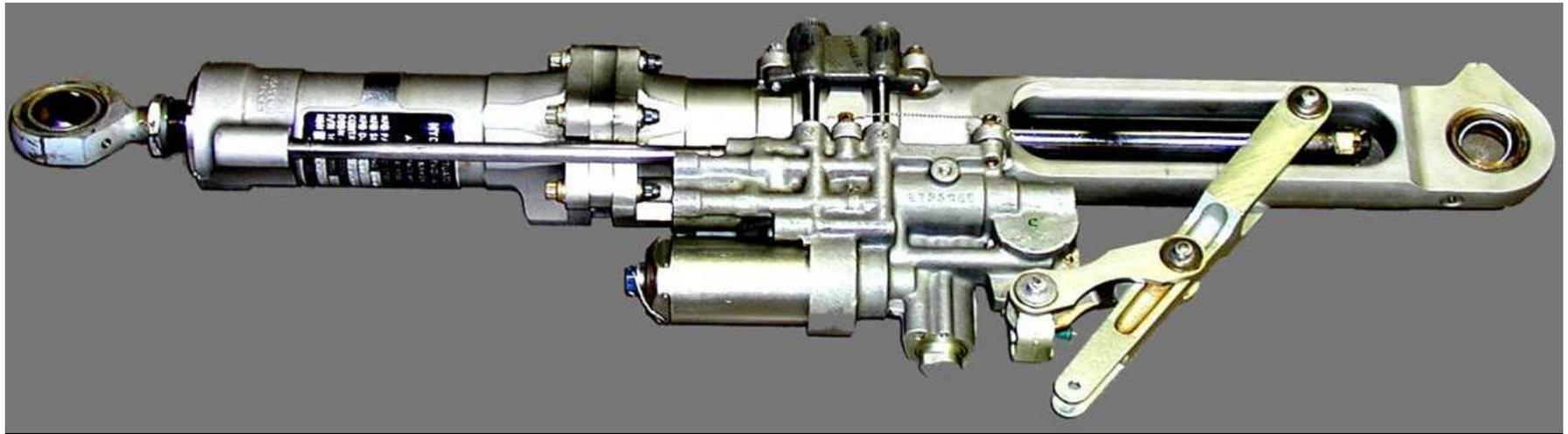
Hard Chrome Alternatives for Hydraulic Components



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Hard Chrome Alternatives for Hydraulic Components

- A-10 Aileron Actuator
 - Provides actuation of the ailerons on the A-10 aircraft



Hard Chrome Alternatives for Hydraulic Components

- A-10 Aileron Actuator
 - Specifications
 - P/N: 2730500-5
 - Stroke: 5.81 in.
 - Operating Pressure: 3000 psi
 - Primary Piston OD: 1.2475 in.; Primary Head OD 2.2415 in.;
Secondary Piston OD: 1.248 in.; Secondary Head OD 2.241 in.
 - Piston Rod Material: 4340
 - Coating Material: WC-CoCr – Piston Rod and Head
 - Seals: Coorstek Metaplast



Hard Chrome Alternatives for Hydraulic Components

- A-10 Aileron Actuator
 - ARINC subcontracted the A-10 Aileron to Parker (OEM) in Los Angeles, California
 - Coating
 - Performed by PTI of Torrance, California
 - Testing
 - Testing was performed by Parker
 - Endurance
 - 1,875,200 Cycles
 - Temperature
 - -40° F to 275° F
 - Salt Fog
 - Per MIL-STD-810B, Method 509, Procedure 1



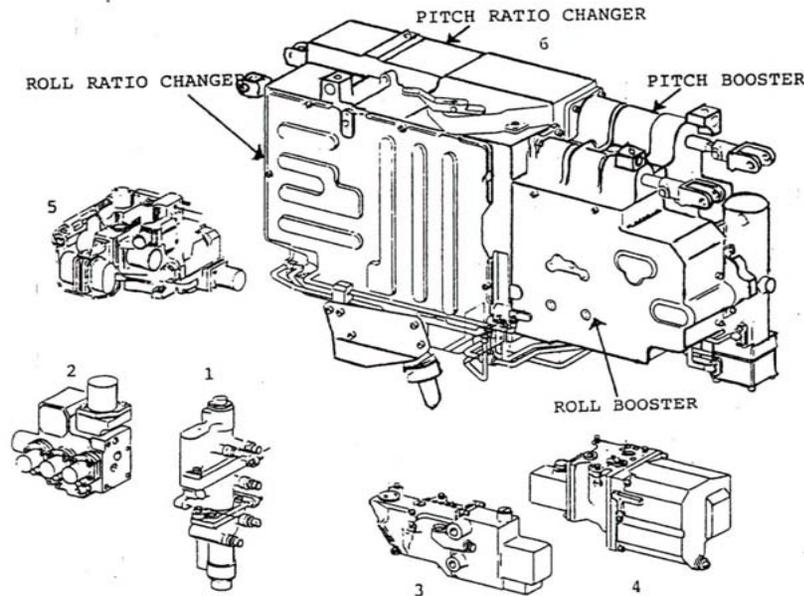
Hard Chrome Alternatives for Hydraulic Components

- A-10 Aileron Actuator
 - Endurance Testing Results
 - Testing in process, close to completing 3 of 5 layers (1,125,120 cycles)
 - Had a couple of fixture failures, unrelated to the HVOF surfaces
 - Temperature Testing Results
 - Pending, testing should be complete by September 15, 2004
 - Salt Fog Testing Results
 - Pending, testing should be complete by September 15, 2004
 - Similarity Arguments
 - A-10 rudder and elevator actuators



Hard Chrome Alternatives for Hydraulic Components

- F-15 Pitch/Roll Channel Assembly (PRCA)
 - Serve as mechanical link between the pilot's stick and the flight control actuators, summing pilot input with additional inputs such as altitude, attitude, and airspeed. It provides hydraulic boost and variable ratio output scheduling based on speed and acceleration.



Hard Chrome Alternatives for Hydraulic Components

- F-15 Pitch/Roll Channel Assembly (PRCA)
 - Subcontract expected to be awarded to MOOG (OEM) by end of July 2004.



Hard Chrome Alternatives for Hydraulic Components

- T-38 Aileron Actuator
 - Used to operate the aileron on the T-38 aircraft



Hard Chrome Alternatives for Hydraulic Components

- T-38 Aileron Actuator
 - Specifications
 - P/N: 2-431610-505/506/508
 - Stroke: 2.02-2.10 in.
 - Retracted/Extended Length: 8.62 in/10.80 in
 - Operating Pressure: 3000 psi
 - Piston OD: .9 in.; Head OD 2.1 in.;
 - Piston Rod Material: 4130
 - Coating Material: TBD
 - Seals: TBD



Hard Chrome Alternatives for Hydraulic Components

- T-38 Aileron Actuator
 - Subcontract was awarded to Smiths Aerospace (OEM) in Duarte, California



Hard Chrome Alternatives for Hydraulic Components

- C-130 Ramp Actuator
 - Used to operate the C-130 Ramp Door



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Hard Chrome Alternatives for Hydraulic Components

- C-130 Ramp Actuator
 - Specifications
 - P/N: 370750-1
 - Stroke: 64.998 in.
 - Retracted/Extended Length: 139.6 in/74.6 in
 - Operating Pressure: 3000 psi
 - Piston OD: 1.8 in.; Head OD 2.3 in.;
 - Piston Rod Material: 4340
 - Coating Material: WC-CoCr – Piston Rod and Head
 - Seals: ACGTL (G-T), AGT (G-T), VL Seal (S), Custom Seal (S), RSA (G-T)



Hard Chrome Alternatives for Hydraulic Components

- C-130 Ramp Actuator
 - Coating
 - 2 rods were coated with WC-CoCr by Southwest United in Tulsa, Oklahoma
 - Testing
 - Performed by ARINC and OC-ALC/ENFLL in the OC-ALC Engineering Laboratory
 - Endurance
 - Each actuator was subjected to 20,000 cycles
 - Temperature
 - Each actuator was subjected to a cold soak at -65° F, then cycled 5 times while still at -65° F



Hard Chrome Alternatives for Hydraulic Components



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Hard Chrome Alternatives for Hydraulic Components

- C-130 Ramp Actuator
 - Endurance Testing Results
 - Actuator A – ACGTL Rod Seals (G-T) and Coorstek Scraper
 - Rod leakage was excessive
 - G-T developing modification to seal material for future testing
 - Actuator B – Coorstek Scraper and Rod seals included: AGT (G-T), VL Seal (S), Custom Seal (S), and RSA (G-T)
 - AGT – excessive leakage (4,302 cycles over 2 seals)
 - VL Seal – excessive leakage (829 cycles over 3 seals)
 - Custom Seal – unable to fully assembly actuator
 - RSA – Complete 20,000 cycles with almost zero leakage.



Hard Chrome Alternatives for Hydraulic Components

- C-130 Ramp Actuator
 - Temperature Testing Results
 - Actuators were soaked for approximately 17 hours then cycled through 5 complete cycles.
 - Some leakage occurred, but due to ice, it is unknown exactly how much fluid was collected.
 - Similarity Arguments
 - C-130 Aft Cargo Door Actuator



Hard Chrome Alternatives for Hydraulic Components



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Hard Chrome Alternatives for Hydraulic Components

- C/KC-135 Main Landing Gear Actuator
 - Used to extend and retract the C/KC-135 MLG



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Hard Chrome Alternatives for Hydraulic Components

- C/KC-135 MLG Gear
 - Specifications
 - P/N: 5-84046-6
 - Stroke: 13.78 in.
 - Operating Pressure: 3000 psi
 - Piston Rod Material: 4340
 - Piston OD: 2.995 in.; Head OD 4.8 in
 - Retracted/Extended Length: 30.84 in/44.62 in
 - Coating Material: WC-CoCr – Piston Rod and Head
 - Seals: O-ring with Back-ups and Spring Energized Coorstek Rod Seal (also has new Coorstek scraper)



Hard Chrome Alternatives for Hydraulic Components

- C/KC-135 Main Landing Gear Actuator
 - Coating
 - Performed by Southwest United in Tulsa, Oklahoma
 - Testing
 - Performed by ARINC and OC-ALC/ENFLL in the OC-ALC Engineering Laboratory
 - Endurance
 - Each actuator was subjected to 20,000 cycles
 - Temperature
 - Each actuator was subjected to a cold soak at -65° F, then cycled 5 times while still at -65° F



Hard Chrome Alternatives for Hydraulic Components



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Hard Chrome Alternatives for Hydraulic Components

- C/KC-135 Main Landing Gear Actuator
 - Endurance Testing Results
 - Testing should be completed by July 21, 2004.
 - Currently
 - The O-ring configuration is leaking, but still under allowable limits.
 - The spring energized seal has leaked very limited amount.
 - Temperature Testing Results
 - To be completed on July 22-23, 2004
 - Similarity Arguments
 - E-3 MLG Actuator (identical actuator with different part number)



Hard Chrome Alternatives for Hydraulic Components

- C/KC-135 Main Landing Gear Door Actuator
 - Used to open and close the C/KC-135 MLG Door



Hard Chrome Alternatives for Hydraulic Components

- C/KC-135 Main Landing Gear Door Actuator
 - Specifications
 - P/N: 5-84045-9
 - Stroke: 20.66 in.
 - Retracted/Extended Length: 51.66 in/ 31.00 in
 - Operating Pressure: 3000 psi
 - Piston OD: 1.3 in.; Head OD 2.1 in.;
 - Piston Rod Material: 4140 or 4340
 - Coating Material: TBD
 - Seals: TBD



Hard Chrome Alternatives for Hydraulic Components

- C/KC-135 Main Landing Gear Door Actuator
 - Testing
 - To be performed in the future.



Hard Chrome Alternatives for Hydraulic Components

- C/KC-135 Aileron Snubber Actuator
 - Used to dampen the oscillations of the C/KC-135 aileron



Hard Chrome Alternatives for Hydraulic Components

- C/KC-135 Aileron Snubber Actuator

- Specifications

- P/N: 5-88763-7/10
- Stroke: 1.81 in.
- Piston OD: .6 in.
- Operating Pressure: 3000 psi
- Retracted/Extended Length: 15.595 in/17.455 in
- Piston Rod Material: 4340
- Coating Material: WC-CoCr – Piston Rod
- Seals: O-ring with back-ups and VL Seal (S)



Hard Chrome Alternatives for Hydraulic Components

- C/KC-135 Aileron Snubber Actuator
 - Coating
 - Performed by Southwest United in Tulsa, Oklahoma
 - Testing
 - Performed by ARINC in Oklahoma City, OK facility.
 - Endurance
 - Each actuator completed 21,200 cycles
 - Temperature
 - Each actuator was subjected to a cold soak at -65° F, then cycled 5 times while still at -65° F

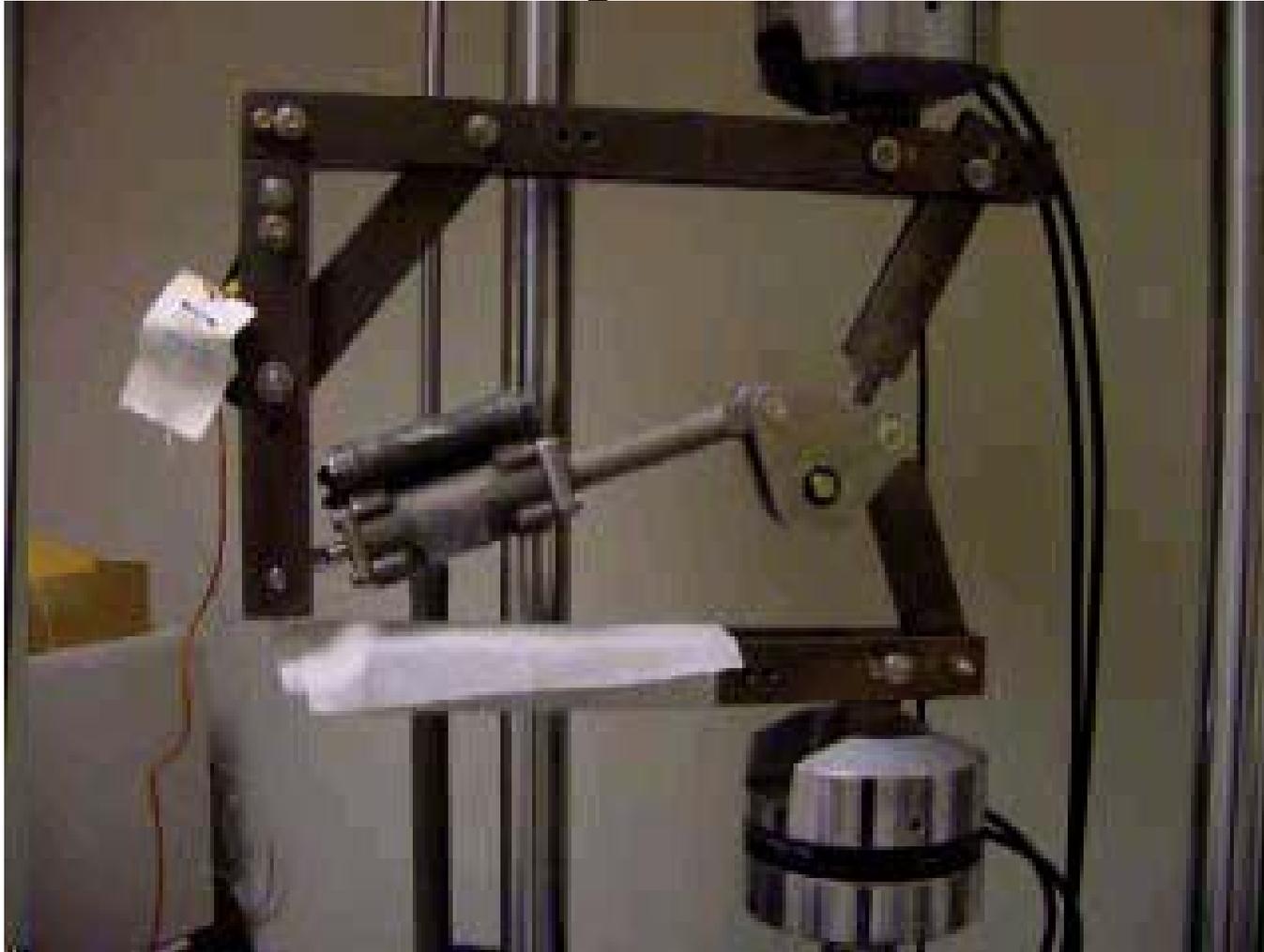


Hard Chrome Alternatives for Hydraulic Components

- C/KC-135 Aileron Snubber Actuator
 - Endurance Testing Results
 - Actuator C, with O-ring and back-ups, completed 21,200 cycles with zero leakage
 - Actuator D, with VL Seal (S), completed 21,200 cycles with 8 total drops of fluid.
 - This piston rod had small circumferential scratch at test completion.



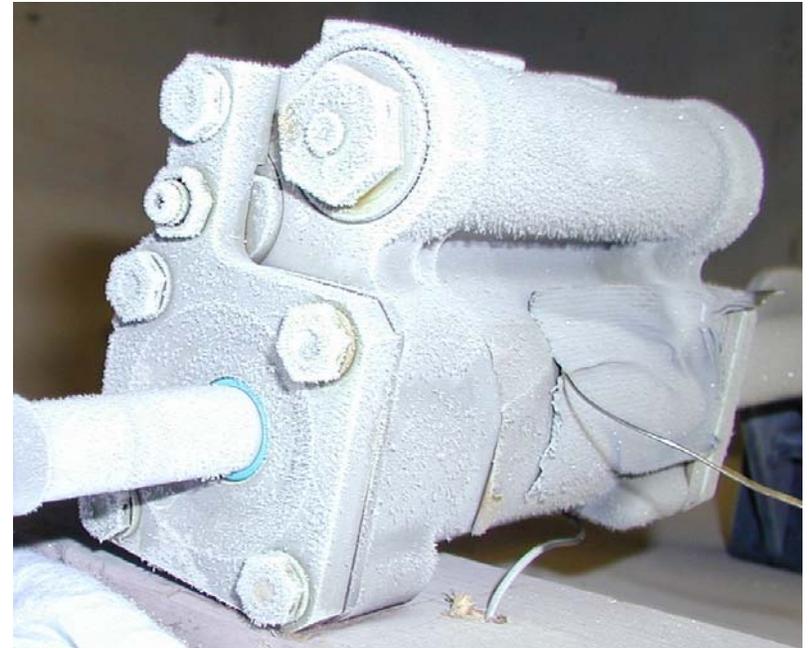
Hard Chrome Alternatives for Hydraulic Components



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Hard Chrome Alternatives for Hydraulic Components

- C/KC-135 Aileron Snubber
 - Temperature Testing Results
 - Actuator C and D both completed low temperature testing with zero leakage.
 - Similarity Arguments
 - C/KC-135 rudder and elevator snubbers



Hard Chrome Alternatives for Hydraulic Components

- KC-135 Rudder Actuator
 - Provides hydraulic power to maneuver the refueling boom



Hard Chrome Alternatives for Hydraulic Components

- KC-135 Ruddevator Actuator
 - Specifications
 - P/N: 65-6750-1
 - Stroke: 5.875 in.
 - Retracted/Extended Length: 19.705 in/25.580 in
 - Operating Pressure: 3000 psi
 - Piston OD: .746 and .748 in.
 - Piston Rod Material: 4140
 - Coating Material: TBD
 - Seals: TBD



Hard Chrome Alternatives for Hydraulic Components

- KC-135 Ruddevator Actuator
 - Testing
 - To be performed in the future.



Hard Chrome Alternatives for Hydraulic Components

- Summary
 - 3 Actuators (B-1 Horizontal Stab, C-130 Ramp, and C/KC-135 Aileron Snubber) have successfully completed qualification tests and are ready for service testing
 - 3 Actuators (C-130 Rudder Booster, A-10 Aileron, C/KC-135 MLG) have completed most testing, all should be ready for service testing by October 2004.
 - 3 Actuators (B-1 SCAS, F-15 PRCA, T-38 Aileron) are currently under contract to be delta-qualified. These test should be completed by July-August 2005.
 - 2 Actuators (C/KC-135 MLG Door and KC-135 Ruddevator) are planned for future testing.



Hard Chrome Alternatives for Hydraulic Components

- Questions?

