HCAT PROGRESS REPORT SEPTEMBER 2002

STATUS

CONDUCTING THREE TESTS:

1. Fatigue of entire MLG - Dash-8 Series 400.

2. High Cycle (Dithering) wear test on hydraulic actuator.

3. Fatigue of MLG pistons 5” and 10” OD (Cr vs. WC-Co-Cr).

HVOF coating is WC-Co-Cr.

Report Documentation Page

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OMB No. 0704-0188

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15. SUBJECT TERMS

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a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**41**	

TEST 1: MLG FATIGUE TEST

CURRENT STATUS

- 14 parts have been HVOF coated (piston, axle, and pins).
- Components sprayed by Vac Aero and Southwest Aeroservice.
- Gear has been assembled, installed in the test rig and testing has begun.

TEST 1: MLG FATIGUE TEST

CURRENT STATUS

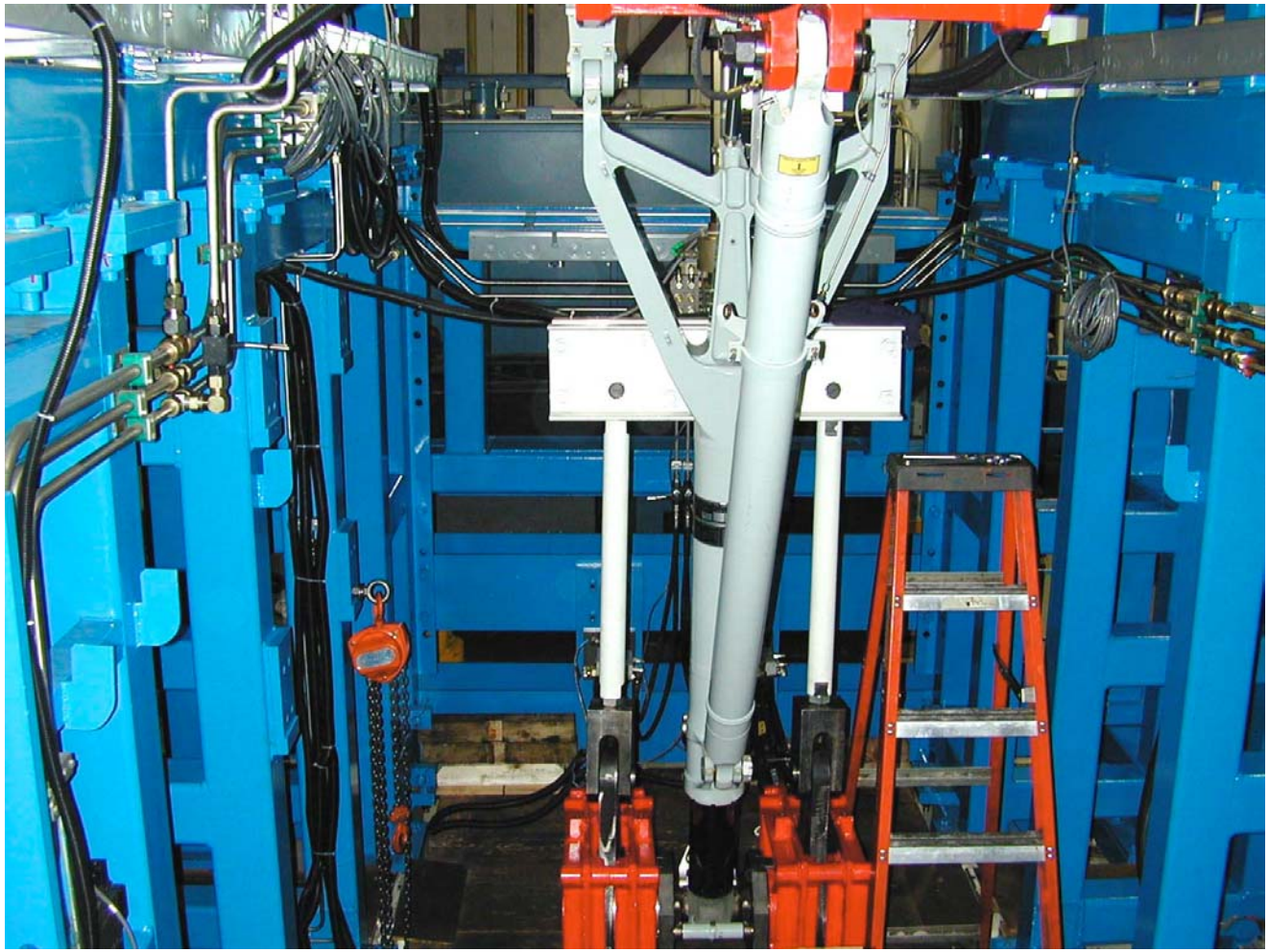
- Testing - 10 layers of testing = 5 lives.
- Each layer includes 32 blocks of test conditions (load location, magnitude, direction and number of cycles).
- 1 layer of fatigue consists of 30 blocks of ground load conditions (= 30,000 flight cycles), 1 block of retraction lug test conditions (66,000 gear extend and 33,000 gear retract flight cycles) and 1 block of stabilizer brace lock link test conditions (99,000 lock and 33,000 unlock flight cycles).

TEST 1: MLG FATIGUE TEST

CURRENT STATUS

- Testing considered successful when the gear withstands 5 lives of fatigue loads without initiation of detectable fatigue cracks. 1st life inspection revealed no issues.
- Test has accrued 1.24 lives (~25% complete). Some delays with the test rig and changing seals.
- Testing began with elastomeric T-type seals but the seals failed after 330,000 cycles.
- Second type of elastomeric seal failed after 480,000 cycles. New Seal Design has recently been installed.

TEST 1: MLG FATIGUE TEST



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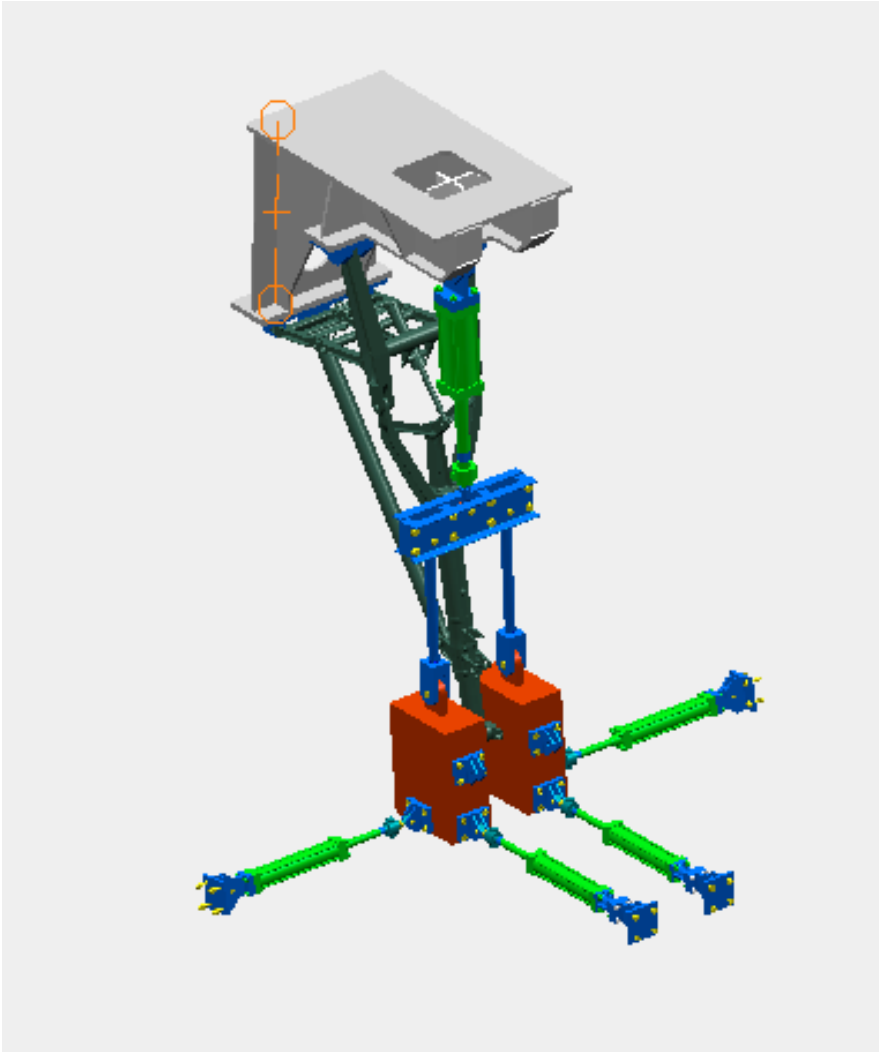

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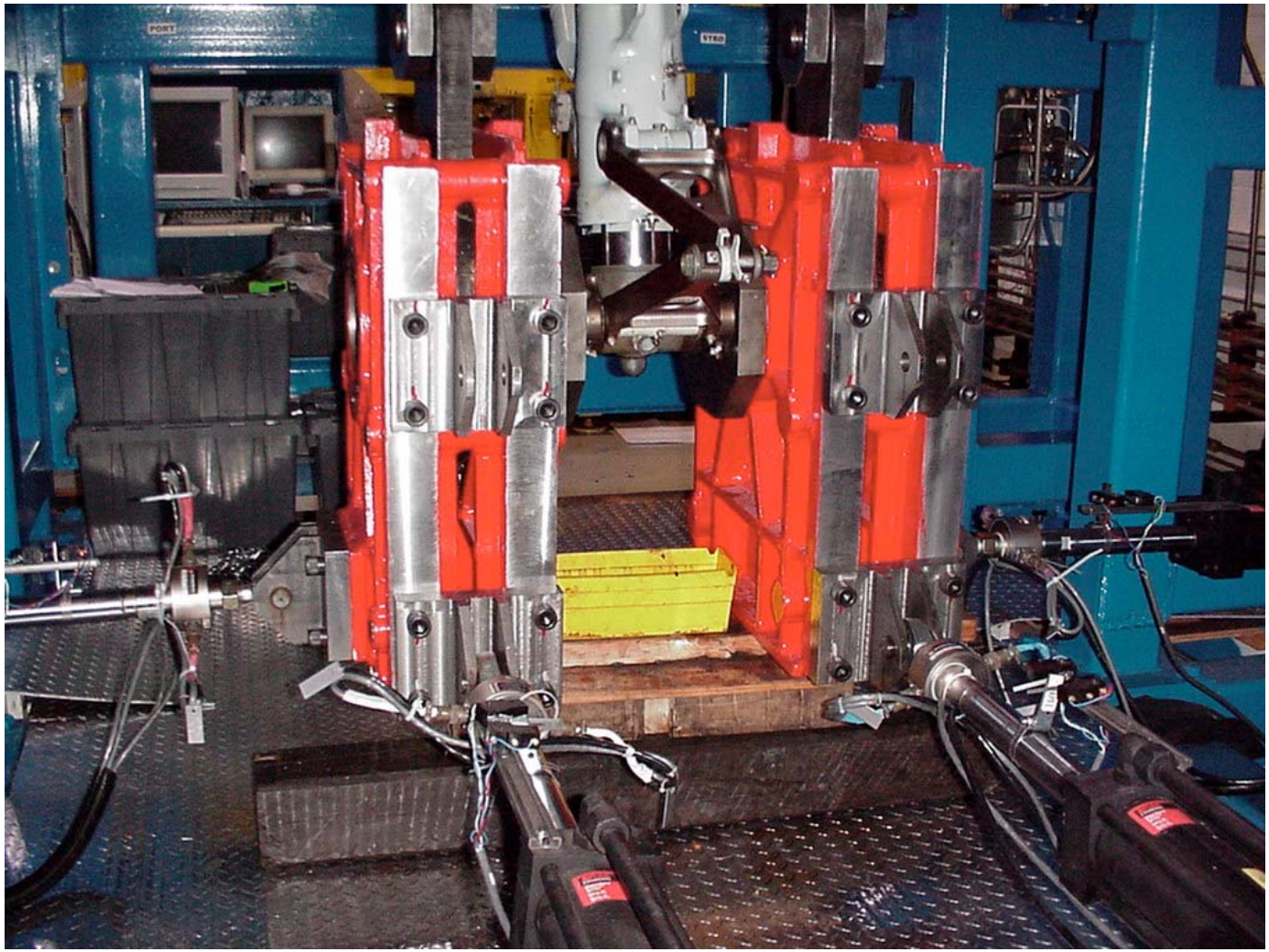


TEST 2: HIGH CYCLE WEAR TEST

CURRENT STATUS

- Purpose: Testing performance of HVOF coating on an aircraft actuator and demonstrate it can withstand constant cycles under endurance stress level for a civil aircraft actuator.
- 3 actuators being tested, 2 chrome plated, 1 WC-Co-Cr coated.
- Chrome finished 8-16 Ra.
- HVOF finished 3 Ra.

TEST 2: HIGH CYCLE WEAR TEST

CURRENT STATUS

- Test program is approximately 95% complete.
- To date scheduled inspections have found the HVOF coating acceptable with no evidence of scratches, cracks or other unacceptable indications.
- No evidence of leakage or wear on the seals.

TEST 2: HIGH CYCLE WEAR TEST

TEST 3: PISTON FATIGUE TEST

CURRENT STATUS

- First test: 5” OD Piston (3 Cr and 3 HVOF) - simulate a commercial regional aircraft.
- Second test: 10” OD Piston (3 Cr and 3 HVOF) - simulate large commercial jet.

TEST 3: PISTON FATIGUE TEST

SCOPE OF TEST

- Purpose: **"…to compare the fatigue performance of simulated LG piston coated with HVOF applied WC-Co-Cr and electrolytic chrome plating."**
- **"This test is aimed at deriving fatigue life design factors…"**
- "The test will be performed until failure of the simulated LG pistons occurs."

SCOPE OF TEST WAS ALTERED FOR 3rd HVOF 5" PISTON

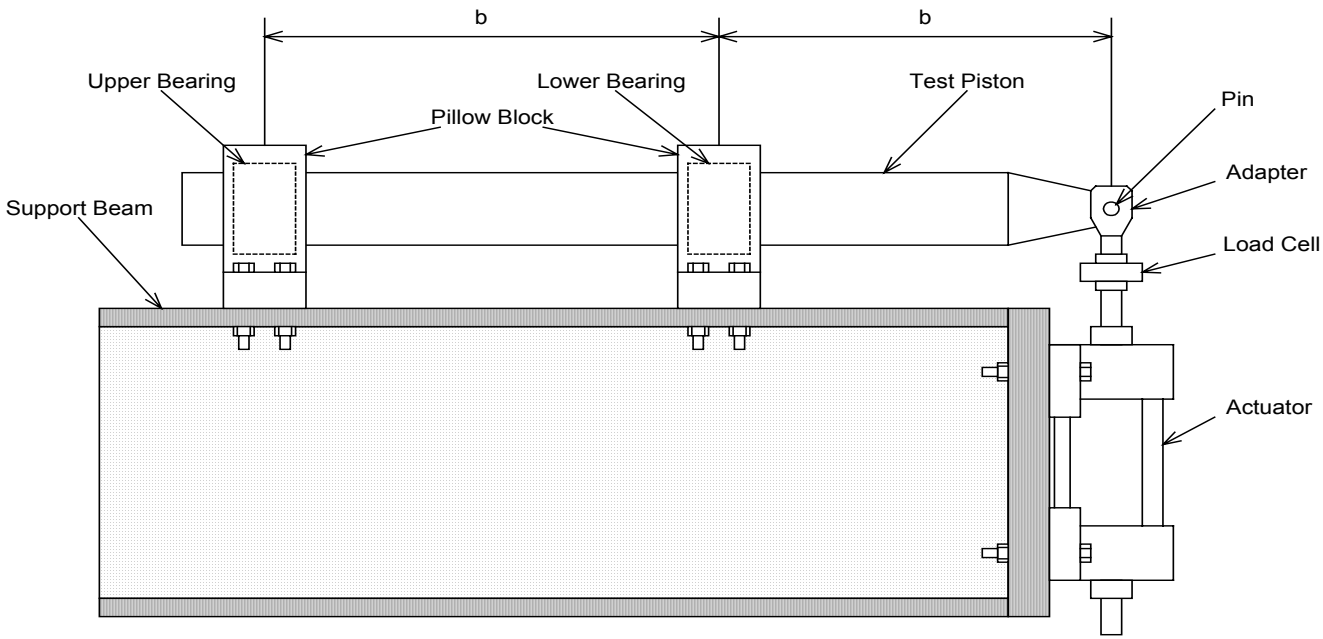
TEST 3: PISTON FATIGUE TEST

Test Conditions

- Bending loads based on fatigue analysis and landing gear fatigue requirements.
- Bending stresses approx. 100 ksi at R= -1.
- 50,000 cycles = 1 block of tests. Inspection after every block.
- Expected lives: 285,000 for 5” pistons, 330,000 for 10” pistons.

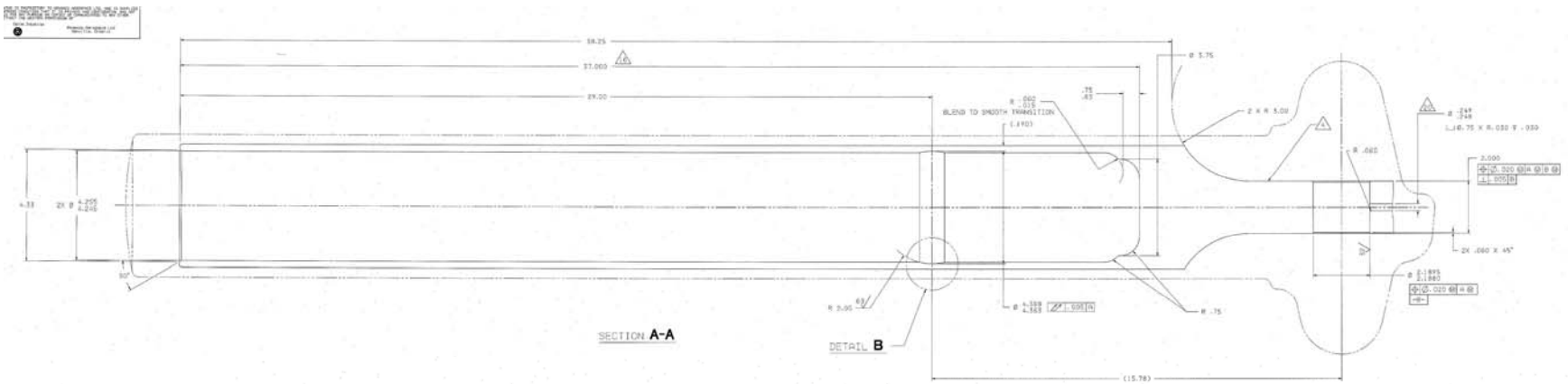
TEST 3: PISTON FATIGUE TEST

TEST CONFIGURATION



TEST 3: PISTON FATIGUE TEST

TEST SPECIMEN CONFIGURATION



TEST 3: PISTON FATIGUE TEST

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CURRENT STATUS

- 5” OD pistons have been HVOF sprayed (Vac Aero), ground and superfinished to 4 Ra by Goodrich (with assistance from Jon Devereaux, US Navy).
- Chrome plated pistons were processed in-house by Goodrich. Finished to better than 16 Ra.
- 10” OD pistons are complete, but not HVOF coated.

TEST 3: PISTON FATIGUE TEST

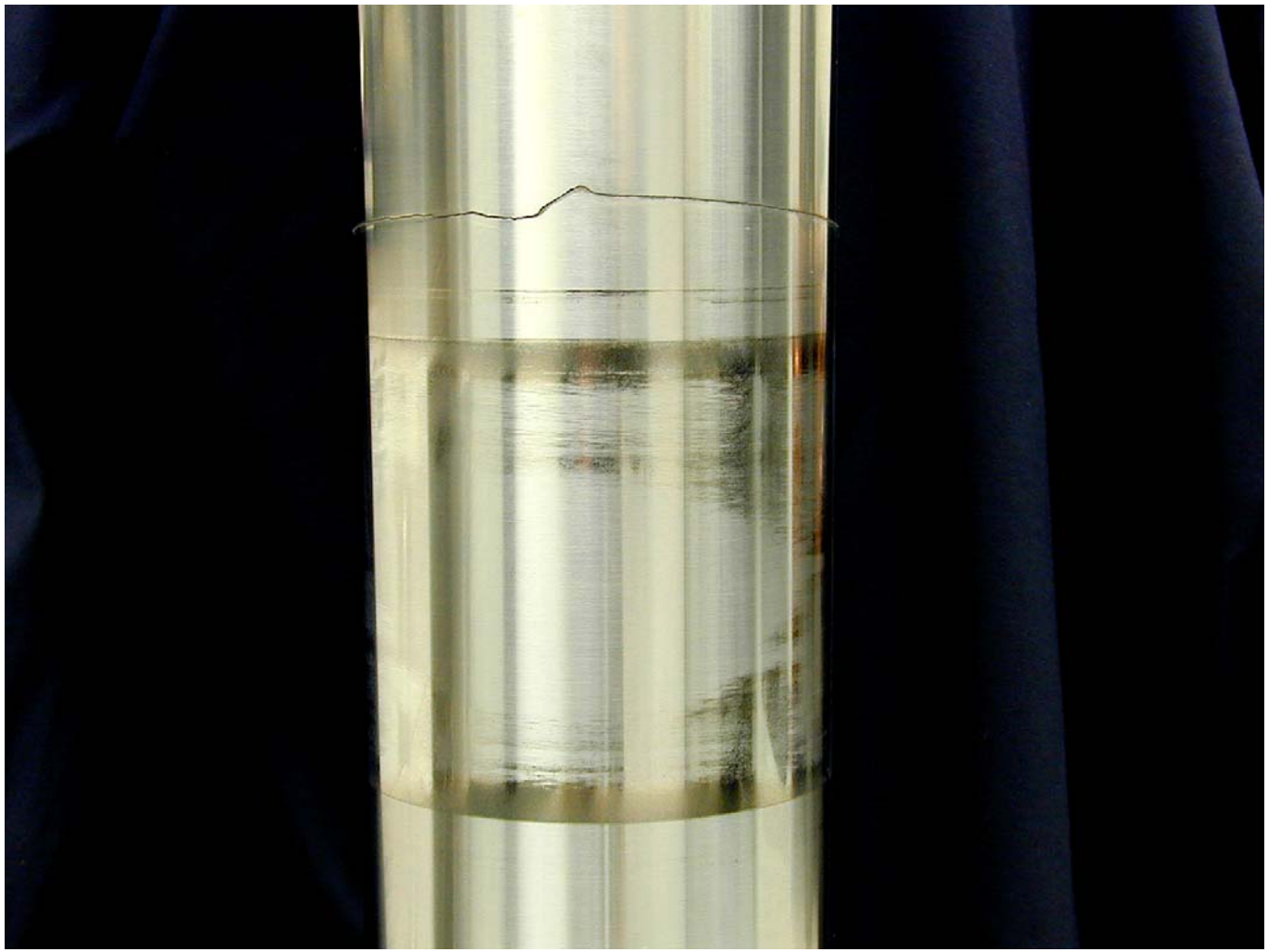
TEST RESULTS

- **1st chrome plated piston:**
  285,000 + 122,000 cycles. ~100ksi at notch

- No spalling of coating prior to failure. Some surface wear noted on chrome plating.

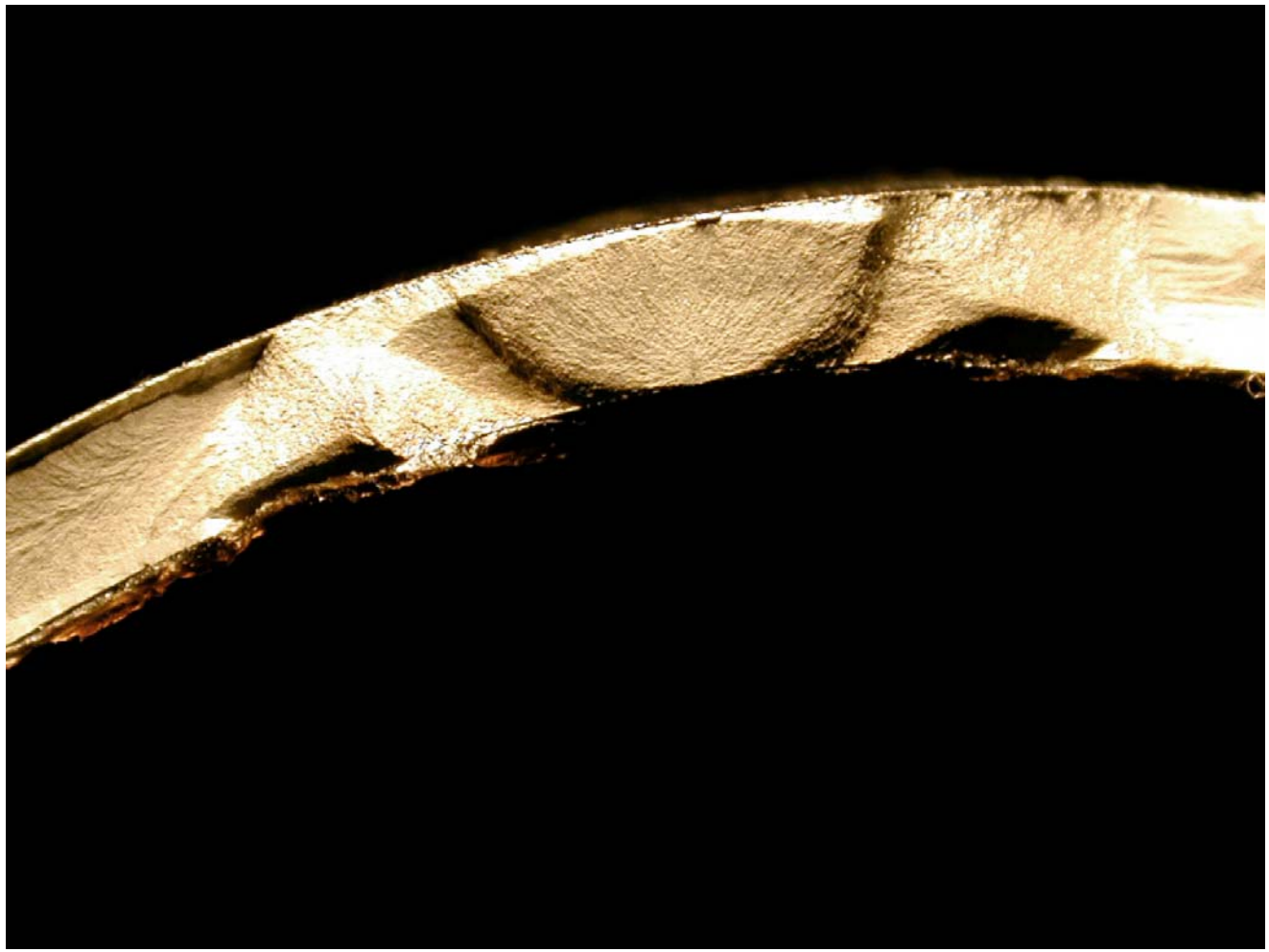
- **Piston failed at notch.**
  Crack initiated near the piston inner diameter at an **inclusion** - extended circumferentially outward.

TEST 3: PISTON FATIGUE TEST



CHROME PLATED 5 INCH PISTON

TEST 3: PISTON FATIGUE TEST



CHROME PLATED 5 INCH PISTON

TEST 3: PISTON FATIGUE TEST

CHROME PLATED 5 INCH PISTON

PISTON FATIGUE TEST

TEST RESULTS

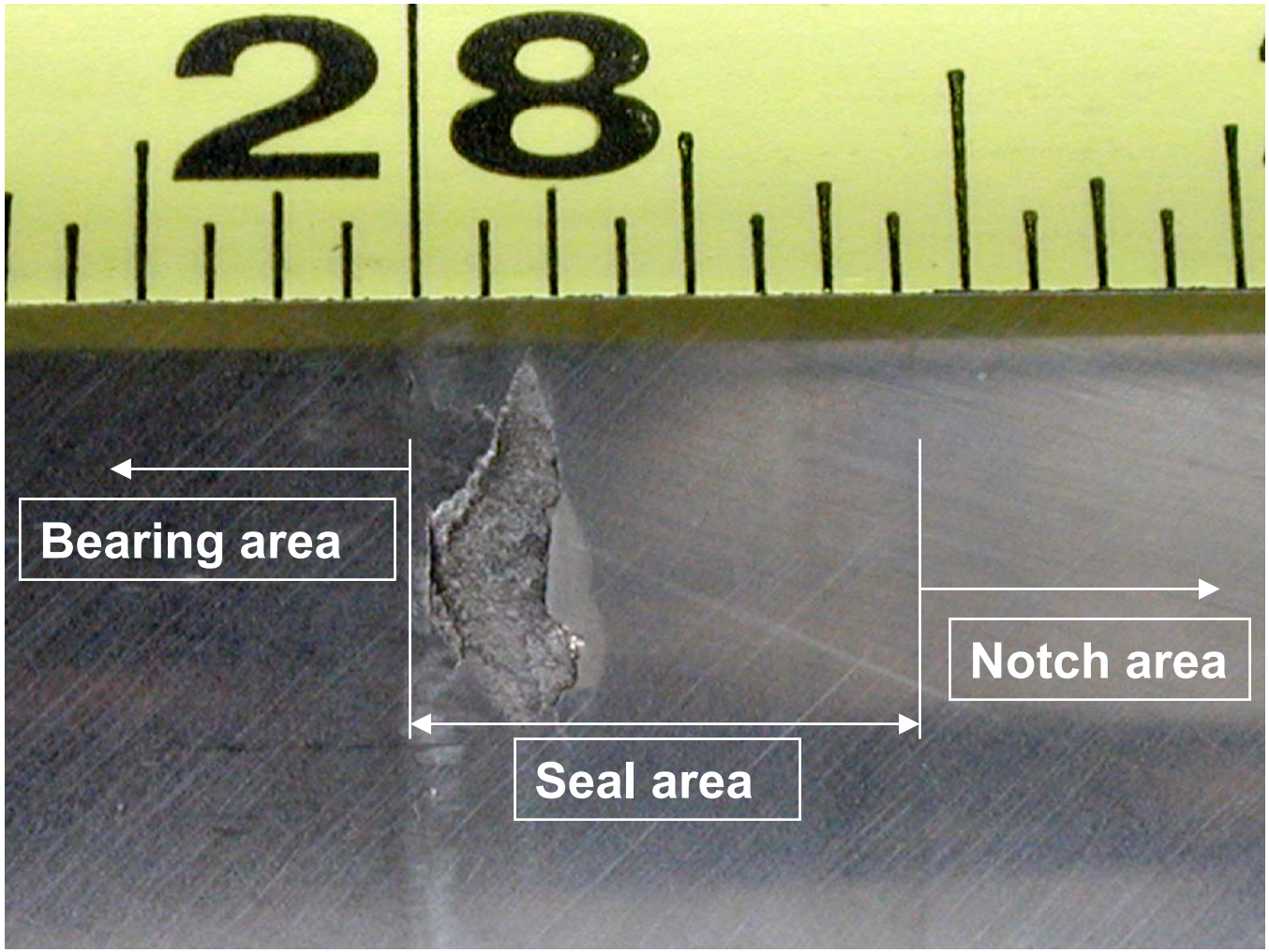
- **1st HVOF coated piston:**
  570,000 cycles, i.e. 2 lives, ~ 100ksi at notch
  184,500 cycles, ~ 110ksi

- Small area of failed coating (approximately .150” x .350”), between 250,000 - 285,000 cycles at bottom.

- Visual, MPI, LPI and Barkhausen Noise inspection after 570,000 cycles did not find evidence of substrate cracking.

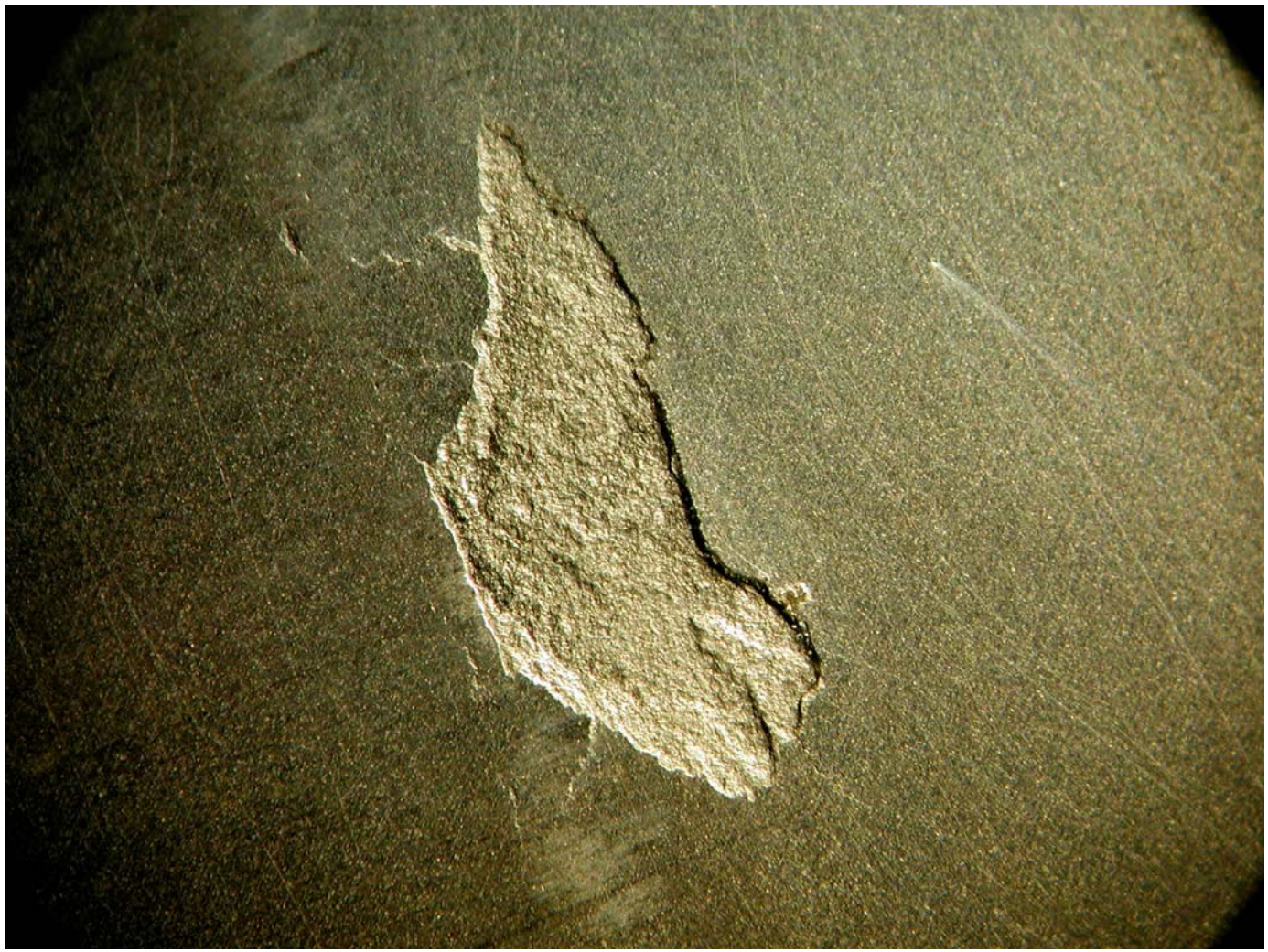
- **Piston failed at bearing contact point**

TEST 3: PISTON FATIGUE TEST



HVOF COATING AFTER 285,000 CYCLES

TEST 3: PISTON FATIGUE TEST



HVOF COATING AFTER 285,000 CYCLES

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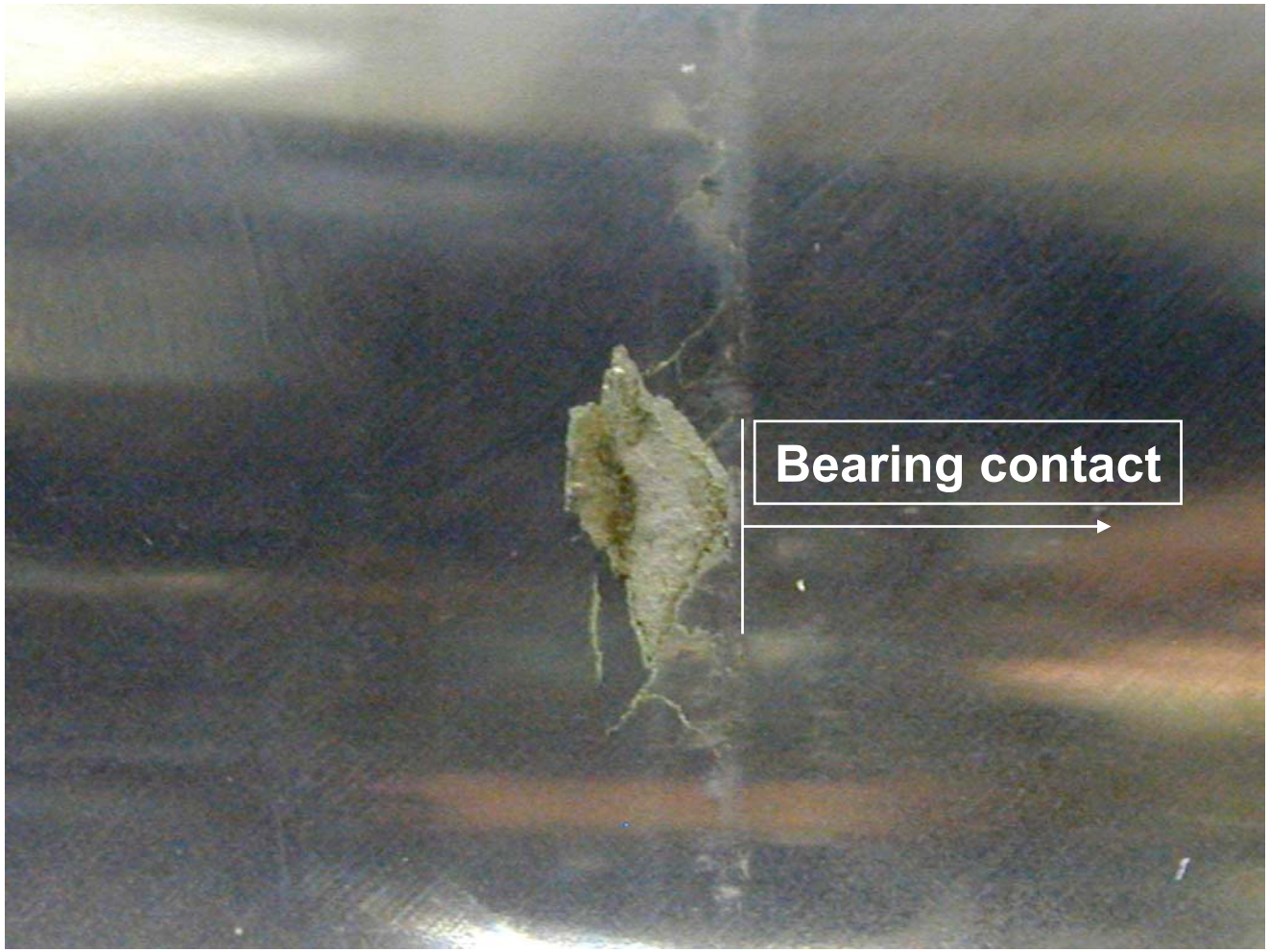
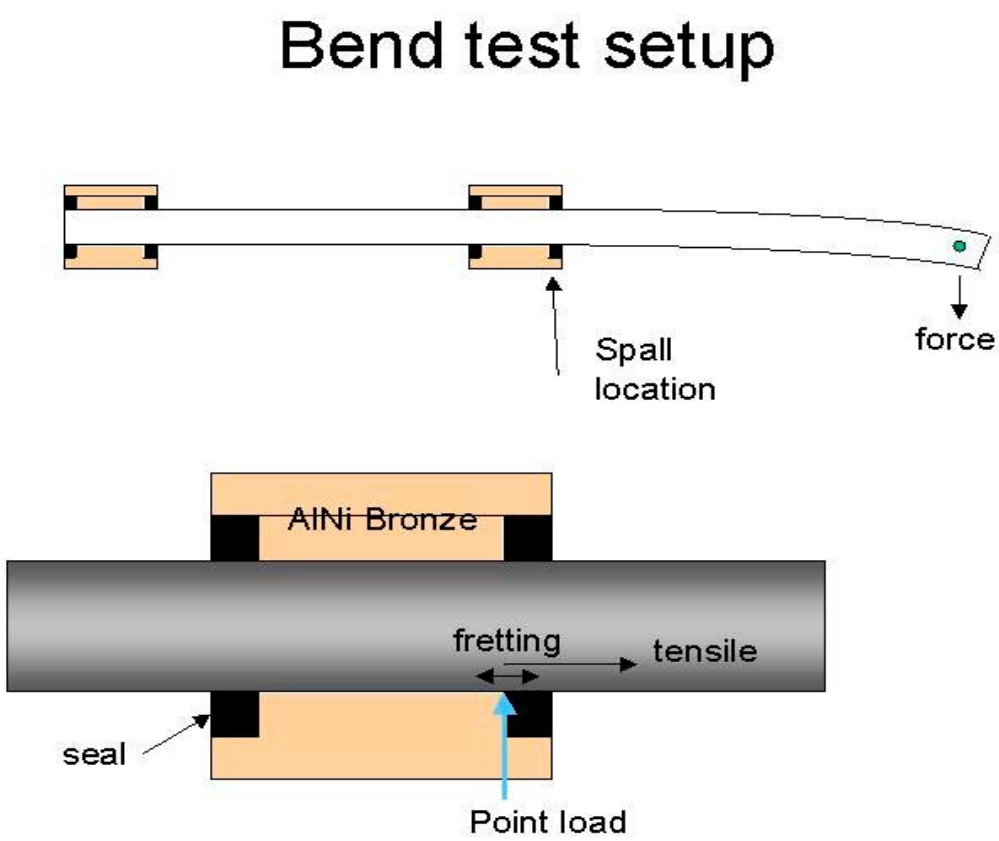


HVOF COATING AFTER 570,00 CYCLES

TEST 3: PISTON FATIGUE TEST



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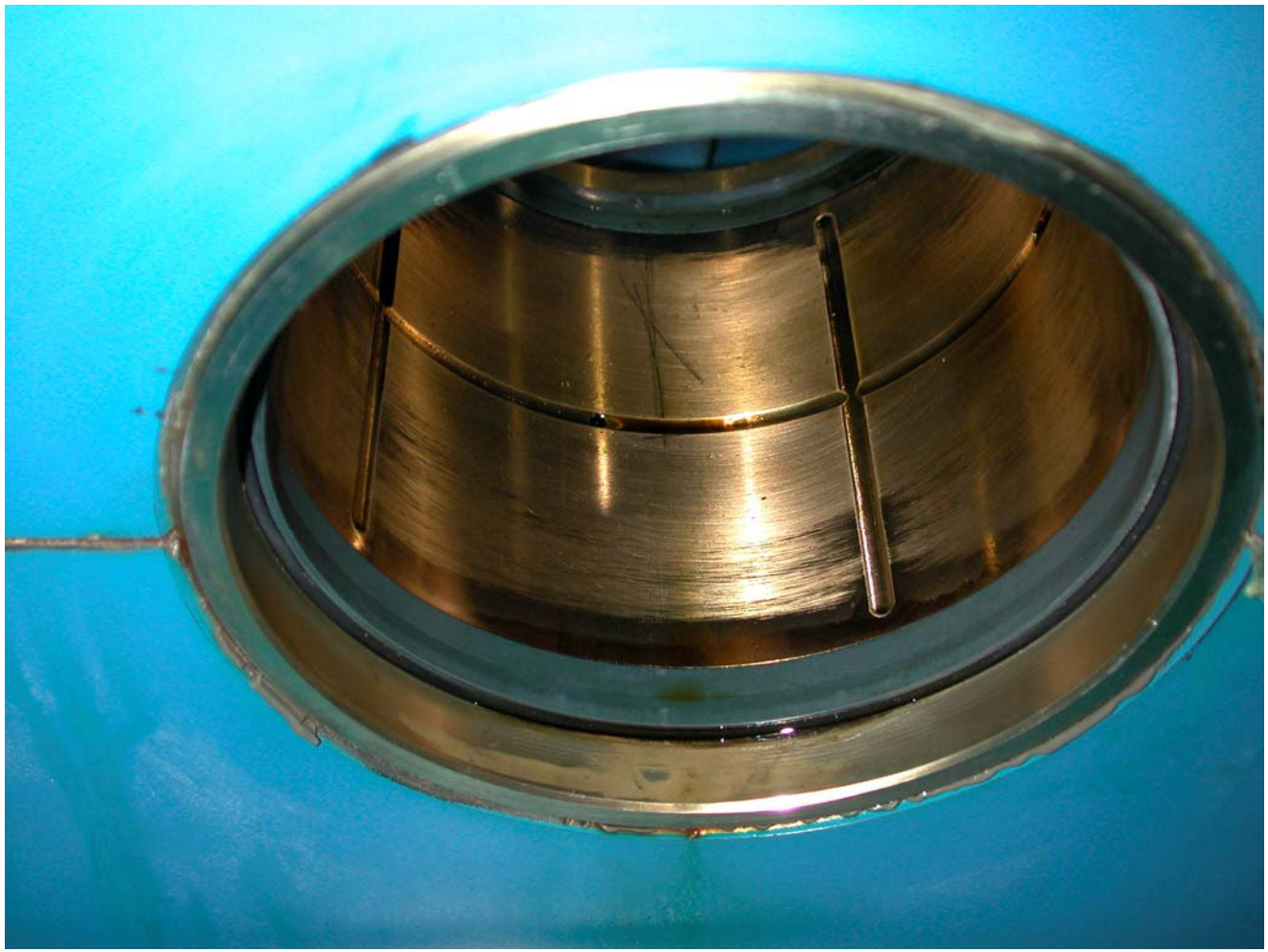


BUSHING CONFIGURATION

TEST 3: PISTON FATIGUE TEST

TEST RESULTS

- **2nd Chrome plated piston:**
  1,000,000 cycles. ~110ksi at notch
  20,000 cycles. ~135ksi at notch

- **Piston failed at notch**

- **3rd Chrome plated piston:**
  62,000 cycles. ~125ksi at notch

- **Piston failed at notch**

TEST 3: PISTON FATIGUE TEST

TEST RESULTS

- **2nd HVOF coated piston:**
  33,000 cycles. ~125ksi at notch

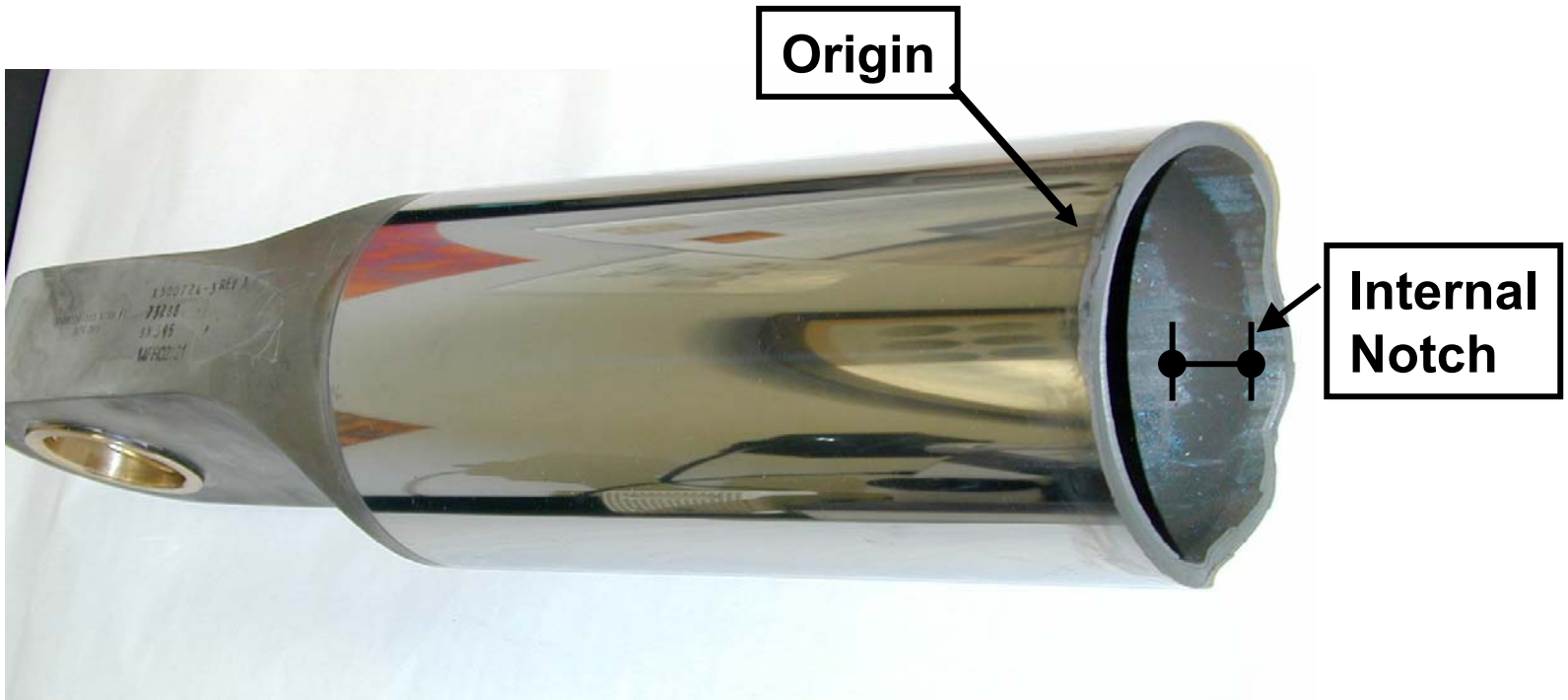
- **Piston failed at bearing contact point, large area of coating failure 2”x0.25”- top and bottom**

SCOPE OF TEST ALTERED

Coating Application? (different coating supplier)
Understanding of coating failure mechanism
Comparison of LG spectrum to test conditions

TEST 3: PISTON FATIGUE TEST

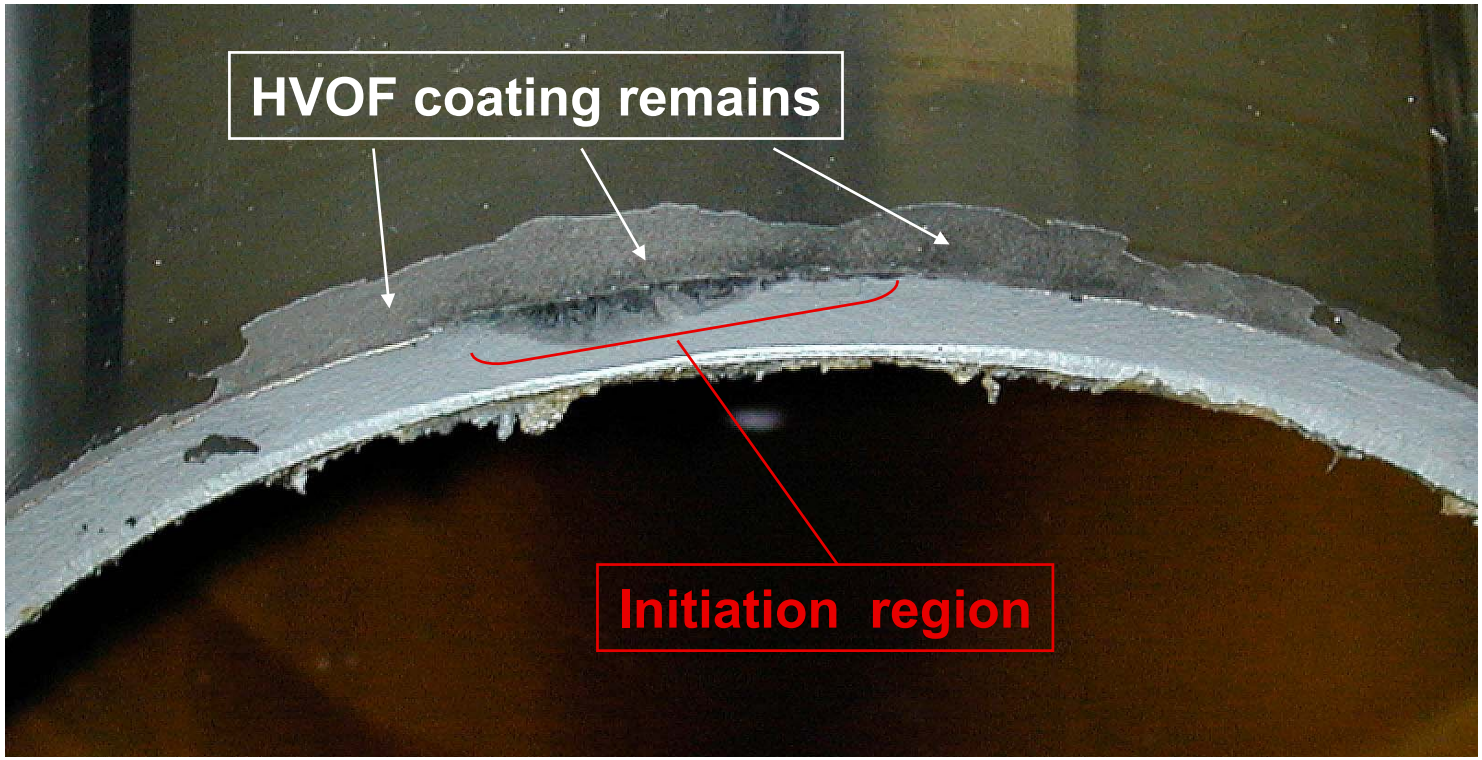
TEST RESULTS



2nd HVOF coated specimen

TEST 3: PISTON FATIGUE TEST

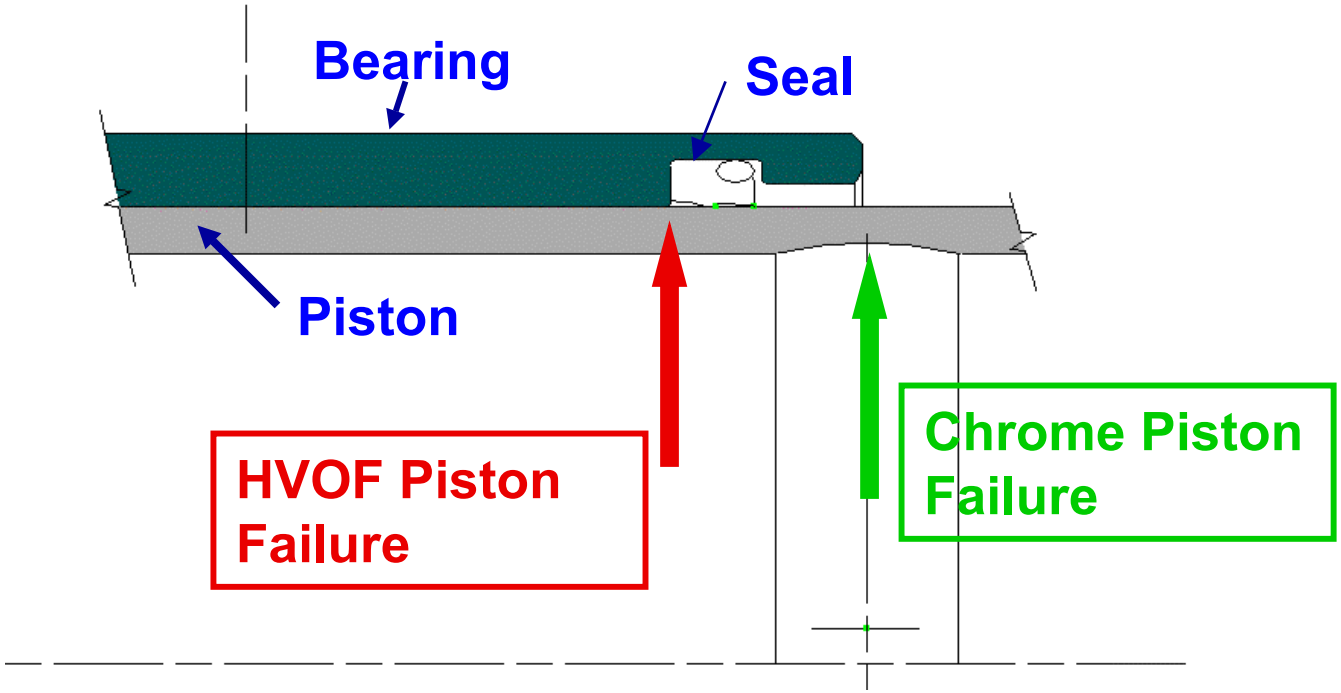
TEST RESULTS



2nd HVOF coated specimen

TEST 3: PISTON FATIGUE TEST

TEST RESULTS



TEST 3: PISTON FATIGUE TEST

TEST RESULTS

- **3rd HVOF piston, coated by SouthWest Aero :**

2,000 cycles ~125 ksi

5,000 cycles - some cracking top and bottom

10,000 cycles - significant circumferential cracking

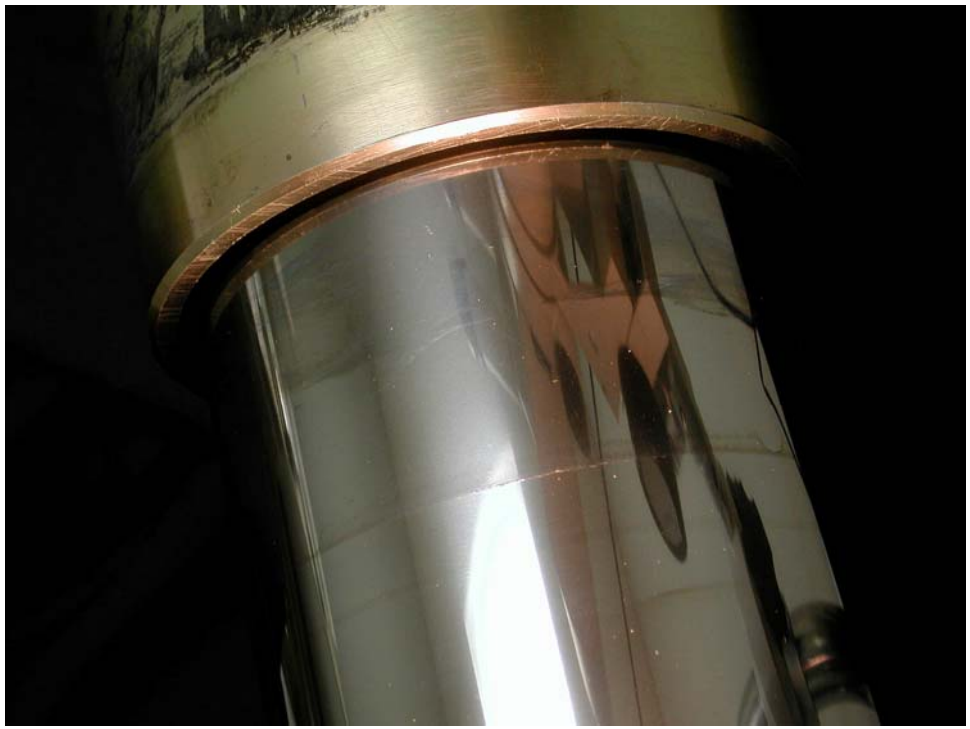
15,000 cycles - coating separation evident

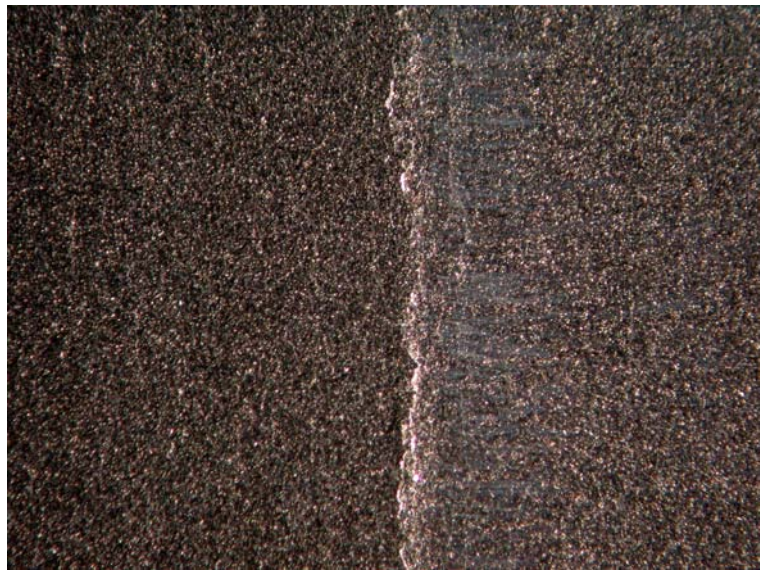
20,000 cycles - coating blistering 2” x 0.15”

25,300 cycles - failure at the bearing contact point initiating at bottom

TEST 3: PISTON FATIGUE TEST

TEST RESULTS





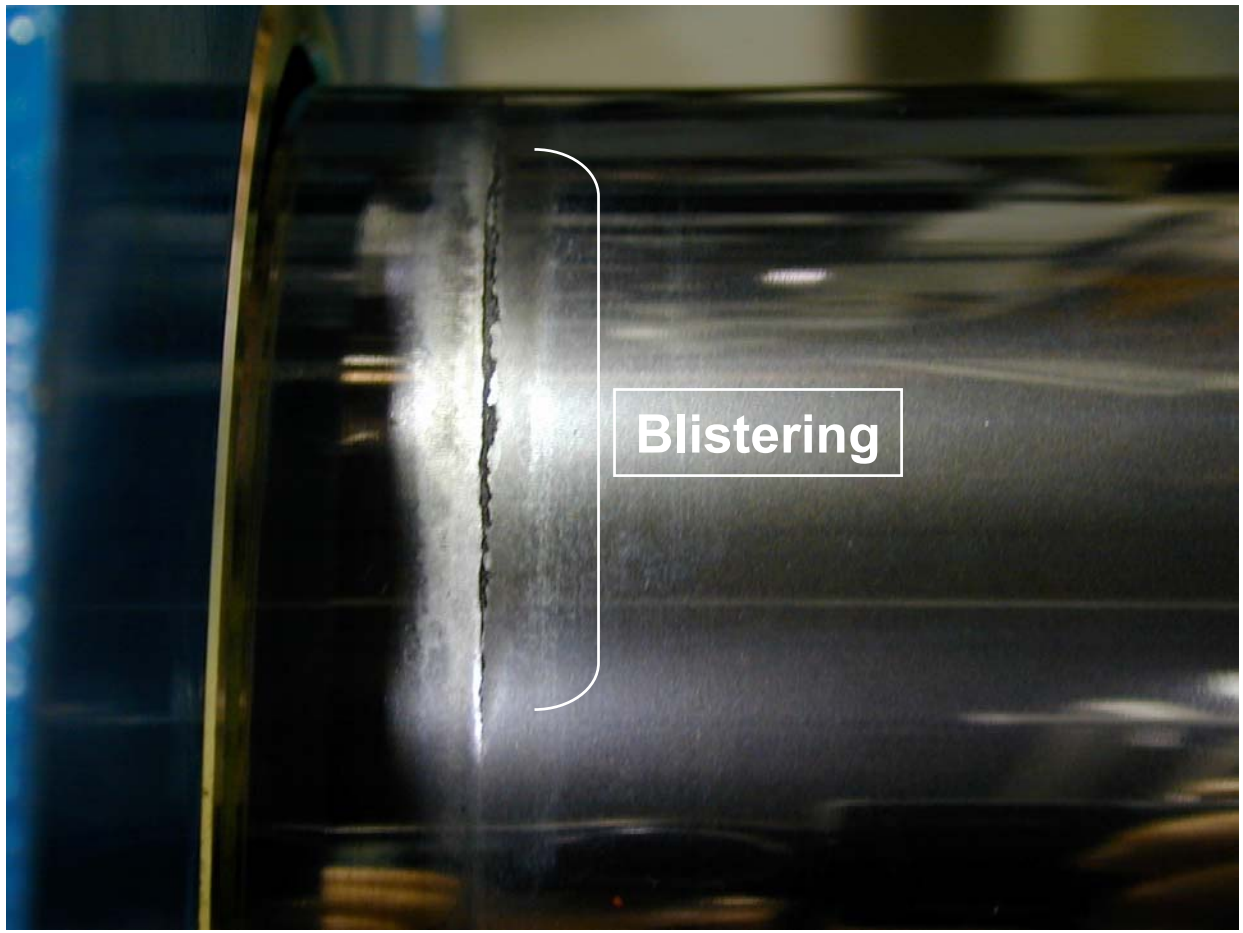
X~10

Bearing area

Appearance of coating after 10,000 cycles

TEST 3: PISTON FATIGUE TEST

TEST RESULTS



Appearance of coating after 25,000 cycles

TEST 3: PISTON FATIGUE TEST

SUMMARY

Piston	Stress (bending)	Cycles	Failure Mode
1st Cr	100 ksi	407K	ID, @ notch (inclusion)
2nd Cr	110 ksi	1M	
	135 ksi	20k	ID, @ notch
3rd Cr	125 ksi	62K	ID, @ notch
1st HVOF	100 ksi	570k	coating failed (250K)
	110ksi	185K	OD, @ bearing
2nd HVOF	125 ksi	33K	OD, @ bearing
3rd HVOF	125 ksi	25K	OD, @ bearing

SUMMARY

- HVOF pistons failed at contact point with bearing - Failure originated at OD; Chrome plated pistons failed at notch - Failure originated at ID.
- Cracking of coating is circumferential, localized and appears to occur relatively early ~5 K cycles @125ksi
- Coating failure is cohesive (substrate still coated).
- Coating application and finish - not a factor.
- Commercial Landing Gear Stresses are comparable to test - but # of cycles much smaller.
  - LG spectrum 125 ksi -- 575 cycles/5 lives (120 one life)
  - Test regime 125 ksi -- 5,000 - 7,000 cycles
- Test conditions too severe, not representative of LG.

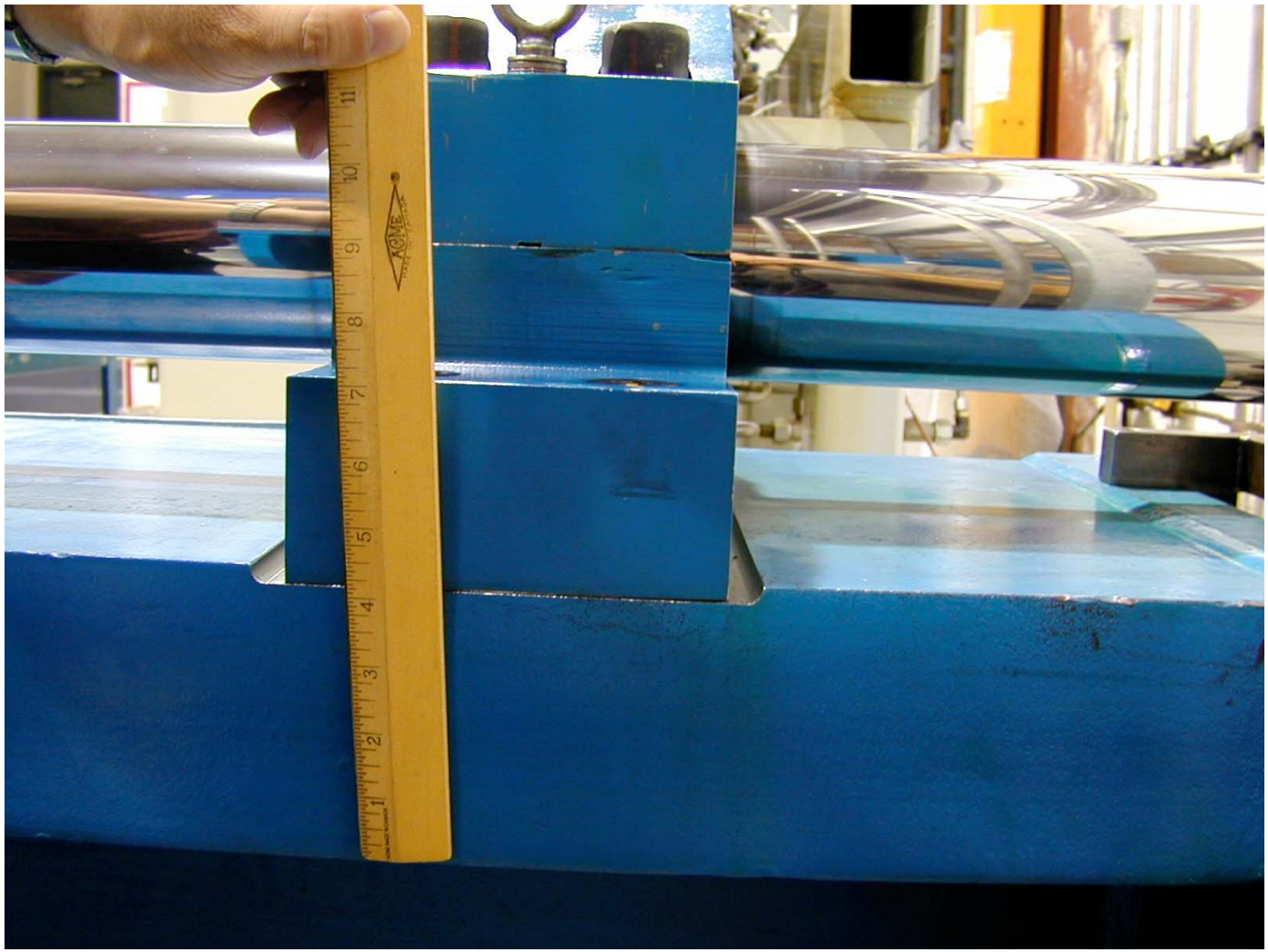
FUTURE ACTIONS

Test conditions too severe, not representative of LG.

1) Rigid bearing reaction
2) Single stroke position
3) Monotonic cycling

Scope of test changed to simulate LG conditions - 10” test

- ➢10” Rig will be re-designed to represent LG lower bearing
- ➢Simple spectrum loading will be implemented
- ➢Representative bearing will be implemented


ACME