IOWA STATE UNIVERSITY

CASR

FAA Center for Aviation Systems Reliability

CASR FPI – Engineering Studies: Cleaning in Preparation for FPI

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Cleaning Objectives: Why is it important?

- Visual appearance and inspection
- Remove deposits and prepare surfaces
- Reduce or prevent corrosion
- Reduce mechanical cleaning (media blasting)
- Enhance nondestructive testing performance (FPI, MPI, EC UT)
- Subsequent special processes require clean surface (heat treatment, weld, braze, thermal spray, paint, plate, etc.)

(Ref: Terry Kessler)

How Clean is Clean?

You will know...

- If it looks or feels oily or greasy…
- If dirt wipes off on your finger…
- If the part shows heat scale remaining ...
- If water beads up…
- If FPI penetrant beads up …

IT IS NOT CLEAN ENOUGH!!!!

(Ref: Terry Kessler)

Cleaning Methods

- Chemical and mechanical cleaning tools
- Selected based on contamination/soils to be removed
- Consideration given to alloy (corrosion resistance, removal rates, etc.)

Objectives

- Determine the effect of chemical cleaning, mechanical cleaning, and drying processes on the detectability of low cycle fatigue cracks in titanium and nickel alloys
- Establish the effect of local etching on detectability and provide guidance on best practices for removal of local surface damage from FOD and other surface anomalies
- Update existing specifications to reflect the improved processes and provide best practices documents for use by the OEM's and airlines

Field Studies

- Requires access to typical drying and cleaning methods used in commercial aviation
- Delta Airlines provided access to their facilities
  - June 18 2001
  - October 18 2001
  - February 4 2002
  - Access to cleaning lines for Ti and Ni as well as mechanical blasting facilities
  - FPI line for sample processing
  - Inspection booth for characterization and brightness measurements

Cleaning Study

Cleaning Studies - matrix of contaminants

- Part 1 – October 2001
  - Penetrating oil – applied over crack
  - Anti-galling compound – applied to side of crack
  - RTV compound – applied to side of crack
  - High temperature sealant (Ni) – applied to side of crack
- "Baked-on" contamination Dec 01 – Jan 02
- Part 2 – February 2002
  - Soot – generated using forced air furnace at HW
  - Varnish – generated using forced air furnace at HW
  - Oxidation and scale – generated using forced air furnace at HW

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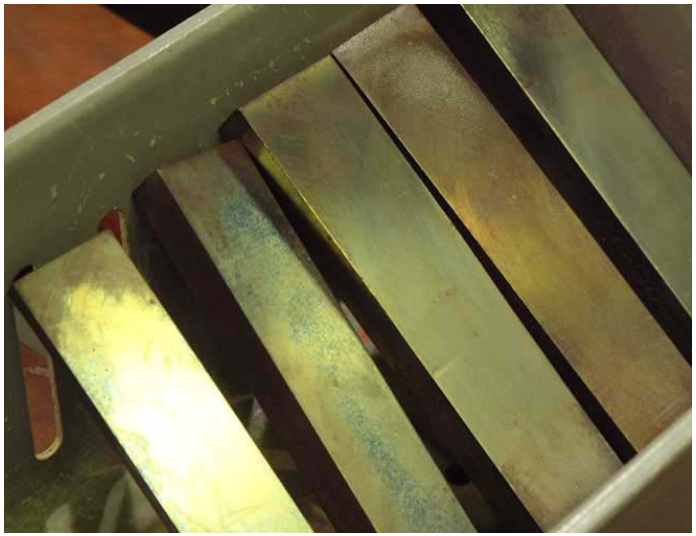
Cleaning Study



Cleaning Study

Contaminants:
- Penetrating Oil
- Antigallant compound
- RTV/Sealant

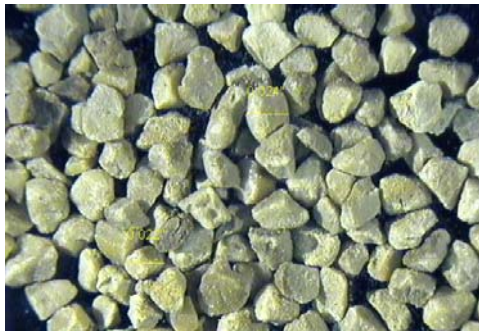
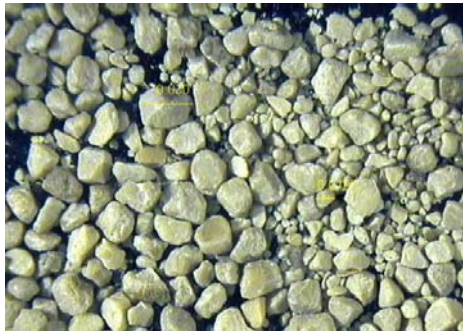
Cleaning Methods
- B1 – 40 psi – Plastic media blast
- B1 – 80 psi – Plastic media blast
- B6 – 50 psi - Walnut shell
- C1 – Aqueous degreaser, cold rinse
- C2a – Ti alkaline derust, short soak, high concentration
- C2b – Ti alkaline derust, long soak, low concentration
- C3 – Ni one step alkaline
- C6 – Ti degreaser followed
- C7a – Ni UT with alkaline derust
- C8 – Rubber stripper

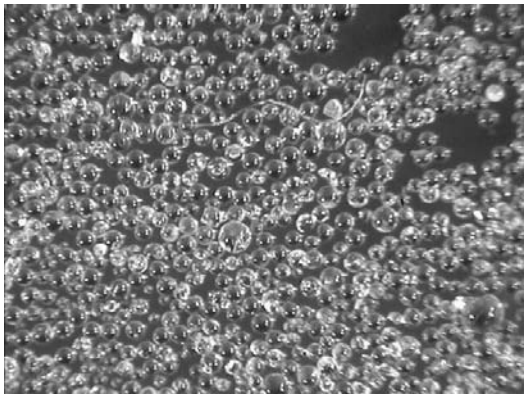
Baked on contaminants

Contaminants:
- Oxidation/scale
- Soot
- Varnish
- Oil

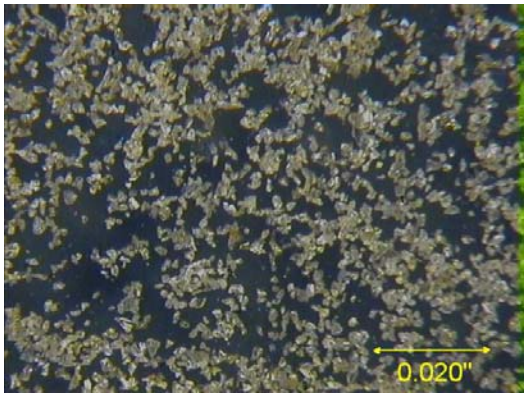
Cleaning Methods
- B1 – 40 psi – Plastic media blast
- B2 – Wet glass bead
- B3 – 240 grit Al_2O_3
- B4 – 320 grit Al_2O_3
- B5 – 500 grit Al_2O_3
- B6 – 50 psi - Walnut shell
- C1 – Aqueous degreaser, cold rinse
- C2a – Ti alkaline derust, short soak, high concentration
- C2b – Ti alkaline derust, long soak, low concentration
- C3 – Ni one step alkaline
- C4 – Ni four step alkaline/acid
- C5 – Alkaline gel cleaner
- C6 – Ti degreaser
- C7a – Ni UT with alkaline derust
- C8 – Rubber stripper

Cleaning Study

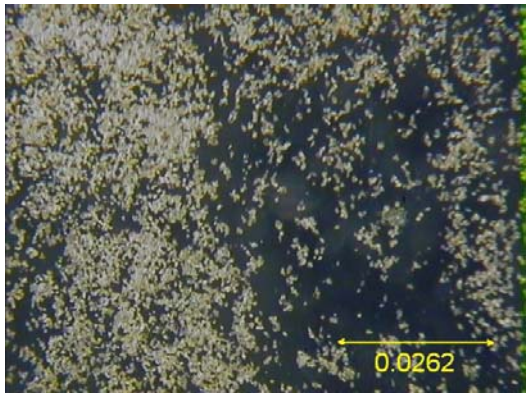
	New	Used
Plastic media		
Walnut shell		



Wet glass bead



Al_2O_3 320 grit



Al_2O_3 500 grit

Cleaning Study

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Cleaning Study

Cleaning Study

Brightness or length greater than baseline	
Brightness or length within range of baseline values	
Brightness or length up to 40% less than baseline	
Brightness or length more than 40% of baseline	
Indication no longer detected	

Cleaning Study

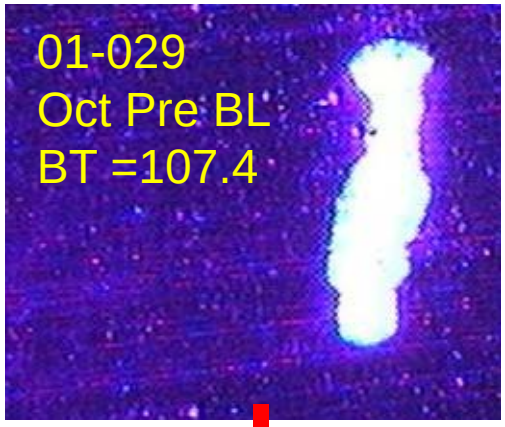
Cleaning Studies – Part 1

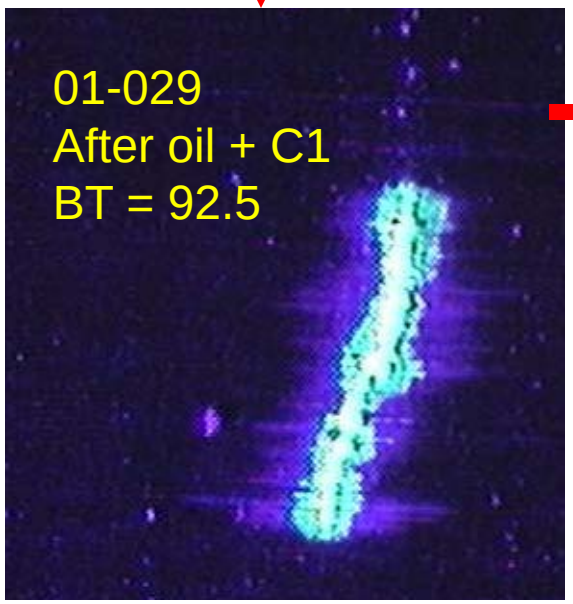
- Penetrating Oils
  - C1 – Aqueous degreaser
  - C2a and C2b– Alkaline De-rust Solution (A and B)
  - C3 – Alkaline one step
  - C6 – Steam with aqueous degreaser
- Anti-Galling Compound
  - C2a and C2b – Alkaline De-rust Solutions (A and B)
  - C7a – Ultrasonic w/alkaline De-rust Solution B
  - B1 – Plastic media blast (at 80 and 40 psi) for 30 sec using pressure cabinet
  - B6 – Shell blast (at 50 psi) for 1 min using pressure cabinet
- RTV Compound and High Temperature Sealant
  - B1– Plastic media blast (at 80 and 40 psi) for 30 sec using pressure cabinet
  - B6 – Shell blast (at 50 psi) for 1 min using pressure cabinet

Oil Contamination

- Penetrating oil applied over crack and allowed to sit overnight prior to cleaning
  - C1 – Aqueous degreaser
  - C2a and C2b– Alkaline De-rust Solution (A and B)
  - C3 – Alkaline one step
  - C6 – Steam with aqueous degreaser
  - C7a – Alkaline De-rust with UT agitation
- C1, C3 and C6 were found to be effective cleaners
- Hot and cold water rinse were found to be equally effective for C3
- C2a/C2b and C7a did not provide consistent cleaning action

01-029 – Ni


01-029
Oct Pre BL
BT =107.4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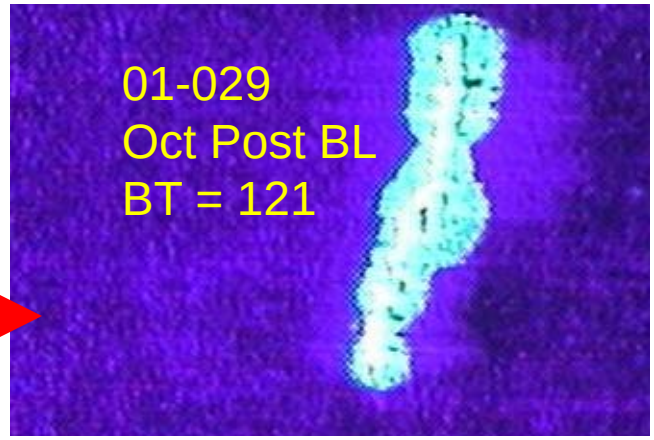
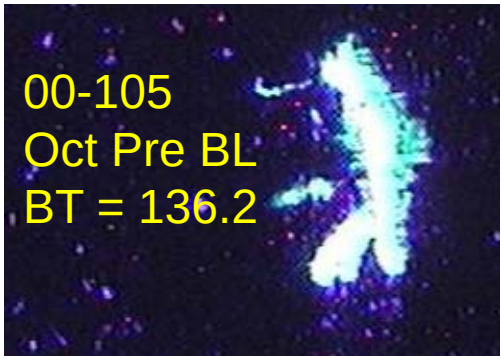
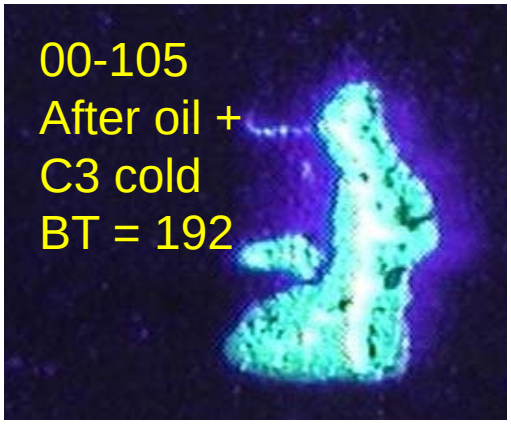
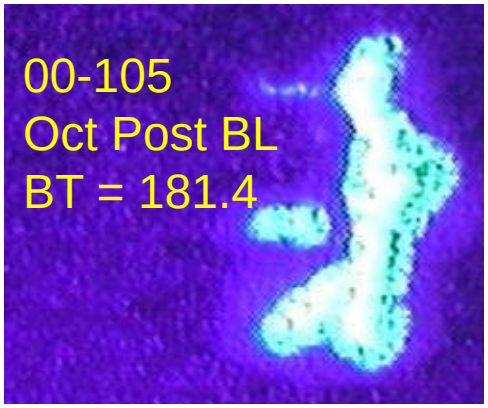
After oil + C1
BT = 92.5

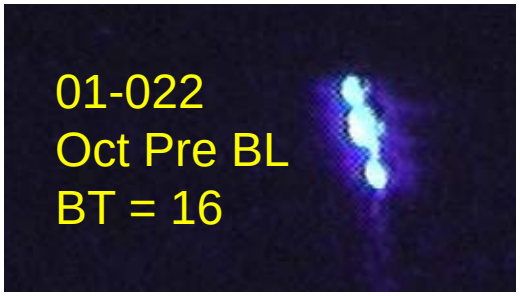

01-029
Oct Post BL
BT = 121

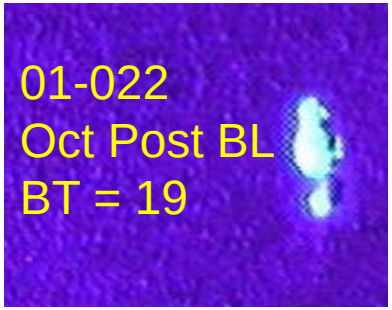
Oil followed by C3 with cold water rinse

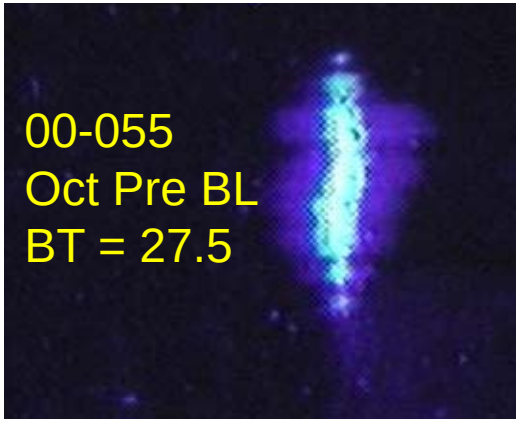


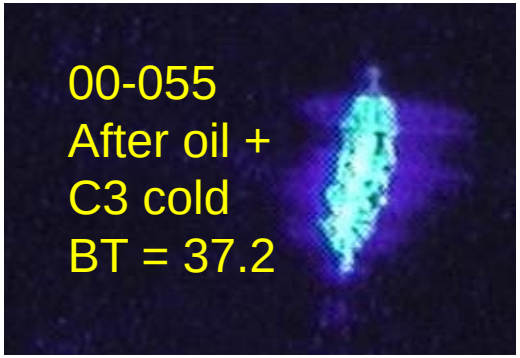




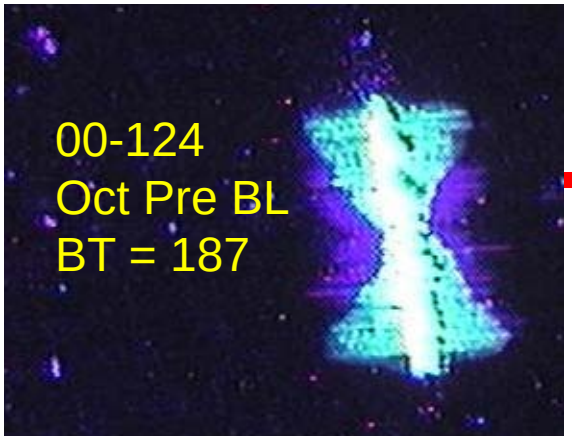


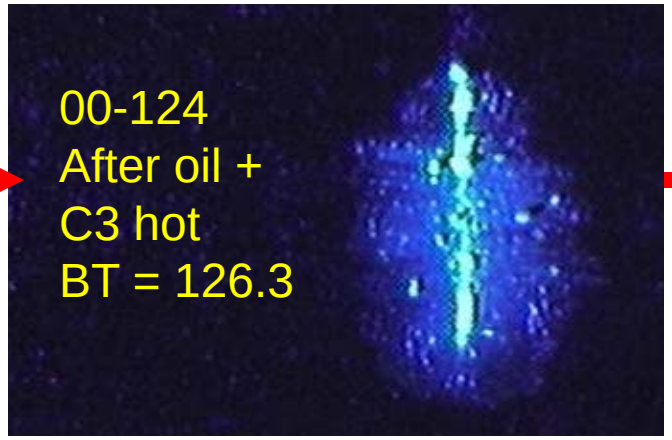


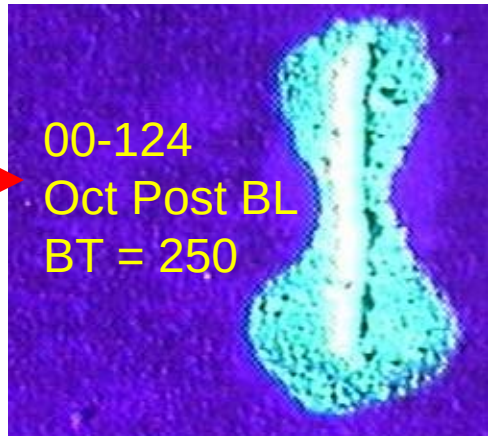


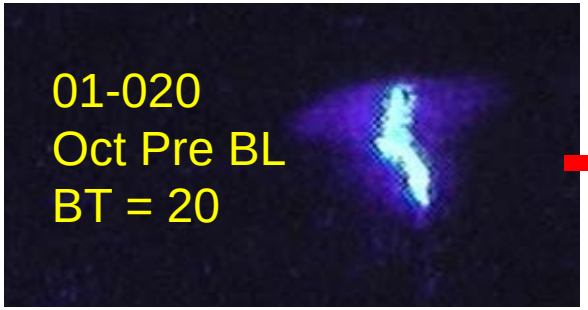


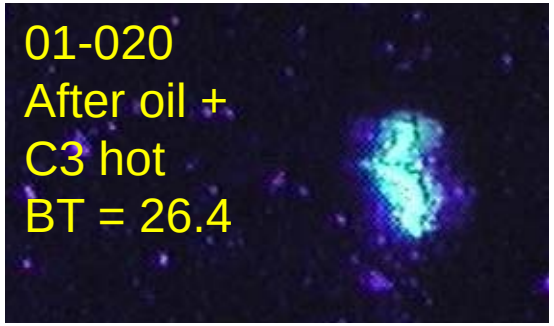
Oil followed by C3 with hot water rinse

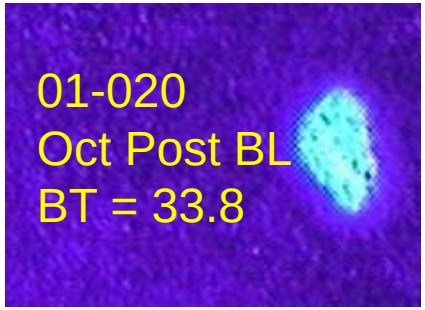


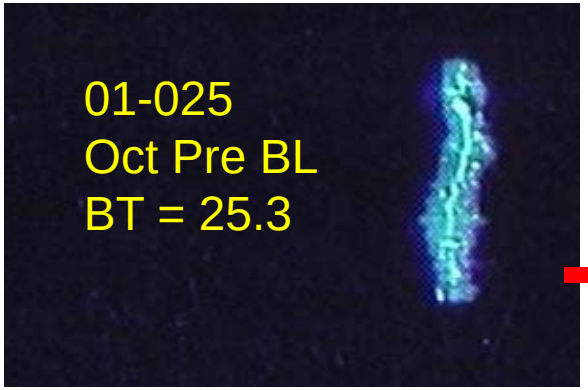


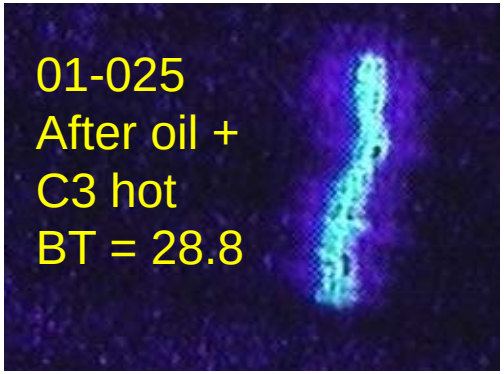


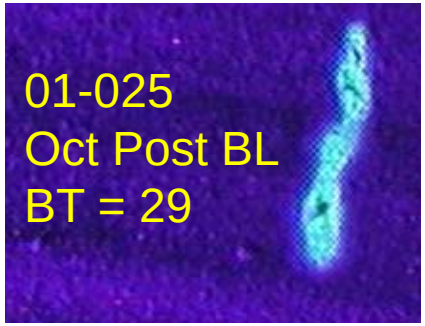




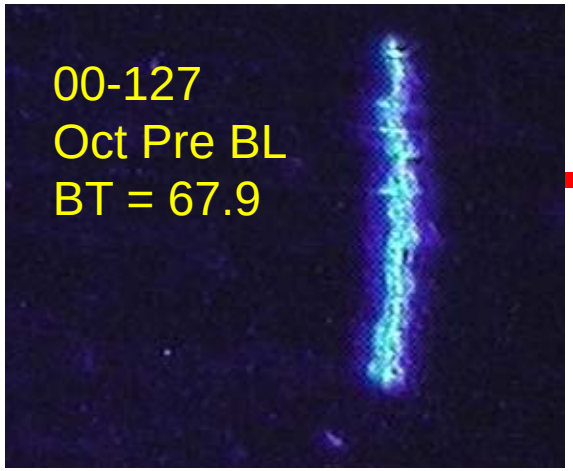


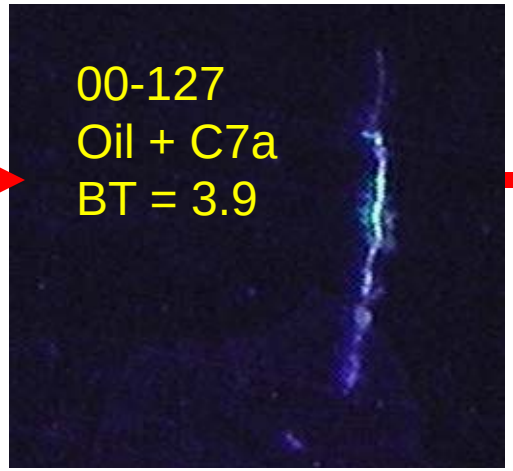


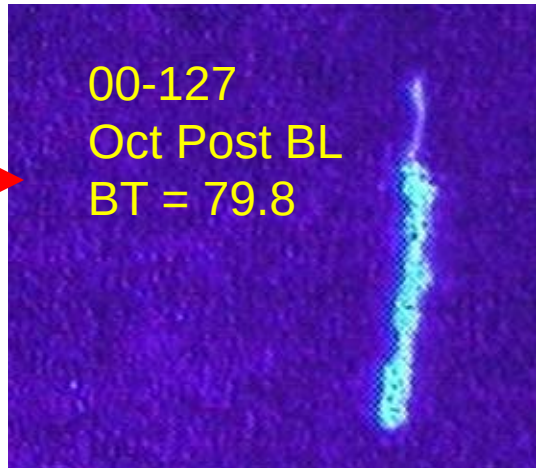


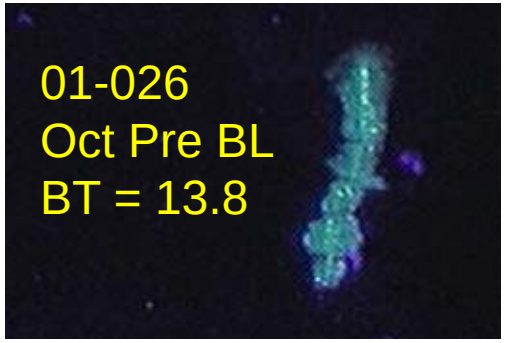


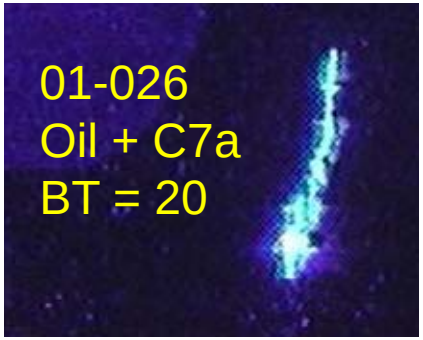
C7a for Oil Contamination

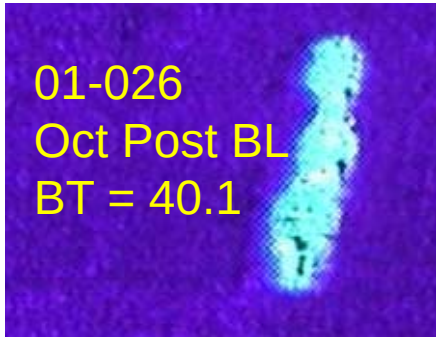


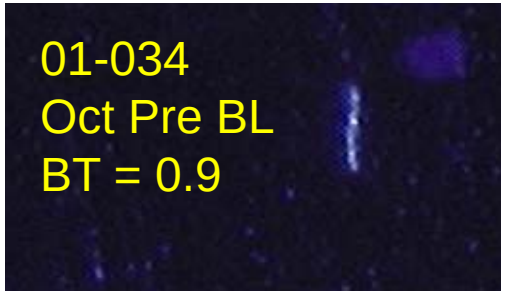


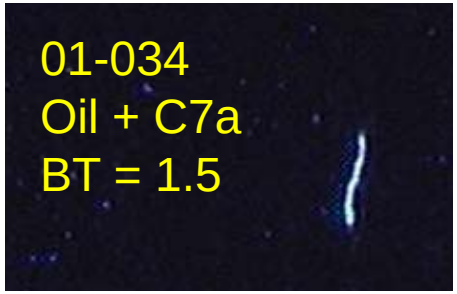


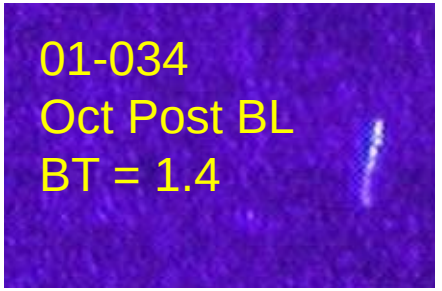












Oil contamination

- C2a process was not effective for oil removal from Ti samples
  - C2a process used for titanium utilizes similar chemistries and concentrations as C3 process for nickel. However, Ti parts are in alkaline for shorter duration.
  - Given better performance for C3 than C2, additional work is needed to understand if this is an alloy effect or a cleaning time effect.

Coating Removal

- All cleaning methods used to remove service coatings (anti-gallant compound, RTV and high temperature sealant) were effective in removal of the coatings
- However, reductions in FPI indication response did occur in some cases

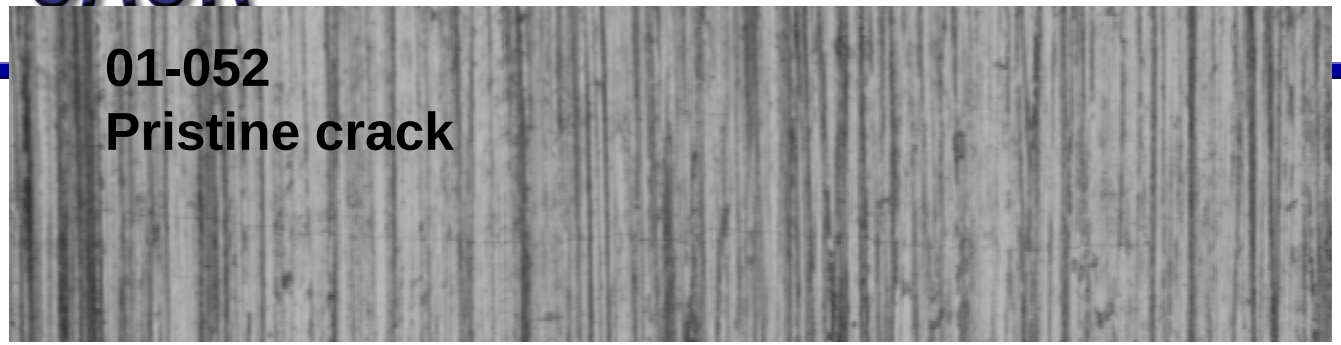
Mechanical Cleaning

- Wet glass bead blast
- Al_2O_3 500 grit
- Al_2O_3 320 grit
- Al_2O_3 240 grit
- Walnut shell blast

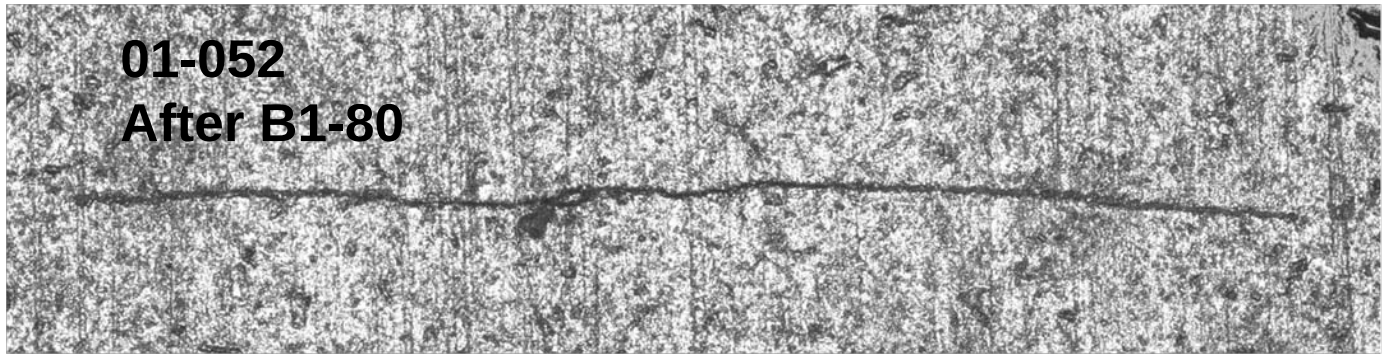
Plastic Media Blast

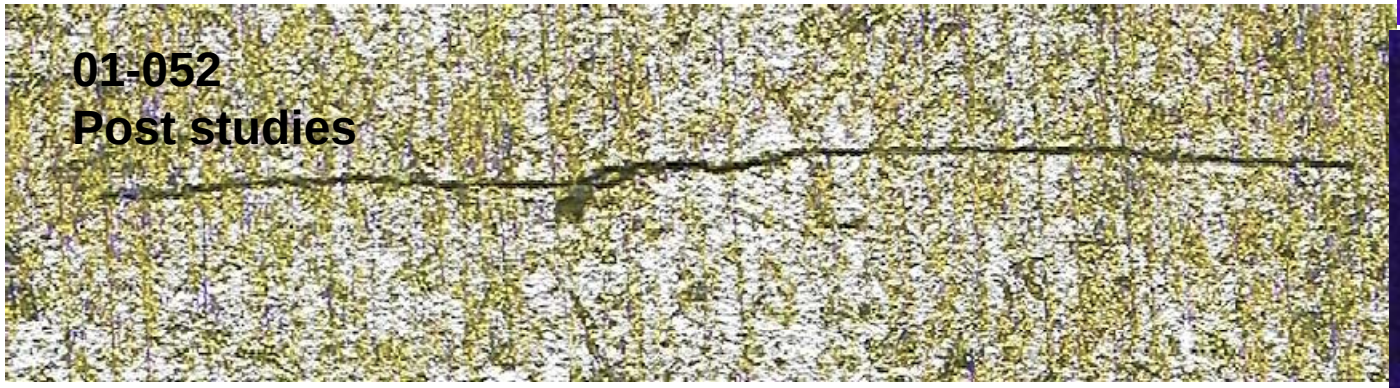
- Typical blast pressures are 40 psi
- Study looked at both 40 and 80 psi
- PMB at 40 psi was found to be effective cleaner with better performance if followed by a “wet” process
  - Remove PMB residue from surface and/or cracks
- PMB at 80 psi led to surface damage and is not recommended as a process to proceed parts that will undergo FPI

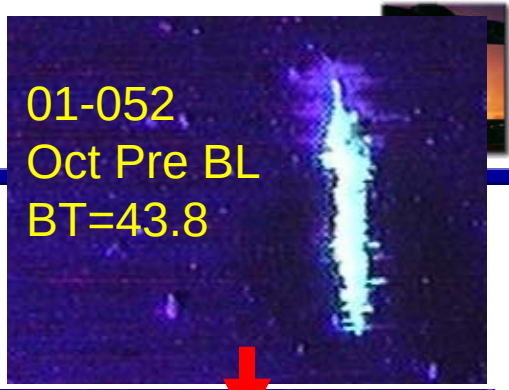
01-052 – Ti

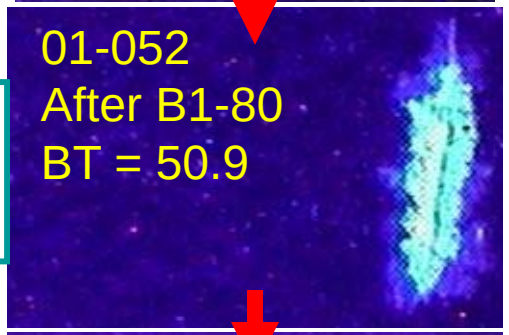


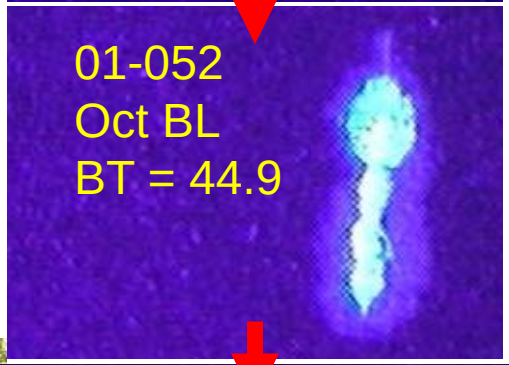
Surface changes indicate removal of sanding marks with B1-80 treatment. Lower image is after soot and subsequent B1-40 treatment. Additional surface changes not evident.

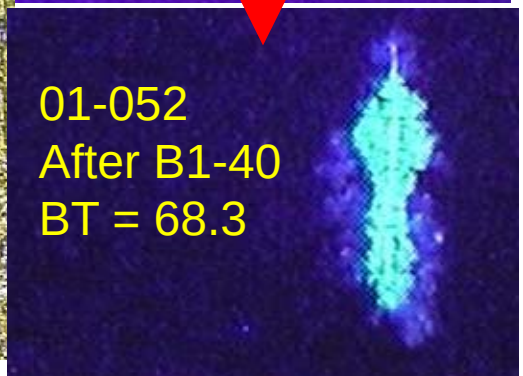






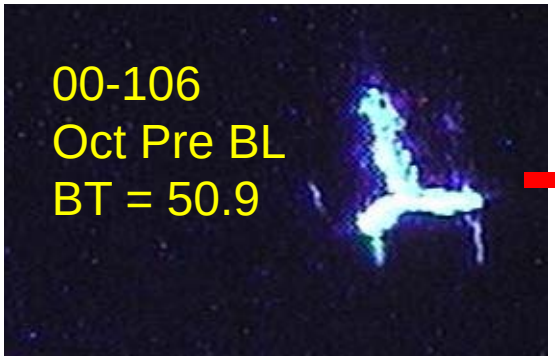


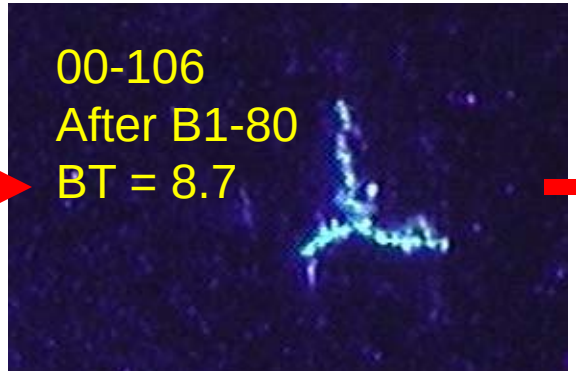


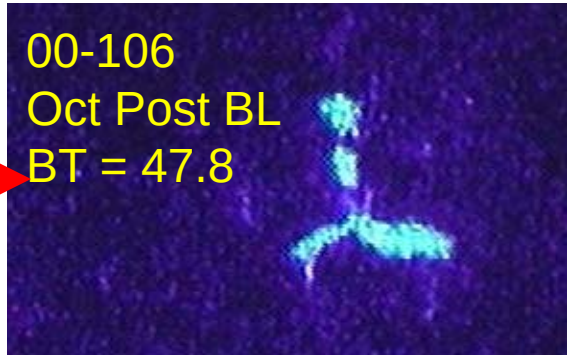


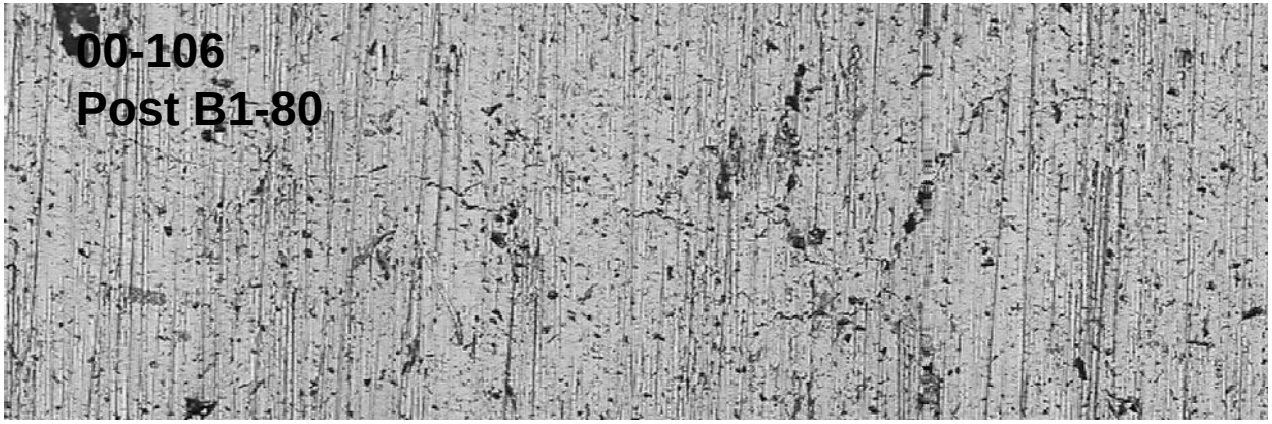
00-106 - Ni

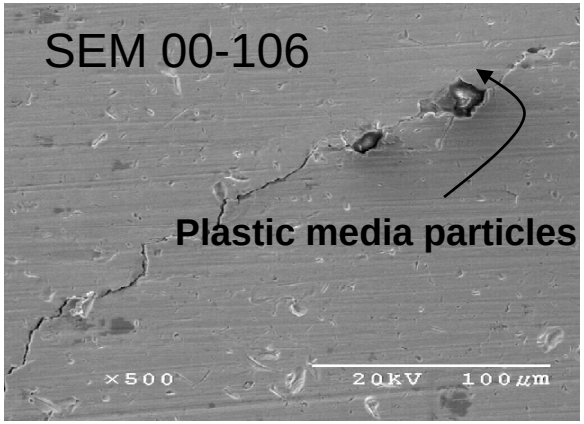

00-106
Pristine crack


00-106
Oct Pre BL
BT = 50.9

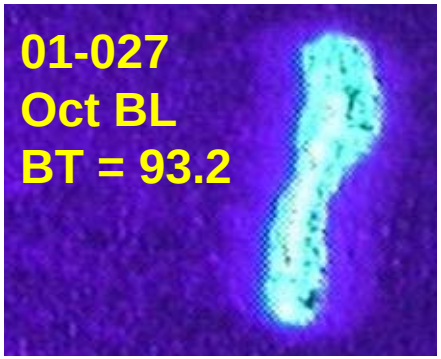

00-106
After B1-80
BT = 8.7


00-106
Oct Post BL
BT = 47.8

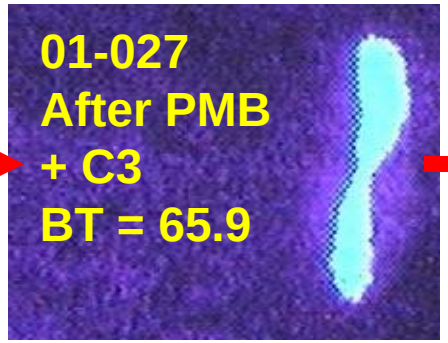

00-106
Post B1-80

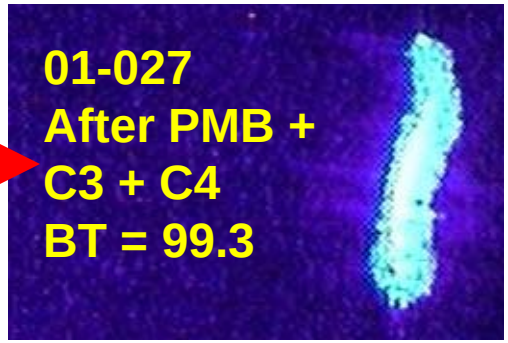

SEM 00-106
Plastic media particles
×500
20kV
100μm

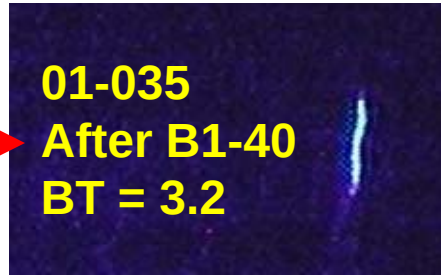
B1-40 applied to Coke/varnish samples

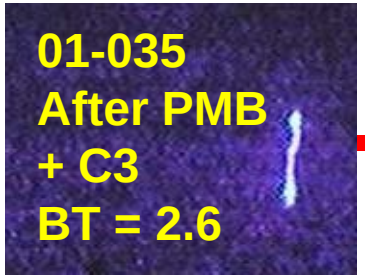


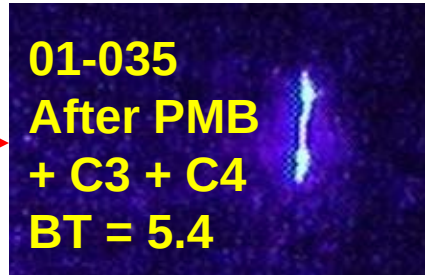
01-027
After PMB
No
indication

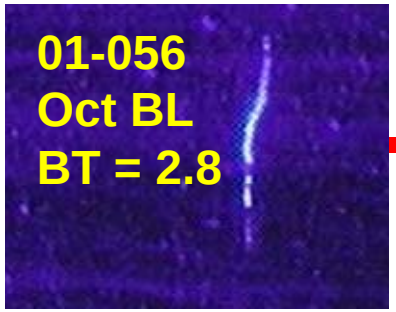


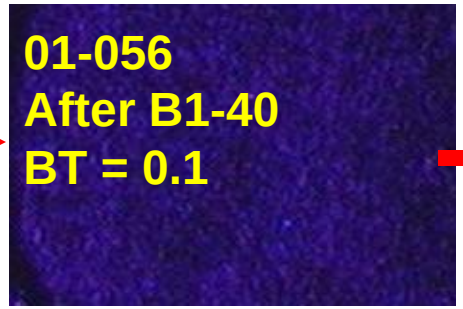




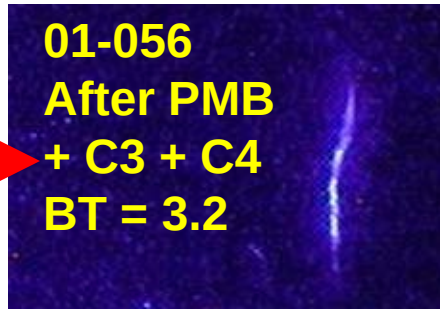






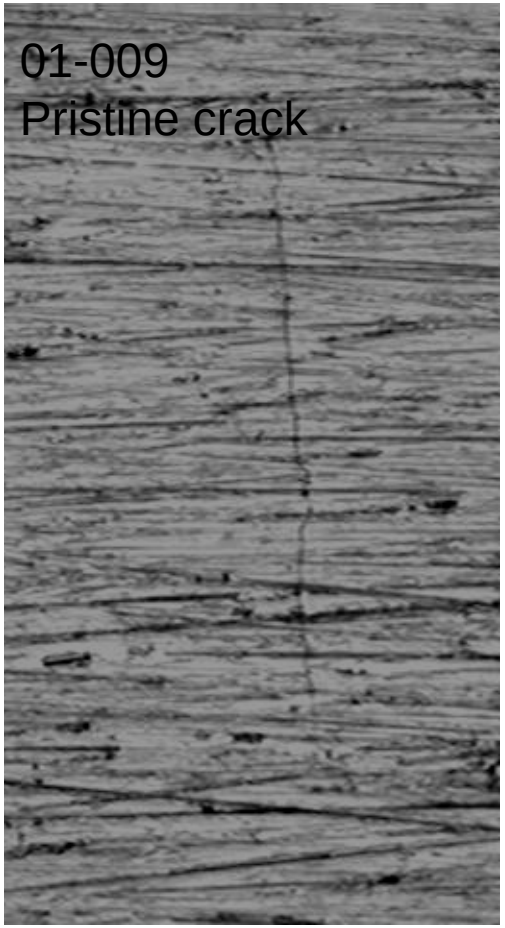


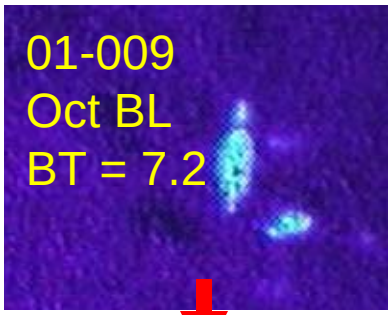
01-056
After PMB + C3
No indication



Wet Glass Bead Blast

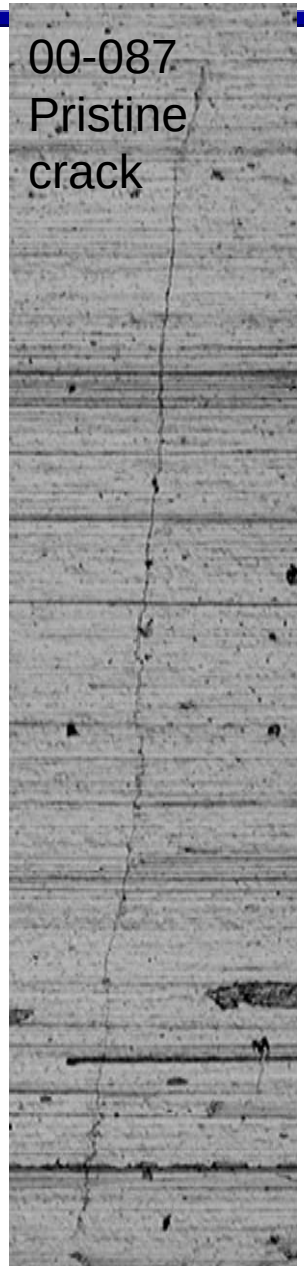
01-009 – Ni

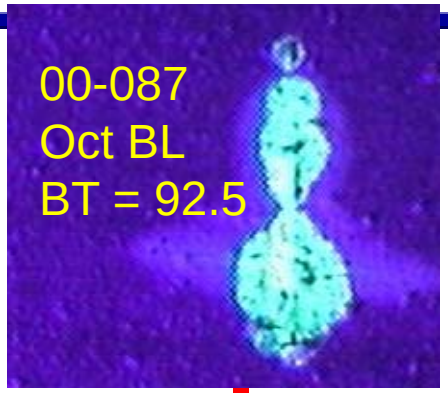


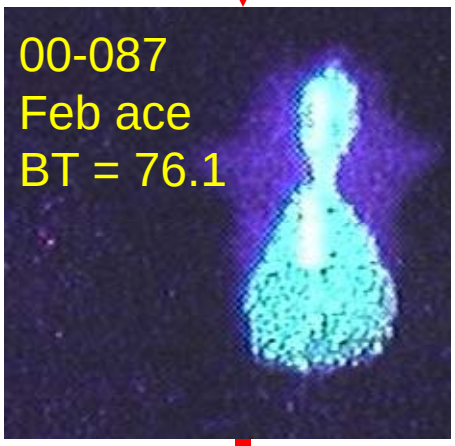


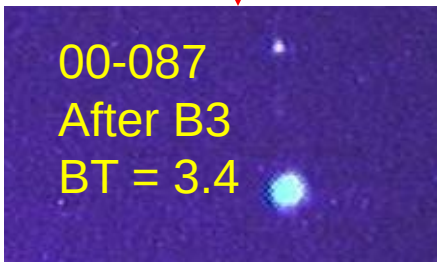
Indication not found after B2 treatment

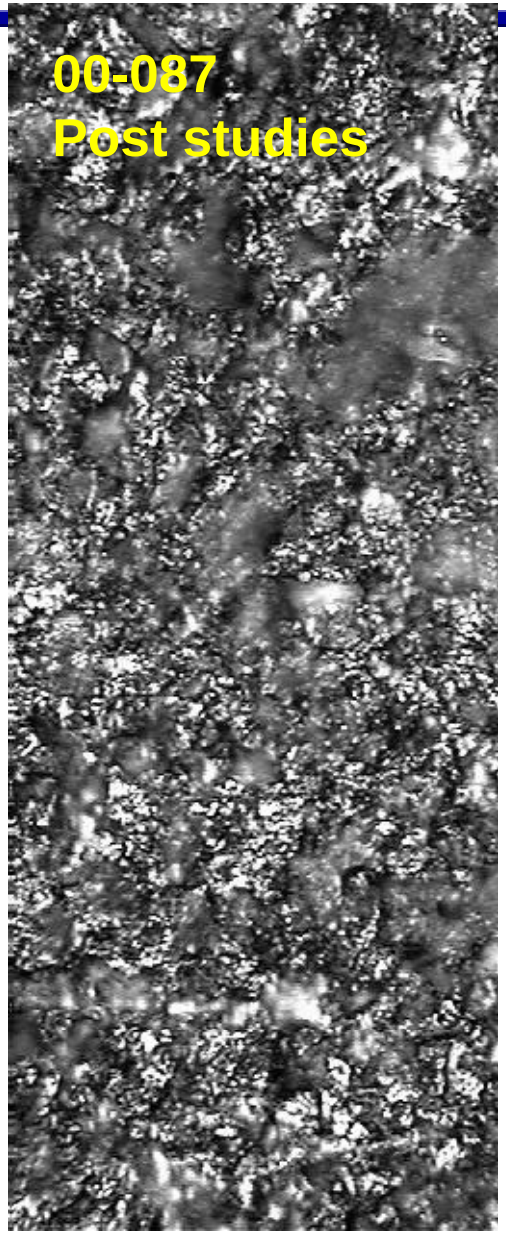
Al_2O_3 240 grit - 00-087 – Ti

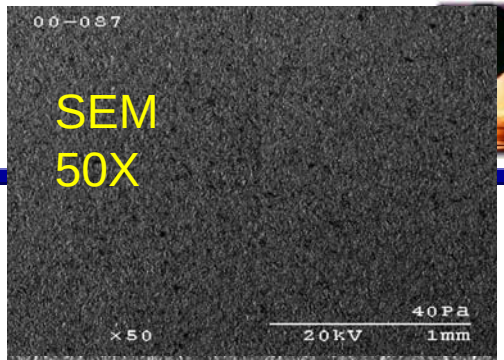


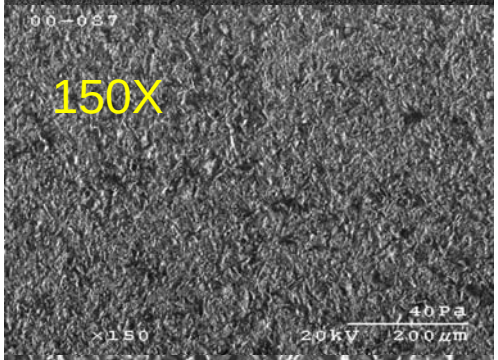


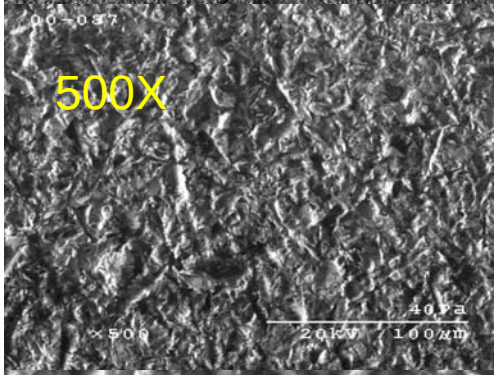


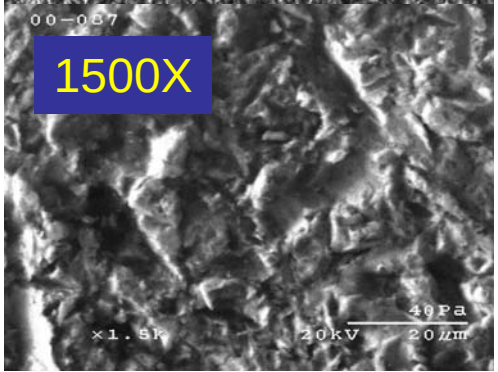




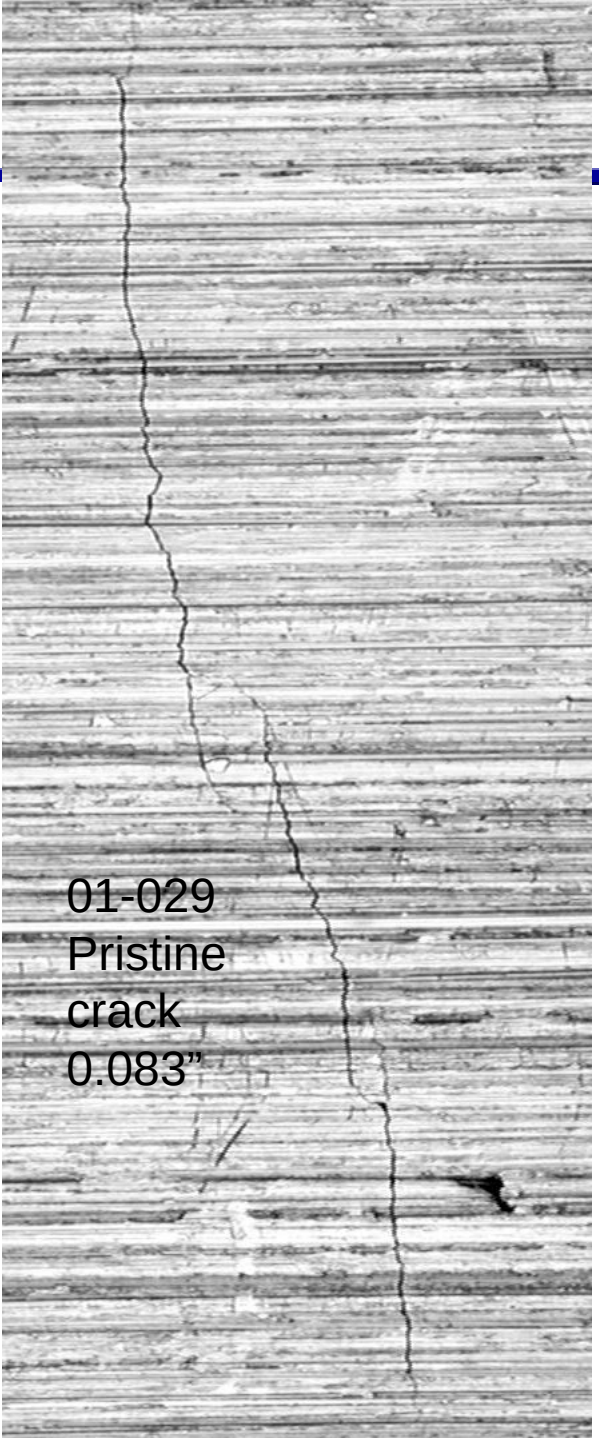


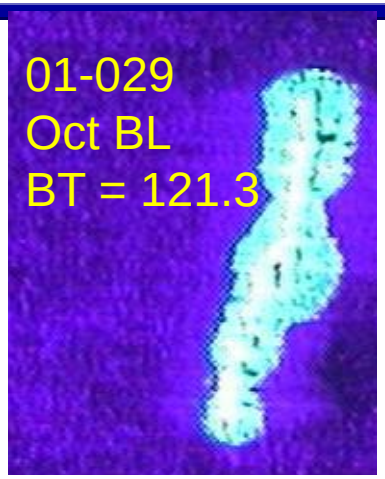


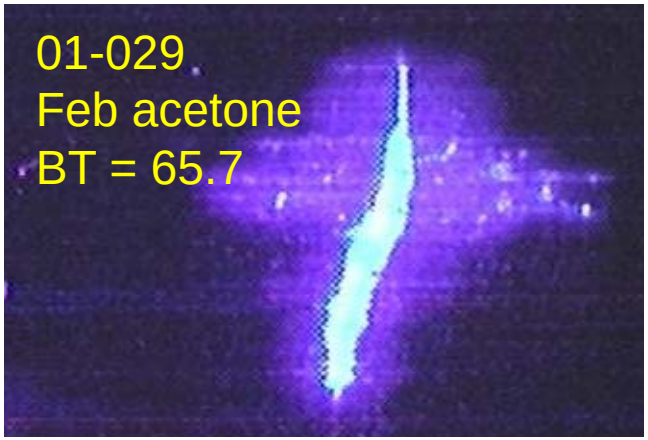




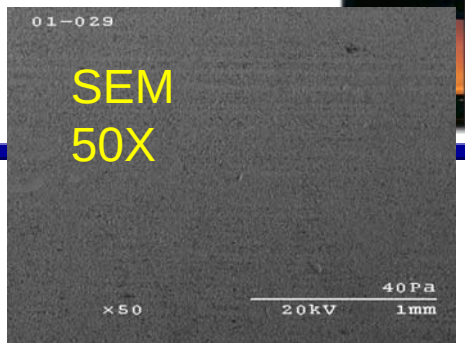
Al_2O_3 320 grit 01-029 – Ni

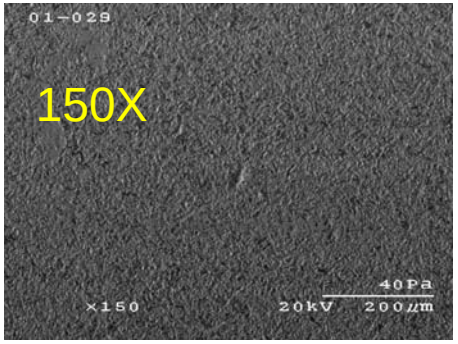


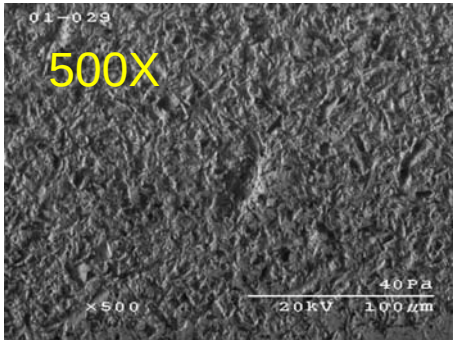


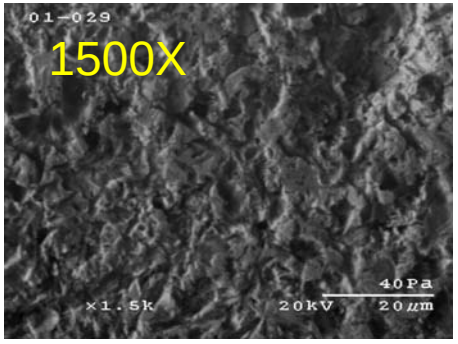


Indication not found after 320 grit process

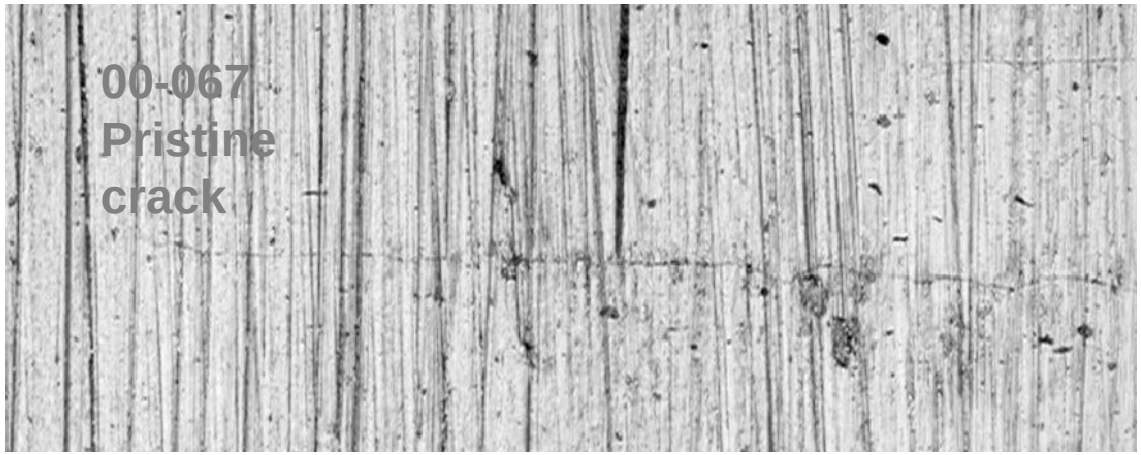


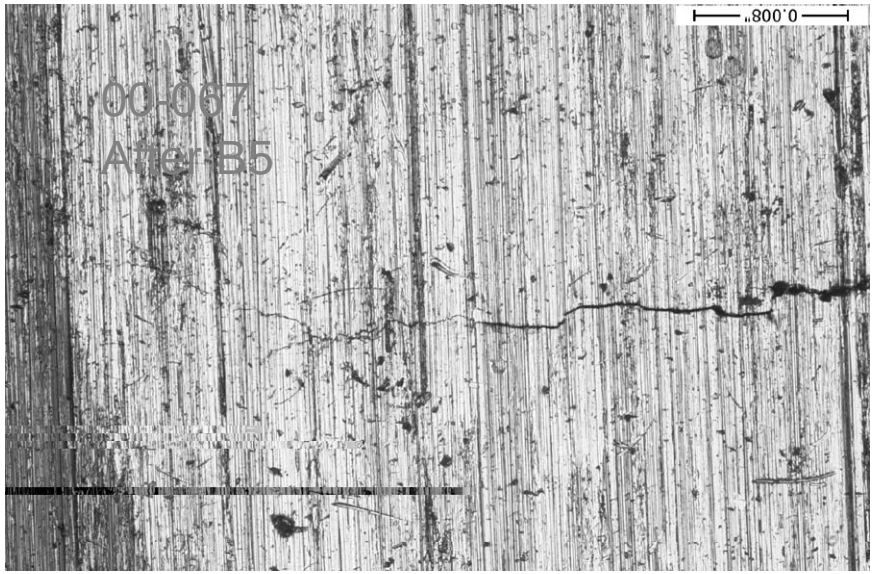


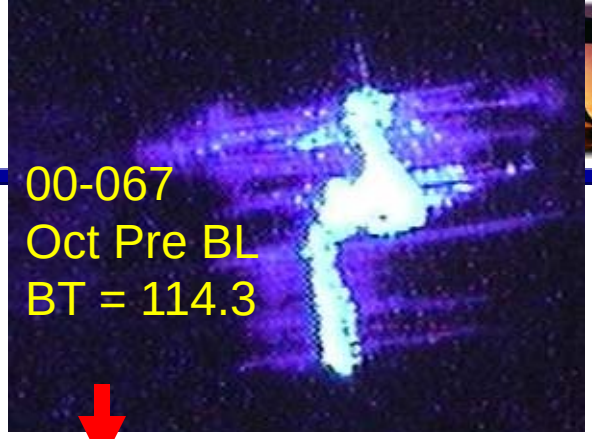


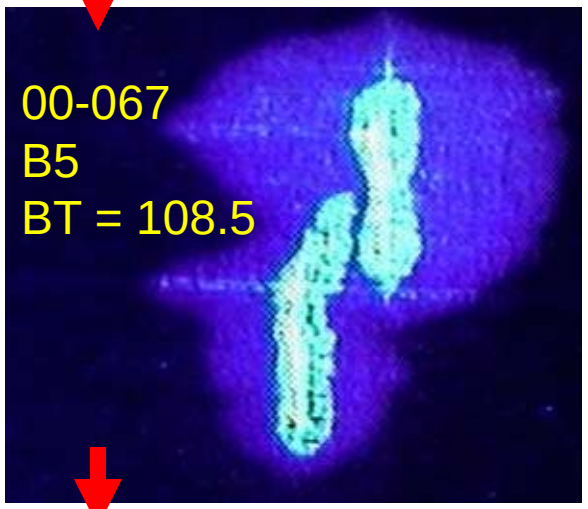


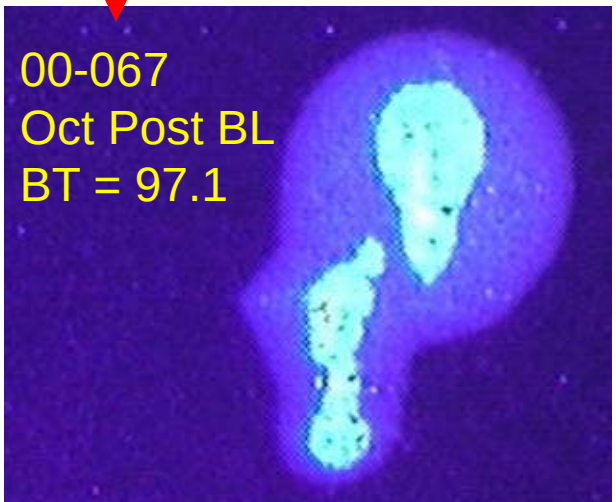
Al_2O_3 500 grit - 00-067 – Ti



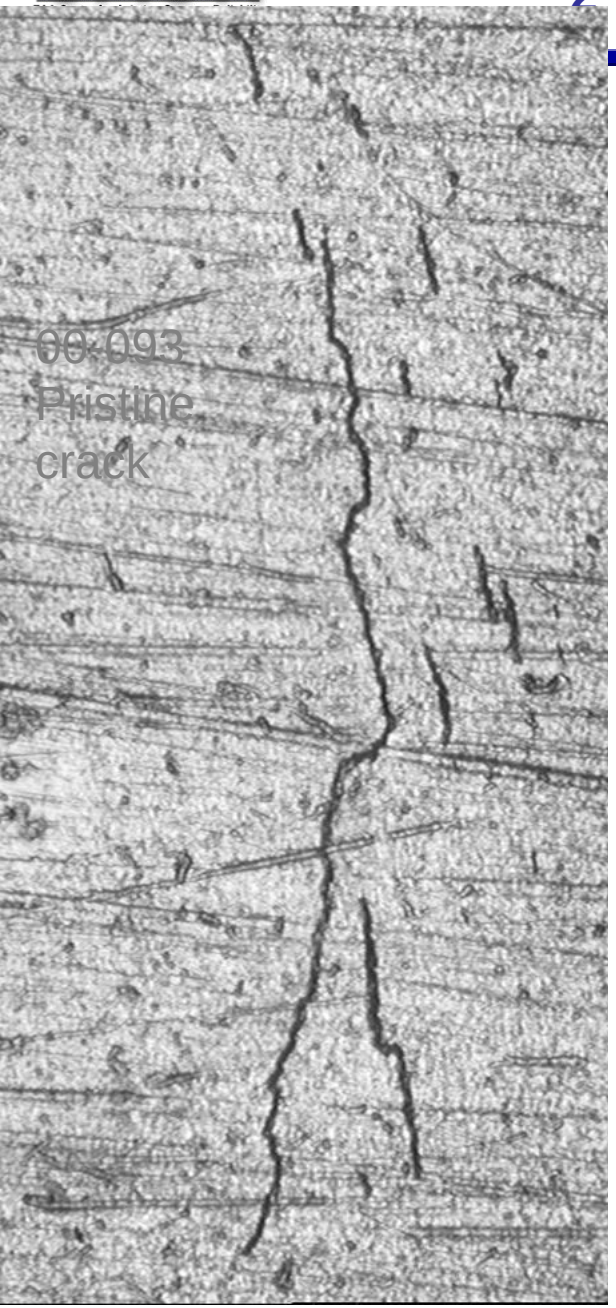


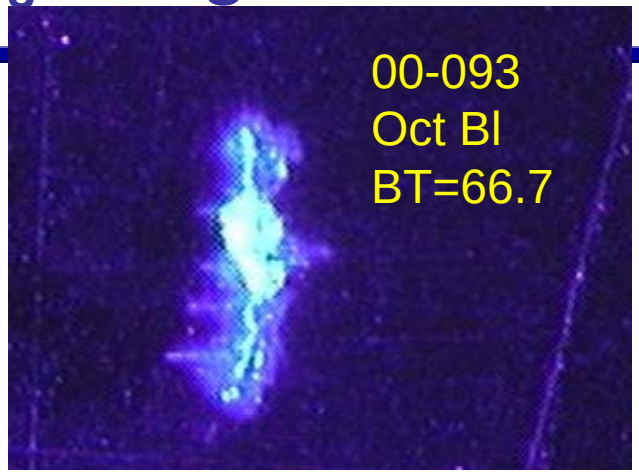


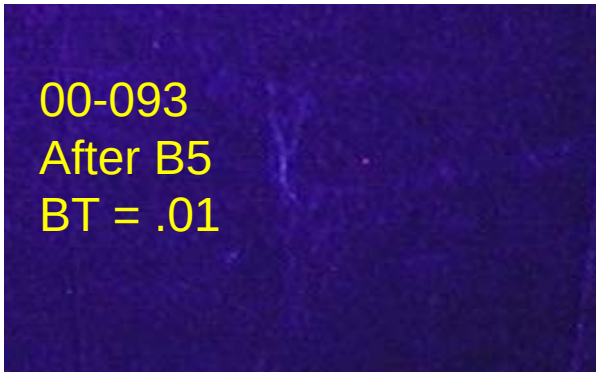


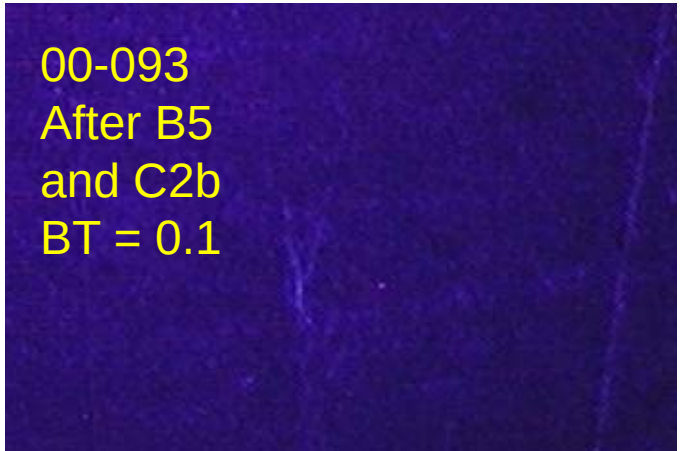


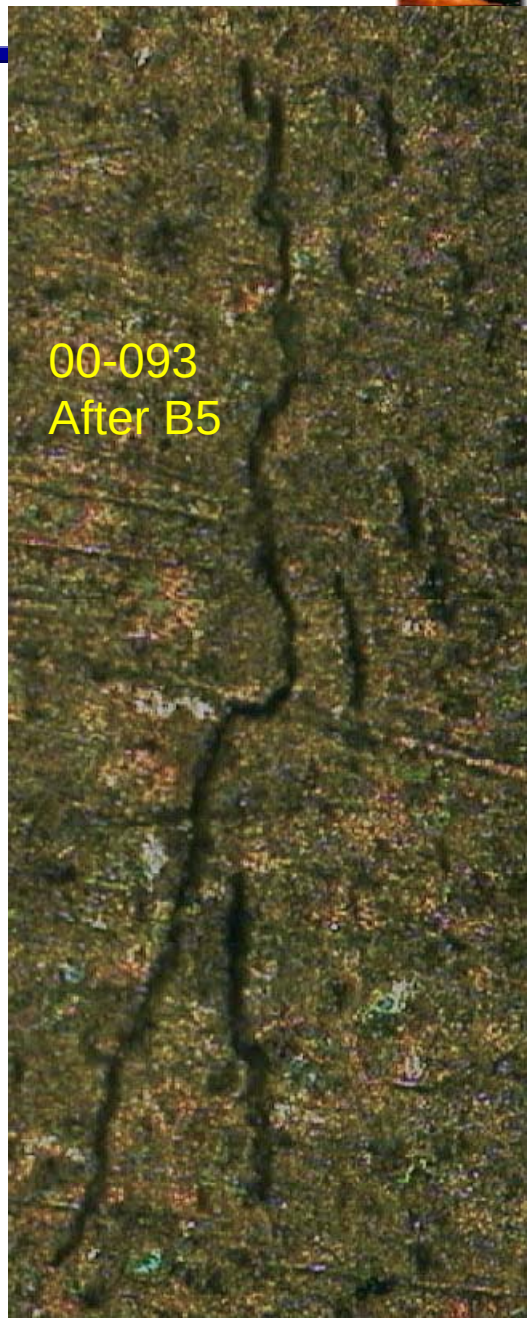
Al_2O_3 500 grit 00-093 – Ti





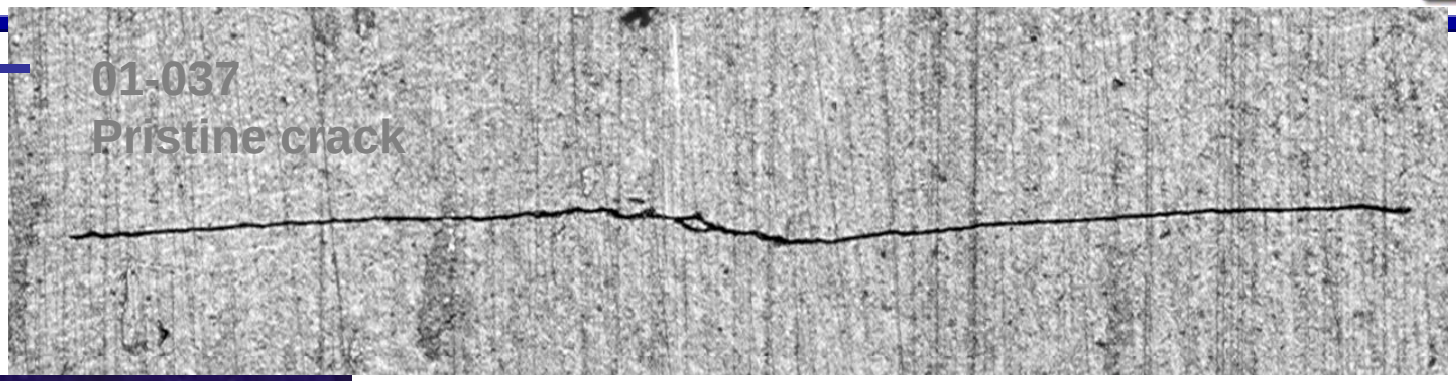


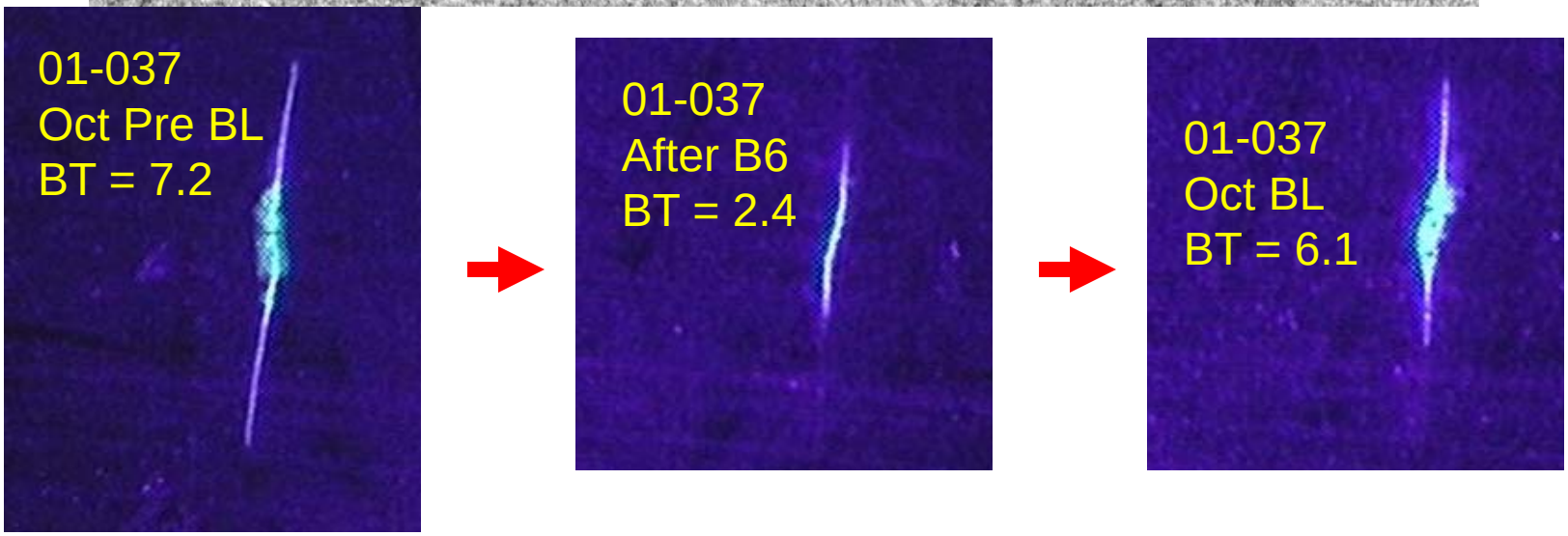


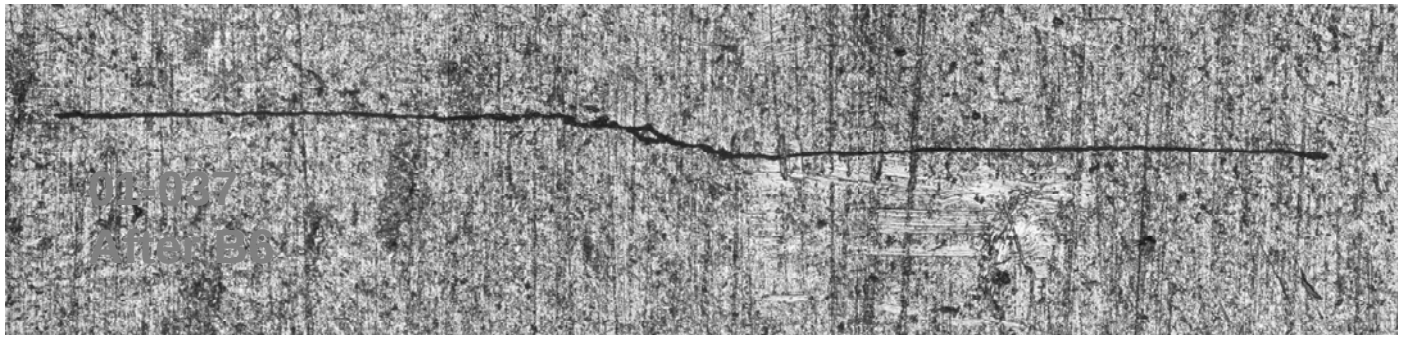


Walnut Shell Media Blast

01-037 – Ti







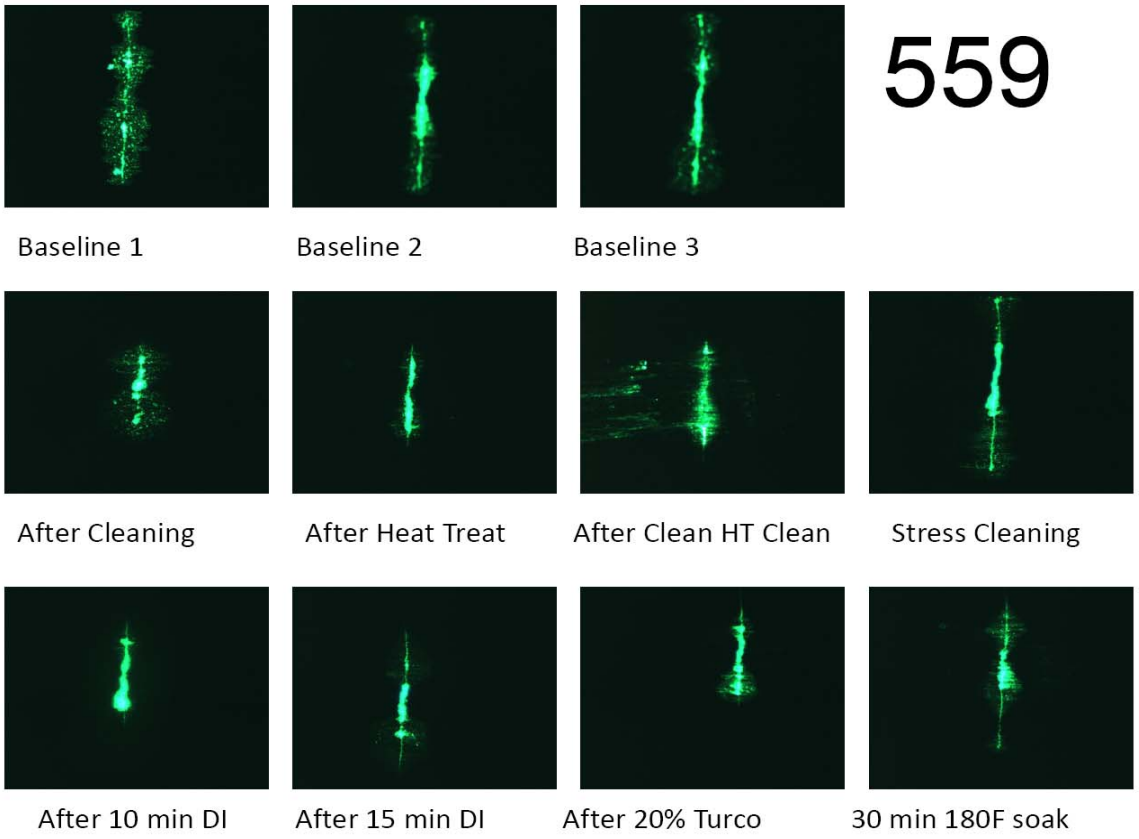
Mechanical Cleaning Methods

- Continue maximum allowable PMB pressure of 40 psi
- Wet glass bead, Al_20_3 240 and 320 grit processes should not be used on parts that will undergo FPI
- Al_20_3 500 grit, walnut shell blast, and PMB are all effective cleaning methods for removal of surface contamination
- Recommend that all mechanical blasting processes be followed by a wet process to remove residue from the blast media
- Mechanical methods are not effective in removing “baked-on” contaminants from inside the crack

Chemical Cleaning Methods

- Alkaline cleaners used for Ti were not found to be effective with “baked-on” contaminants
  - Inconclusive as to whether related to alkaline contamination, poor cleaning, or combination
  - Further documentation of the effect of alkaline on contamination is needed
  - Additional cleaning methods needed for Ti
- The four step process for Ni parts showed the best performance
  - Consider development of similar process for Ti
  - Determine if lack of performance for the one-step alkaline process and the alkaline gel process was related to alkaline contamination or ineffective cleaning

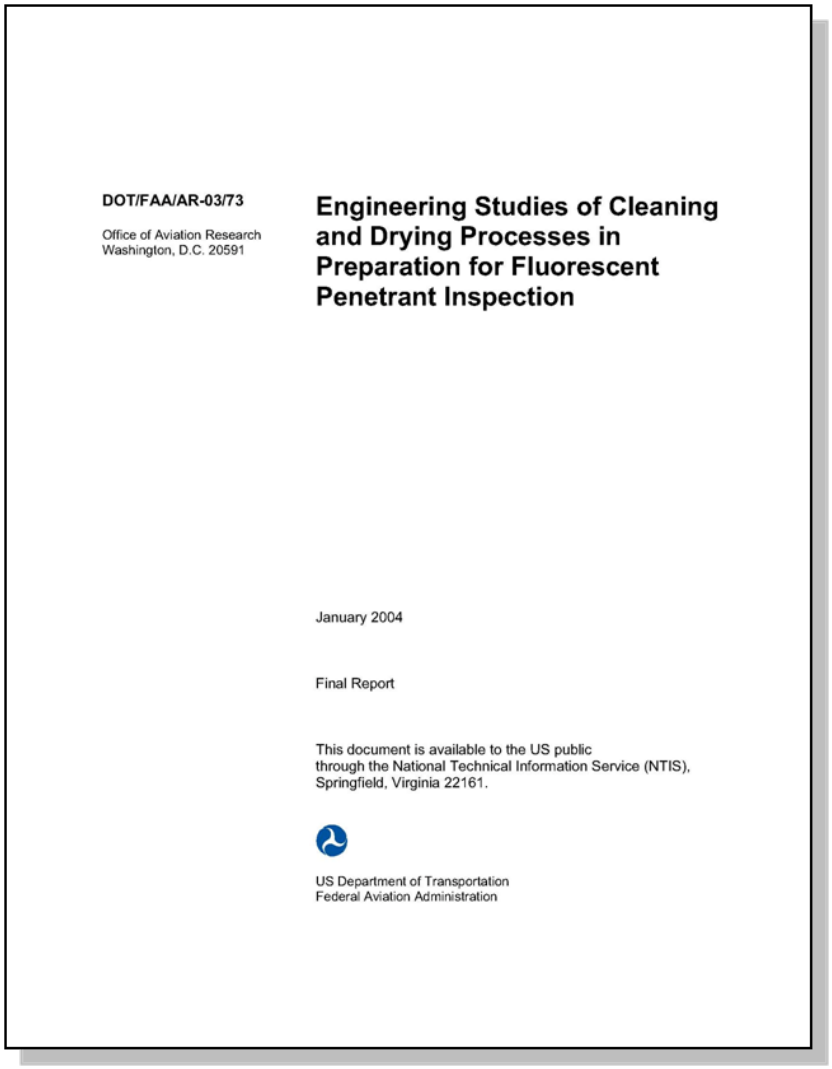
Ti Cleaning Study Evaluation



- Based on Phase I results which indicated problems with cleaning of Ti, initiated incremental cleaning study
- Determine hot water rinse (150F or greater) of at least 15 minutes provides better FPI performance
- Efforts underway to modify engine SOP documents

Conclusions

- Adequate cleaning methods exist for nickel components
- Chemical cleaning of titanium should be followed by a hot water rinse of 150F and 15 minutes
- Changes to allowable mechanical cleaning methods are warranted given the reductions in FPI response and surface changes
- Full report available at:
  http://actlibrary.tc.faa.gov



DOT/FAA/AR-03/73

Office of Aviation Research
Washington, D.C. 20591

Engineering Studies of Cleaning and Drying Processes in Preparation for Fluorescent Penetrant Inspection

January 2004

Final Report

This document is available to the US public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

US Department of Transportation
Federal Aviation Administration