IOWA STATE UNIVERSITY

CASR

FAA Center for Aviation Systems Reliability

CASR FPI – Engineering Studies: Drying in Preparation for FPI

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http://www.cnde.iastate.edu/faa-casr/fpi/index.html

ETC Drying Study

Drying study parameters

- Ultrasonic acetone clean 30 minutes
- Flash dry
  - Water bath at RT (82F – 28C)
  - Flash dry at 150F (66C)
- Oven dry
  - Water bath at RT (82F – 28C)
  - Oven dry at 225F (107C) for 30 minutes
- FPI Process
  - Cool to 40C prior to FPI
  - Level 4 - UltraHigh Sensitivity Post Emulsified Penetrant
- Spotmeter brightness and digital recording of image

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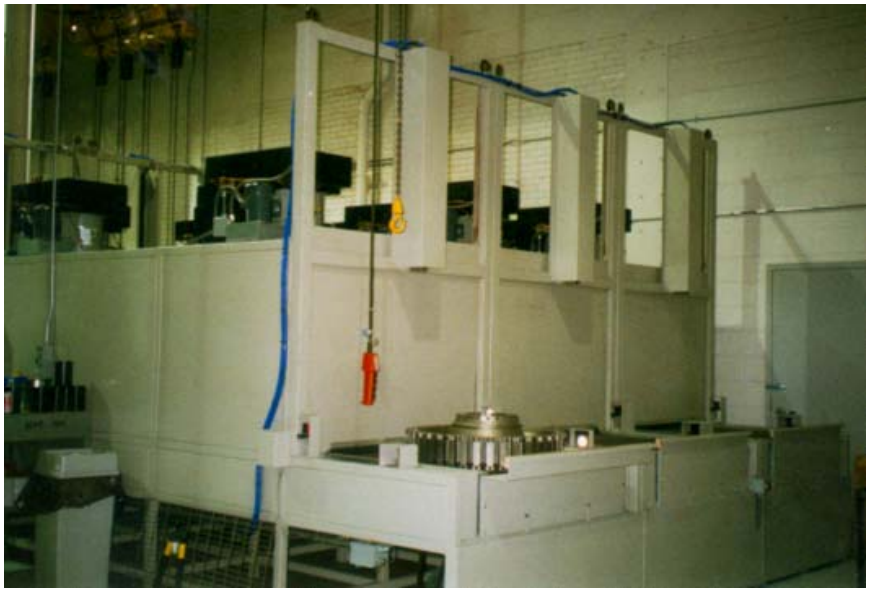
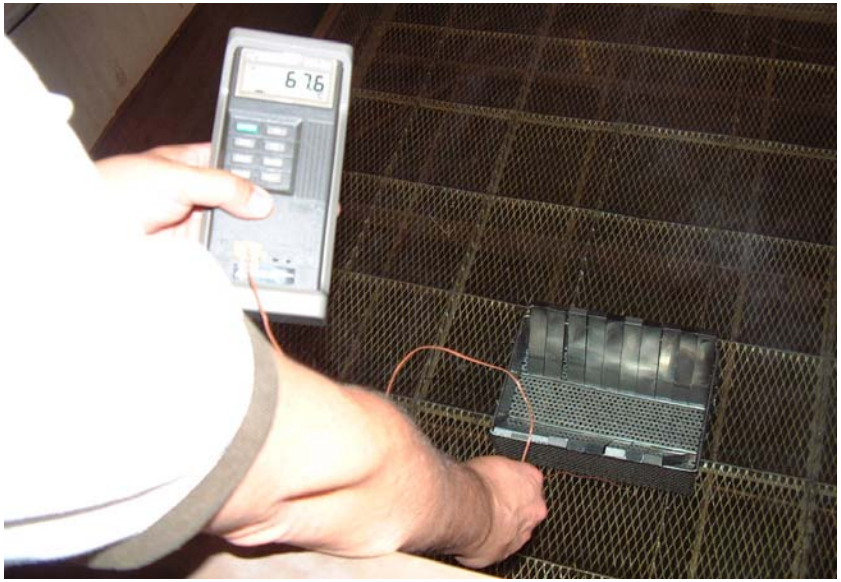
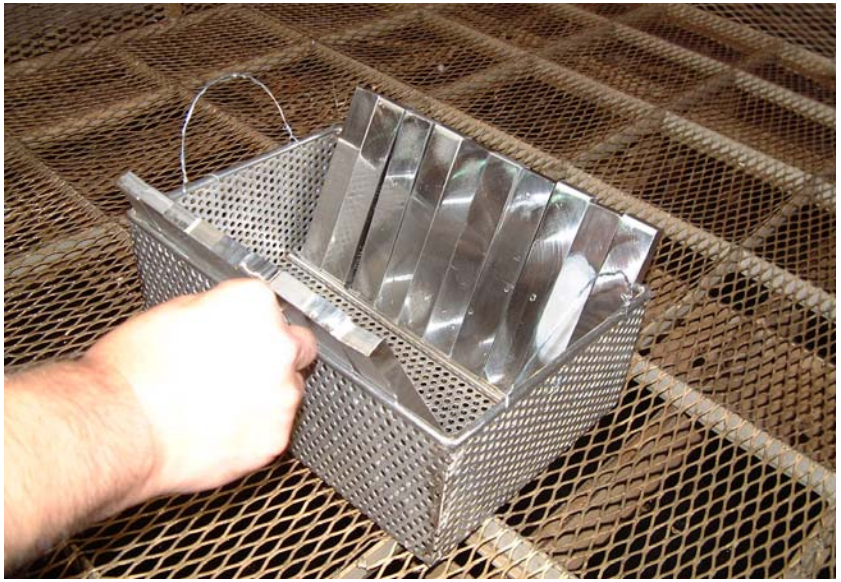
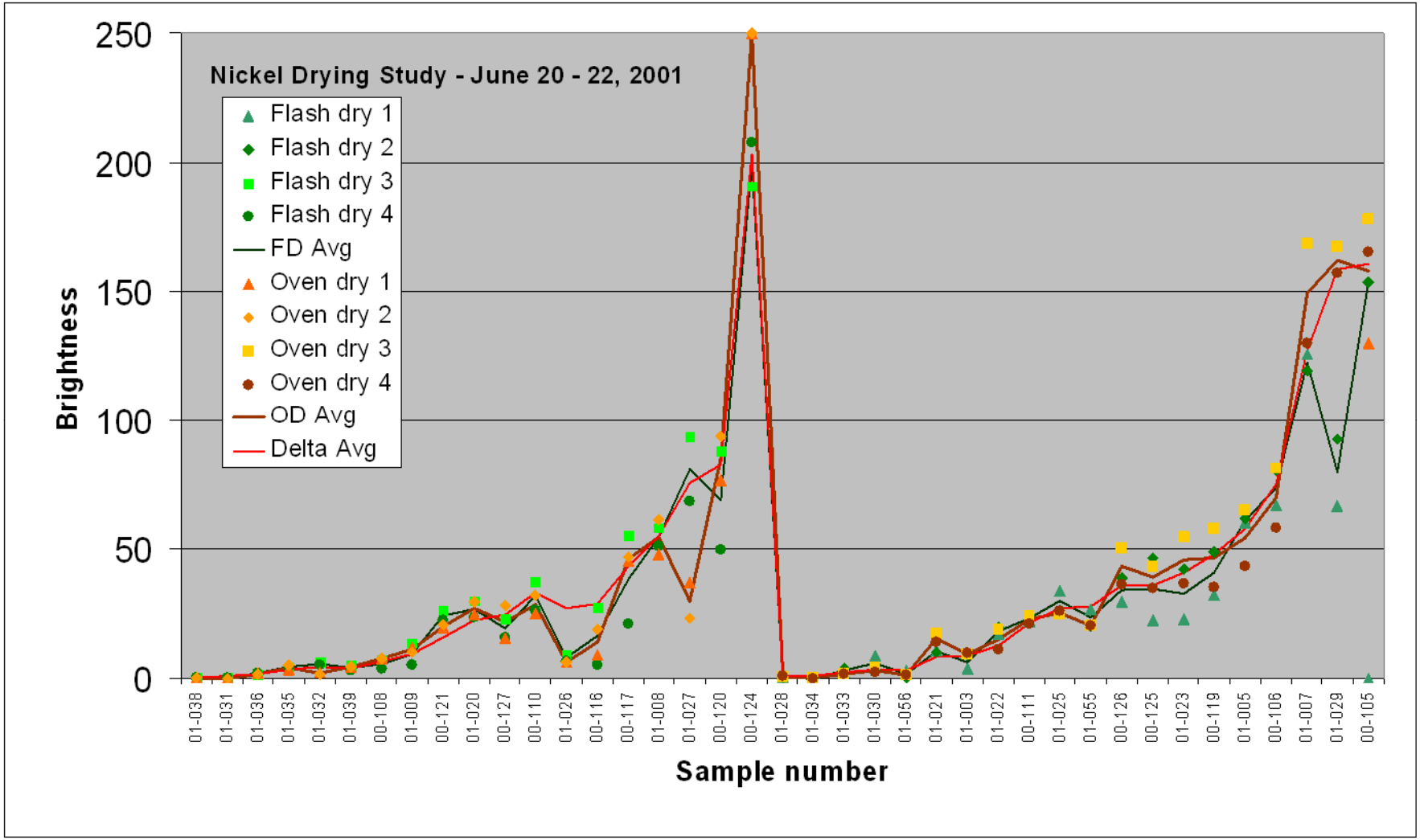
Drying Study



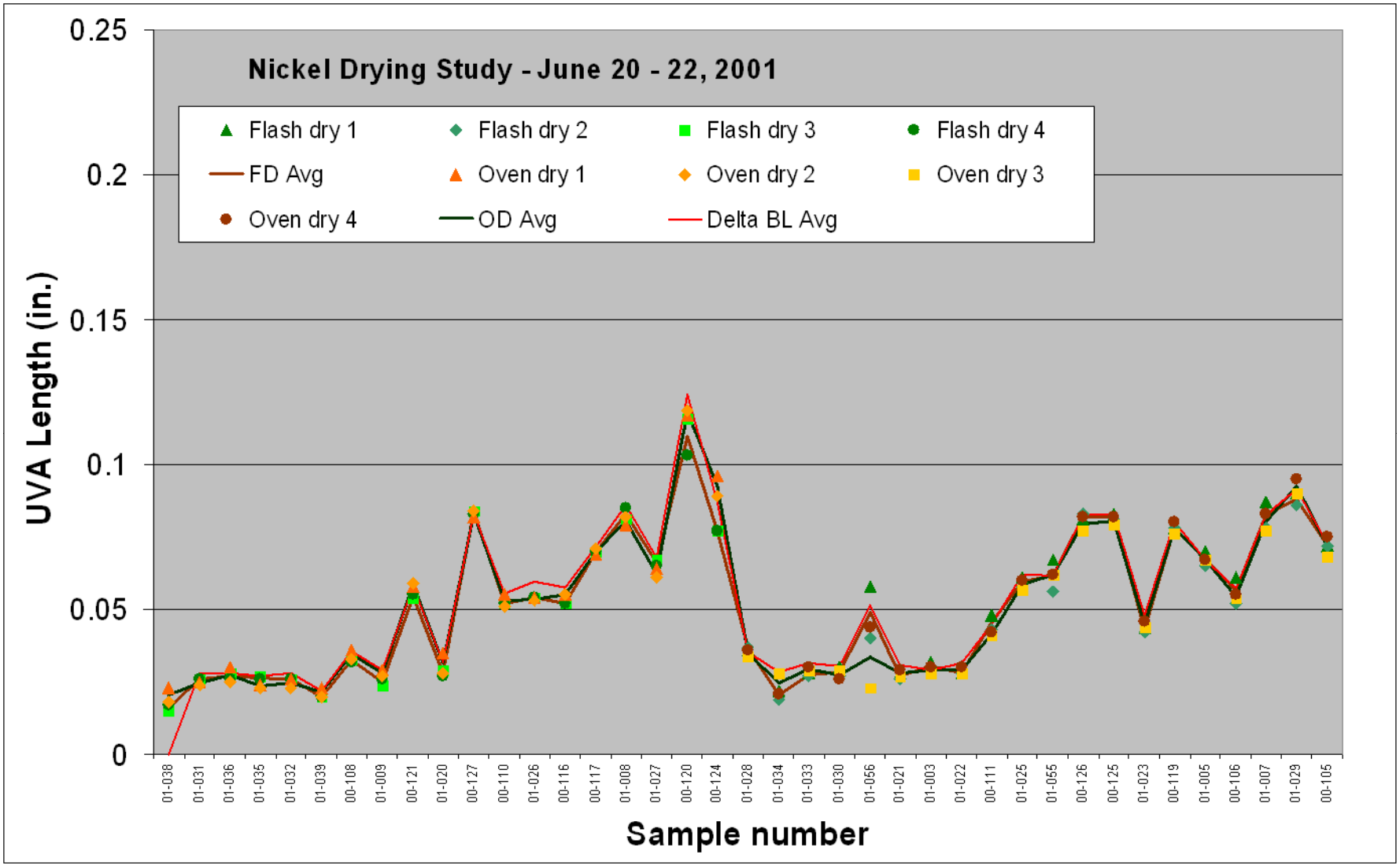




Drying Study



Drying Study

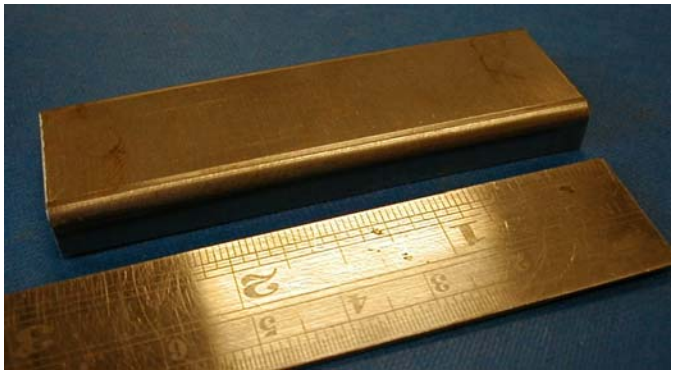


ETC Drying Study

- Statistical analysis of brightness and UVA lengths did not reveal significant differences between the two drying methods at the temperatures used in this study, i.e., flash drying at 150°F and oven drying at 225°F
- Potential factors not considered in the current study are the effect of thermal mass, potential differences in penetrant level, and a range of drying temperatures. Additional studies that explore these factors are underway.
- While significant differences were not found between the two methods, the importance of process monitoring and control for either method should be emphasized in specifications, standard practice documents, and training/guidance materials. Without careful adherence to the recommended practices, reductions in detectability can occur with either method.

CASR Drying Study – ES -9

- Samples included shot peened and as machined surfaces
- Penetrants
  - Level 4 ultrahigh postemulsifiable: Magnaflux ZL – 37
  - Level 3 surfactant based water wash: Magnaflux ZL – 67
  - Level 2 oil based water wash: Magnaflux ZL – 60D
- Additional drying parameters
- POD data generated



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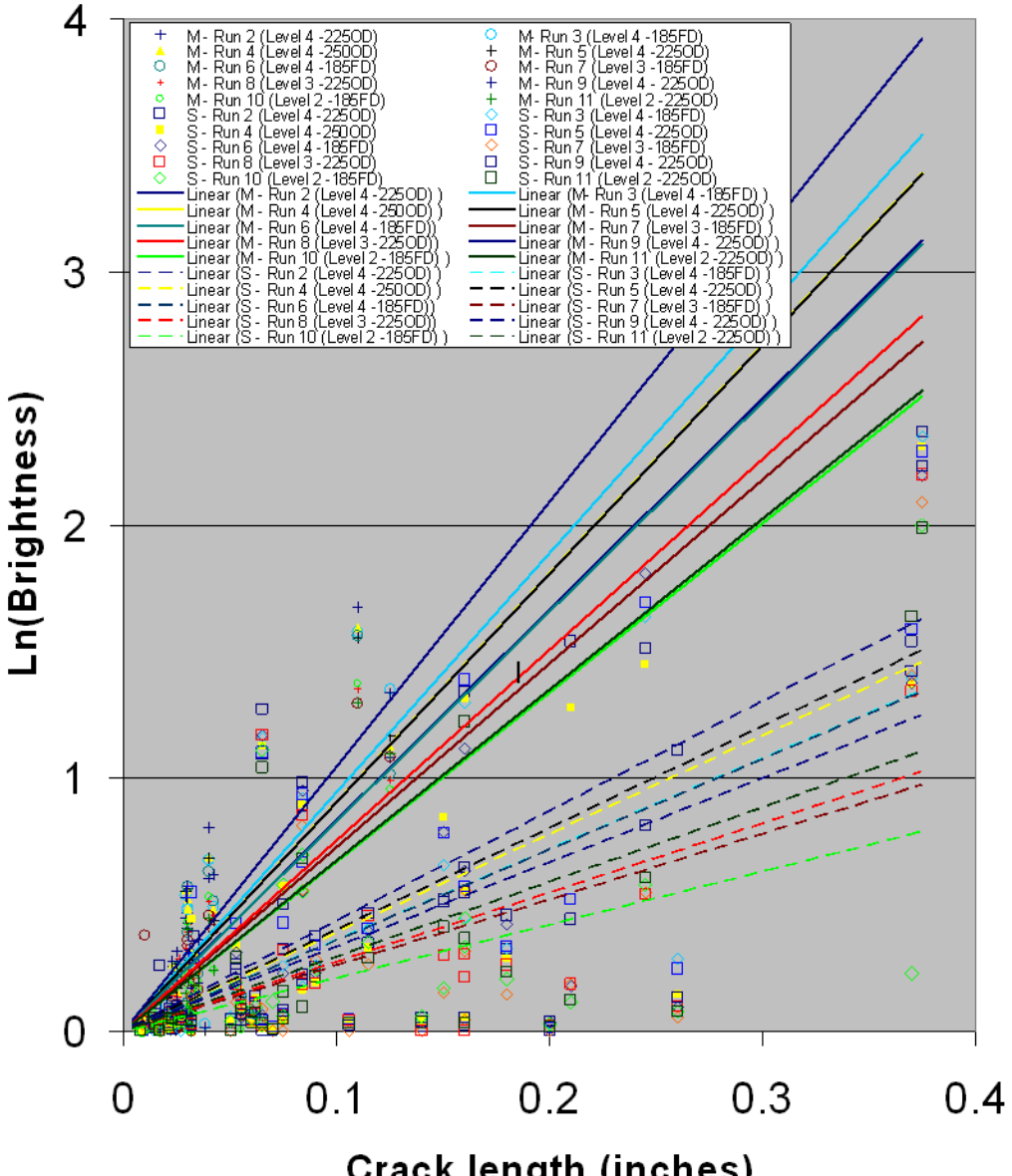
Drying Study Results

- Results analyzed as function of penetrant method, drying parameter, and surface finish
- Strongest factor was surface finish
- Expected differences found between penetrant levels



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Conclusions

- For sample size and crack size used, differences were not found between the two drying methods. Factors not considered include thermal mass which will was later accessed using real parts and appropriate fixtures.
- Differences were found between the two surface finish conditions. Detectability in shot peened surfaces present on these samples was lower than machined surfaces.
- Differences were found between penetrant method with Level 4 found to be more sensitive than Levels 3 or 2. Differences between levels 2 and 3 were not significant for the rinse times used in this study.

Objective

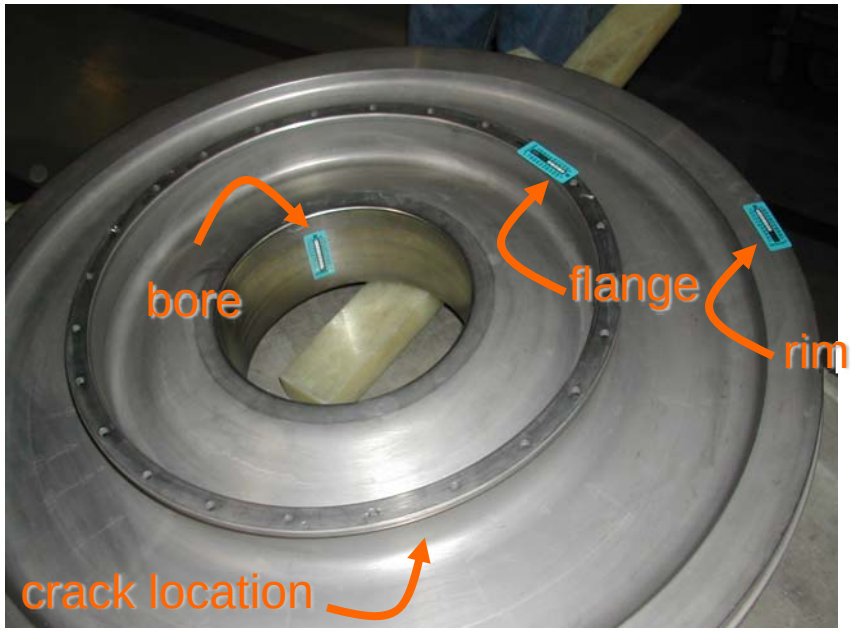
- Evaluate geometry and high thermal mass effects on brightness in response to changes in processing parameters.
- Utilized real part with fatigue cracks generated during spin pit test and provided for use by Rolls Royce.
  - Weights approx. 300 lbs
  - Waspaloy material
  - Changing geometry
  - High mass to volume ratio
  - Shot peened surface

Baseline Process

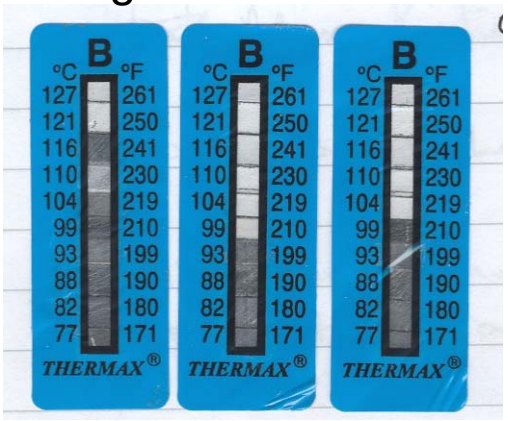
- Vapor degrease 5 mins @ 183F (This increased to default of 20 mins due to persistent FPI indications).
- Oven dry @ 225F for 30 mins
- Cool to 104F (forced air cooled using fan)
- Level 4, PE penetrant (ZL-37), dipped and dwelled for 20 mins
- Wash 60 seconds
- Emulsify using ZR-10B with agitation for 120 seconds
- Wash 60 seconds
- Pre developer dry @ 160F for 20 minutes
- Dry powder developer, ZP-4B, hand processed 10 minute dwell

Temperature Monitoring

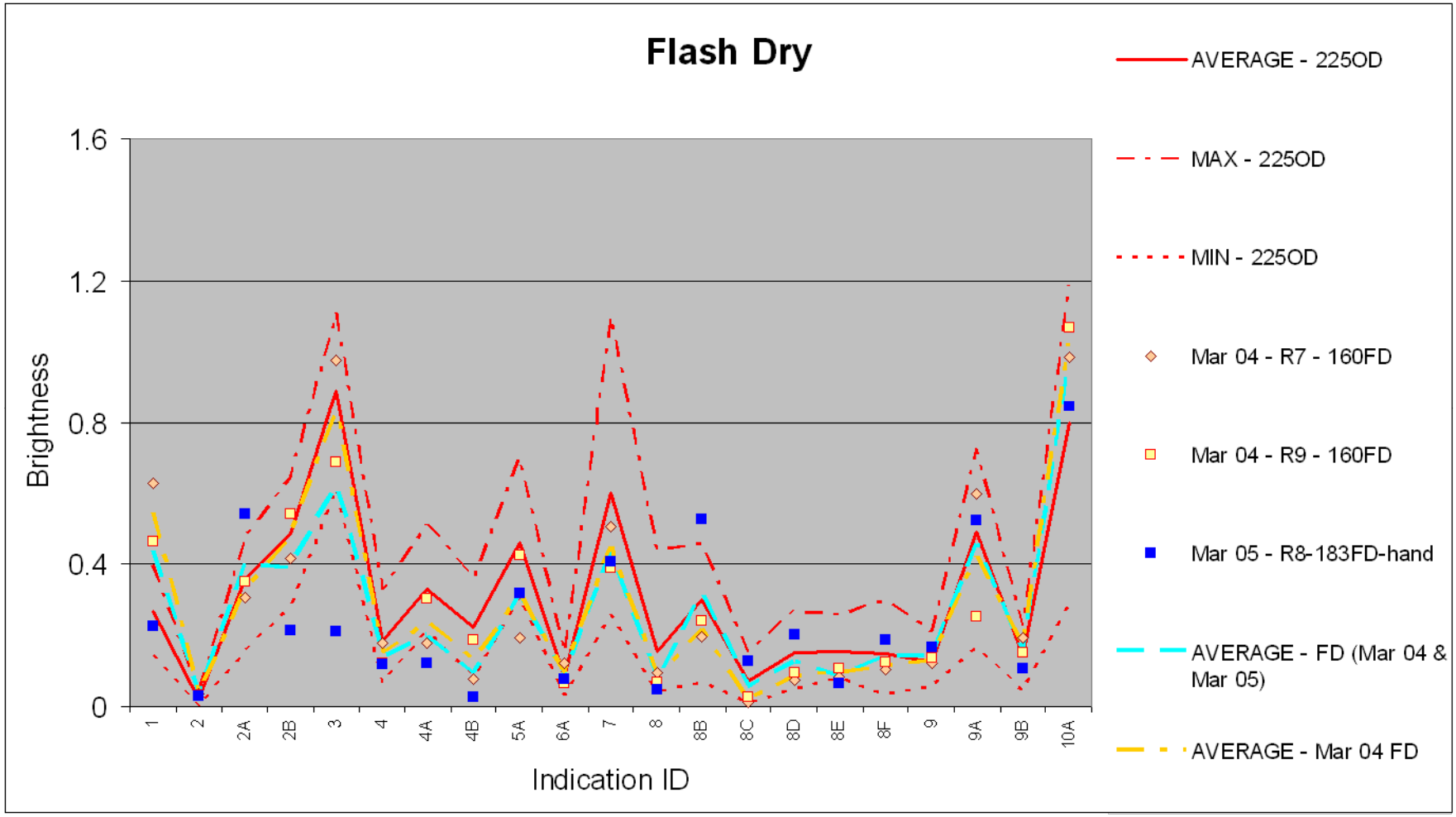
- Temperature gages used to determine variation with part geometry
- Order of increasing temperature:
  - Inner (bore)
  - Outer (rim)
  - Middle (flange)



Flange Bore Rim



Results of Flash Dry Comparison



- Similar average brightness between FD and OD in Mar 04
- More variability and lower average brightness found with FD in Mar 05 than 225OD, possibly due to emulsifier effects

Thermal Mass Drying Study Conclusions

- Average brightness similar for both oven dry temperatures, i.e., 225F and 250F
- Similar performance for flash dry method
- Use of heavy duty alkaline clean led to improvements in brightness

Is Drying Important?

- Selected subset of cracked samples for use in “water contamination” study
- With and without ultrasonic agitation

Water Contamination Study

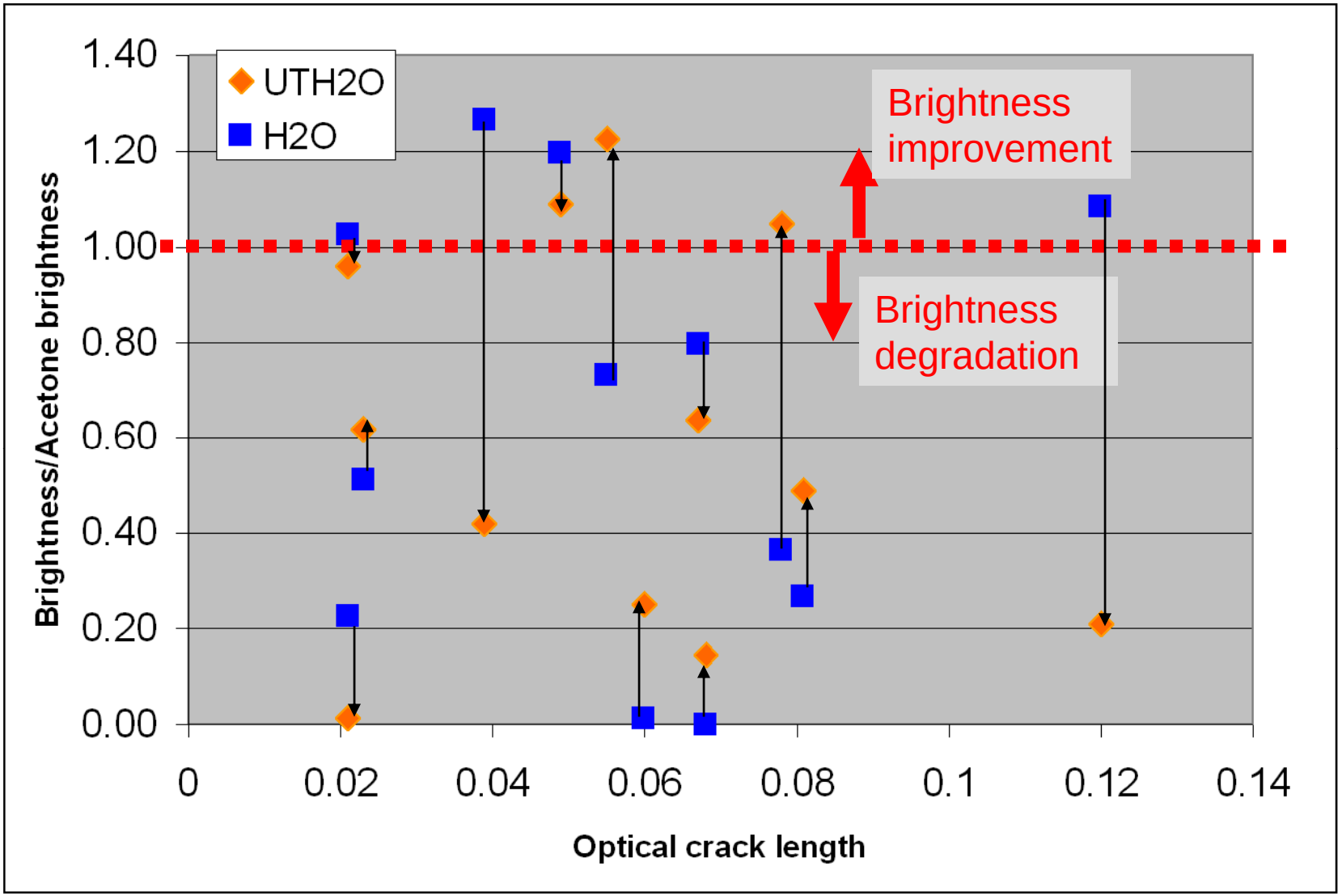
	Contamination	Cleaning Method	Alloy	Specimen	Optical Length	Feb acetone	Feb UTH2O	Feb H2O	Feb acetone	Feb UTH2O	Feb H2O
22	Coke & Varnish +C3+C4+ACE	UT H2O	Ni	01-008	0.078	32.2	33.7	11.8	36.4	0.067	0.081
23	Coke & Varnish +C3+C4+ACE	UT H2O	Ni	01-032	0.021	8	0.1	1.8	4	0	0.024
24	Coke & Varnish +C3+C4+ACE	UT H2O	Ni	00-105	0.067	sat	159.6	198.6	212.6	0.075	0.072
28	Coke & Varnish+C5+C4	UT H2O	Ni	01-026	0.055	30	36.8	21.9	24.6	0.06	0.057
29	Coke & Varnish+C5+C4	UT H2O	Ni	01-022	0.023	27	16.7	13.8	31.2	0.029	0.027
30	Coke & Varnish+C5+C4	UT H2O	Ni	01-039	0.021	7.7	7.4	7.9	8.6	0.023	0.023
2	Oxidation & Scale+C2a+C2b+ace	UT H2O	Ti	00-080	0.057	lost	lost	lost	lost	0	0
3	Oxidation & Scale+C2a+C2b+ace	UT H2O	Ti	00-090	0.060	45.5	11.5	0.6	0.1	0	0.016
18	Soot +C2b+C2b+VDG+ace	UT H2O	Ti	00-081	0.120	161.7	33.8	175.3	sat	0.112	0.081
21	Soot +C5+C2b+VDG+ace	UT H2O	Ti	00-087	0.068	76.1	11.1			0.057	
22	Soot+C1+C2b+VDG+ace	UT H2O	Ti	00-077	0.039	54.6	22.9	69.1		0.041	0.048
23	Soot+C1+C2b+VDG+ace	UT H2O	Ti	01-042	0.058	lost	lost	lost	lost	0	0
24	Soot+C1+C2b+VDG+ace	UT H2O	Ti	01-013	0.081	19.1	9.3	5.1	15.2	0.037	0.038
25	Soot+B1+C2b+VDG+ace	UT H2O	Ti	01-052	0.049	58.4	63.6	69.8	66.2	0.068	0.065

Observations:

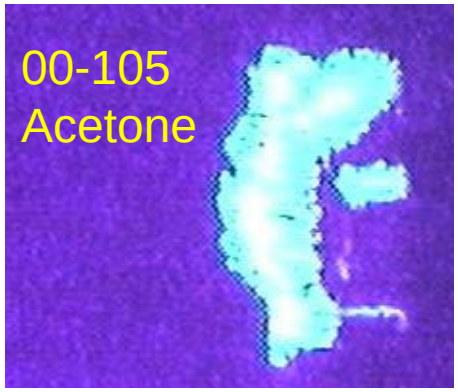
- UT H2O lead to lower brightnesses in all but one case with less impact on length values
- Some cracks showed reduced brightness in “plain” H20 while others showed increased brightness
- Water is a contaminant which degrades penetrant process, i.e., drying is an important step in preparation for FPI
- Ti is more affected than Ni

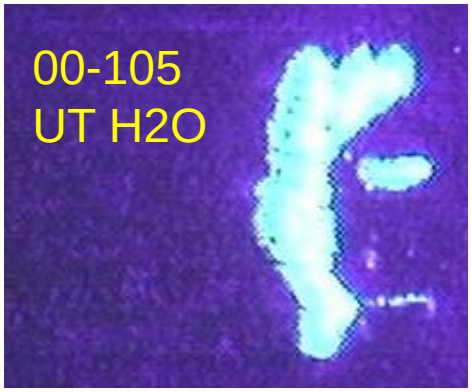
Comparison of UT and Water Soak

- Comparison of brightness after UT assisted water soak and water soak with no dry prior to FPI.
- Values of one would indicate no change from acetone followed by oven dry.



Water study


00-105
Acetone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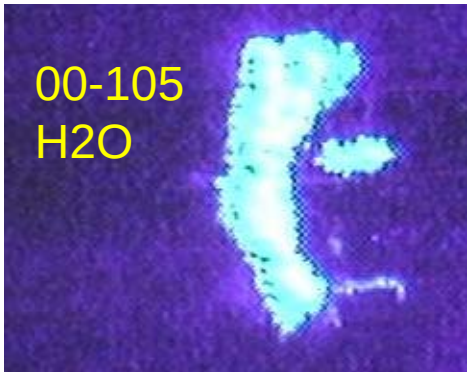
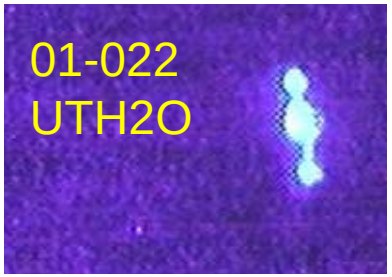
UT H2O


00-105
H2O


01-022
Pre acetone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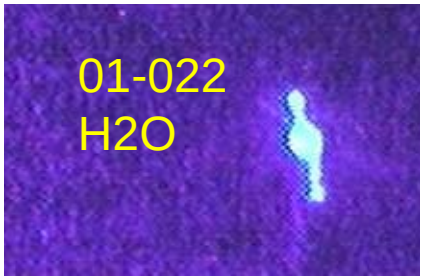
UTH2O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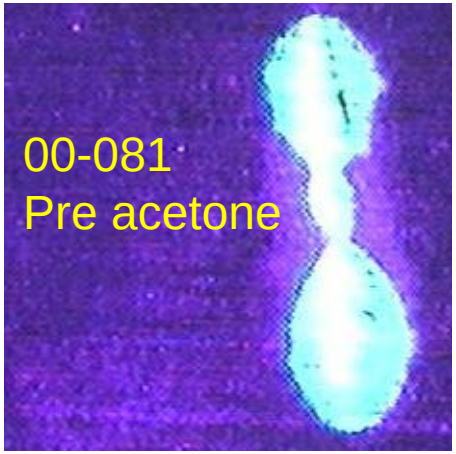
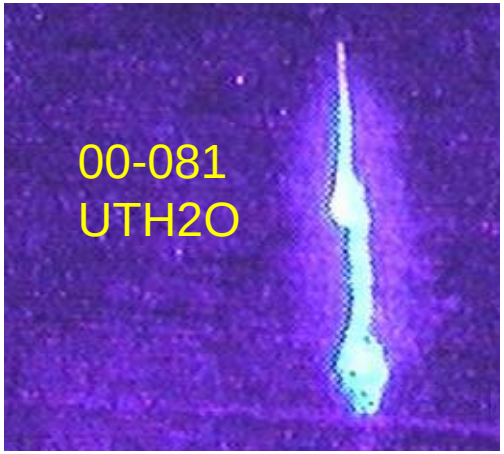
H2O


00-081
Pre acetone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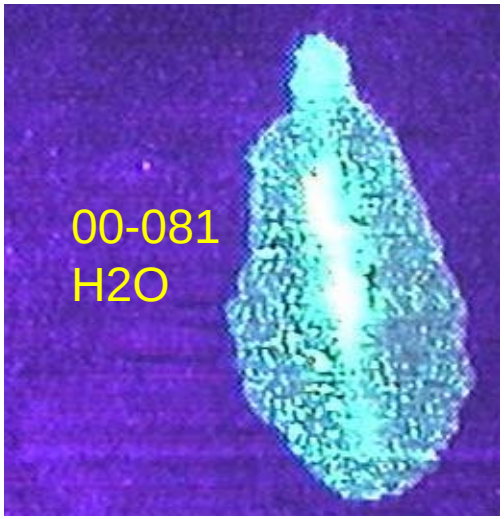
UTH2O


00-081
H2O

Summary

- Water is a contaminant which degrades penetrant process, i.e., drying is an important step in preparation for FPI
- No statistically significant differences found between flash dry and oven dry methods