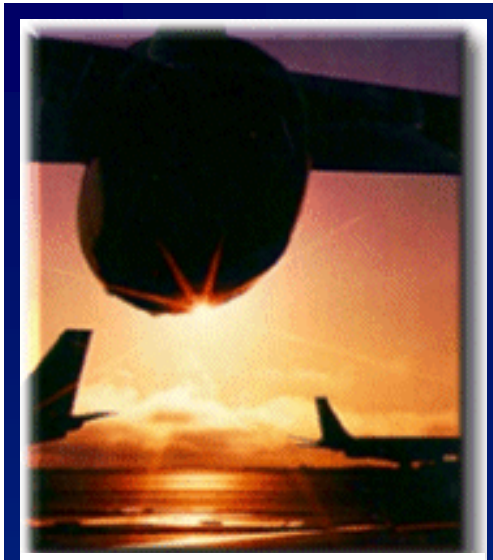


CASR

FAA Center for Aviation Systems Reliability

Summary of Developer Chamber Characterization

Lisa Brasche, Iowa State University

lbrasche@cnde.iastate.edu

ASNT Fall Conference

November 2004

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

Program Timeline

- 1999 – 2002 – Cleaning and Drying Studies performed as part of the Engine Titanium Consortium
- 2002 – 2006 – Engineering Assessment of Fluorescent Penetrant Inspection performed as part of Center for Aviation Systems Reliability effort

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

CASR Engineering Assessment of FPI

- Provide engineering data to support decisions regarding the safe application and relevant use of FPI
- Includes data to support changes in specifications
- Generate tools for use by airlines and OEMS that improve FPI processes
- Strong industry team with extensive experience

BOEING
Delta
delta.com
D&W Enterprises, LTD.
Consulting Services
General Electric Company
IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY
Pratt & Whitney
A United Technologies Company
Rolls-Royce
SHERWIN
INCORPORATED
UNITED

Program Partners

Cooperative university/industry program which brings together aircraft and engine OEMs, airlines, vendors, as well as technical expertise from the NDE community.

ISU: Lisa Brasche, Rick Lopez, Bill Meeker

FAA: Al Broz, Paul Swindell, Dave Galella

Industrial Advisory Panel

Boeing - Long Beach
- Dwight Wilson, John Petty

Boeing - Seattle
- Steve Younker

Delta Airlines - Atlanta
- Lee Clements

United Airlines - Indianapolis
- Tom Dreher

Pratt & Whitney - EH and WPB
- Kevin Smith, John Lively, Pete Ozga

Rolls Royce - Indianapolis and Darby
- Pramod Khandelwal, Keith Griffiths, Bill Griffiths

GE Aircraft Engines
- Terry Kessler, Thadd Patton, Wayne Kitchen

Sherwin - Cincinnati
- Sam Robinson

D&W Enterprises - Denver
- Ward Rummel

Technical Approach

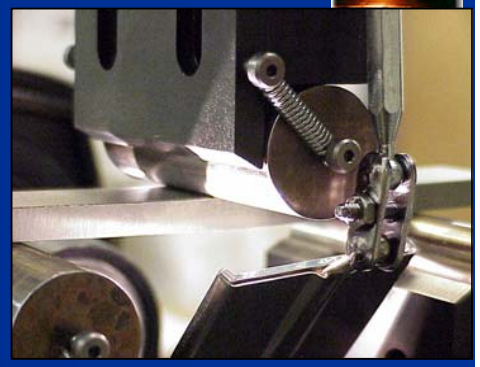
- Define factors for which engineering data is deficient
  - Change in process, e.g., environmental changes
  - Change in applications
  - Data not available in the public domain
- Design engineering study that provides quantitative assessment of performance
  - Brightness measurements
  - Digital recording of UVA indication
  - Probability of Detection
- Complete study using either lab or shop facilities as appropriate
- Distribute results through use of web
- Support changes to industry specifications as warranted
- Utilize results to update/create guidance materials
- Transition process to airlines for internal, self-assessment

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

Sample Fabrication

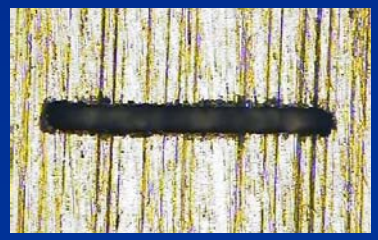
- Titanium 6Al-4V
  - 1/4 and 1/2 inch thick plate
  - ASTM-B-265, Grade 5 and AMS 4911
- Inconel 718
  - 1/2 inch thick plate
  - AMS 5596
- EDM notches used as starter notches
- Three point bending to generate cracks with 2:1 to 3:1 crack aspect ratio
- Crack sizes ranging from 20 to 180 mils, most at 80 mils

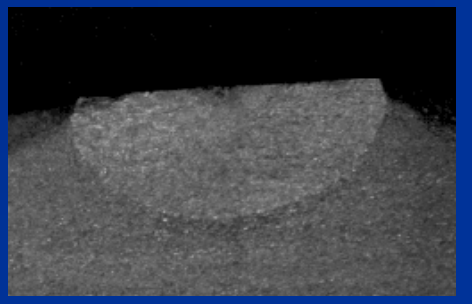
(a)



(b)

(c)

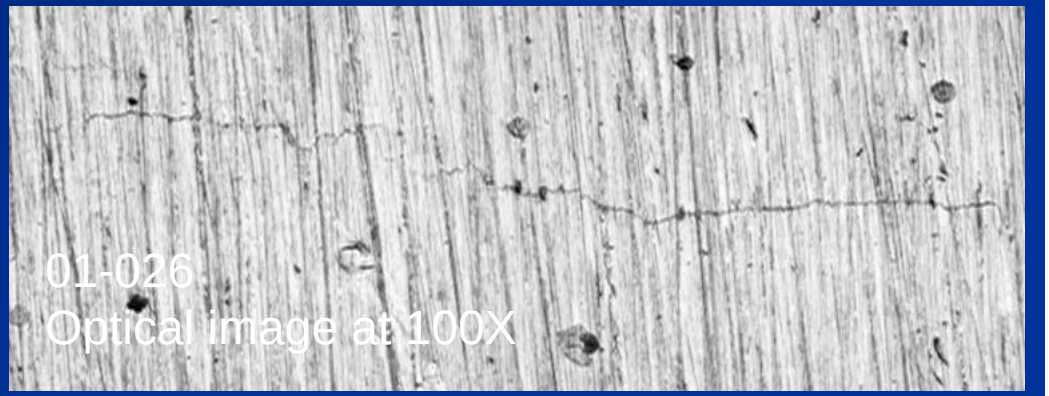




Sample Characterization

- Final surface polish to 32 Ra
- Optical photographs (100X digital)
- Brightness measurements and UVA image capture to establish baseline and remove samples that showed variability

(a)



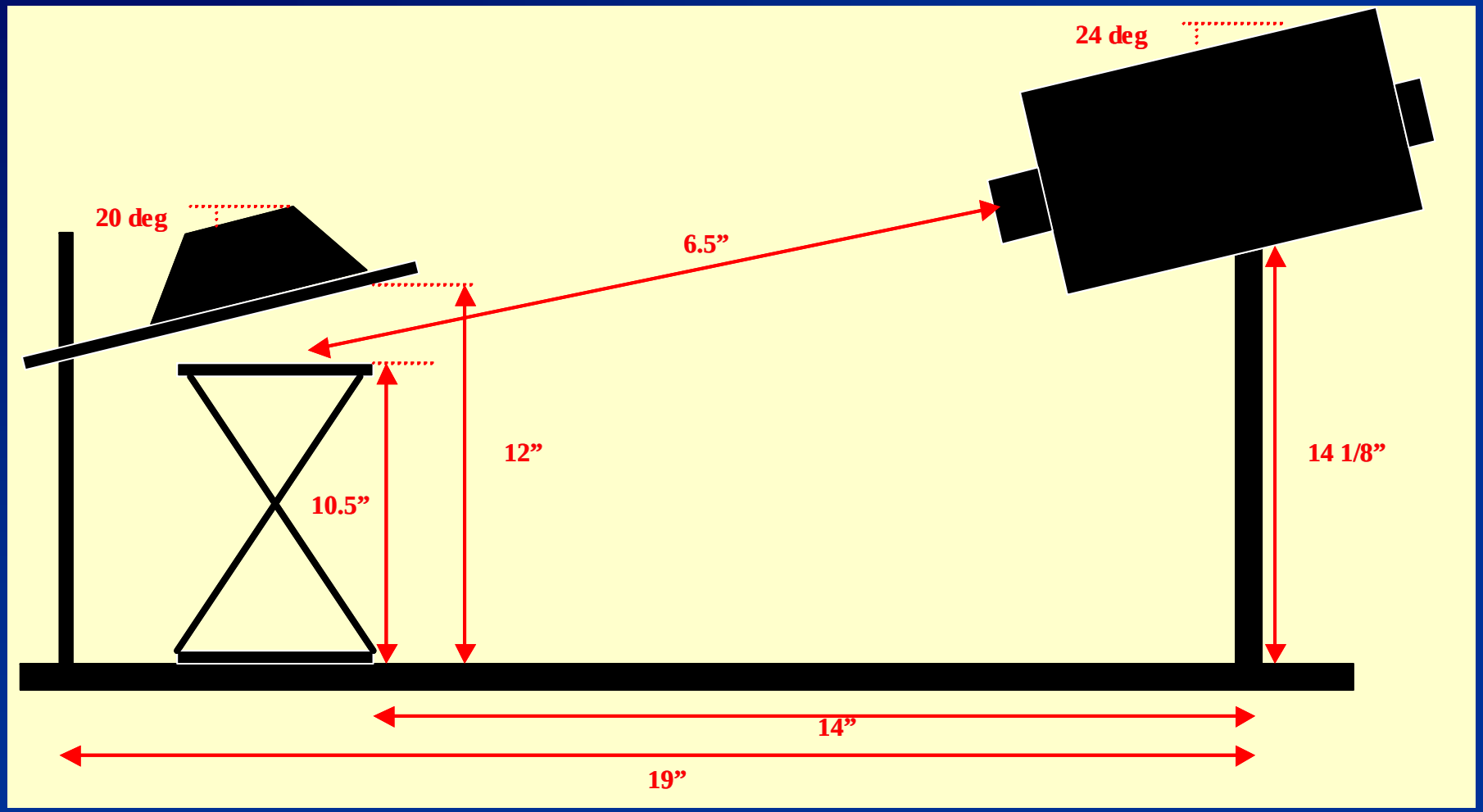
(b)

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

Brightness Measurement

- Used rigid fixturing to assure repeatability with transportability for brightness measurements
- Photo Research PR-880 Photometer used to record indication brightness in ft-Lamberts

Brightness Measurements



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

Field Studies

- Requires access to typical drying, cleaning and FPI methods used in commercial aviation
- Several partners have provided access to their facilities
  - 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

CASR

Field Studies

- 15 - 20 samples per basket
- 20 minute penetrant dwell
- 90 second pre-wash
- 120 seconds emulsifier contact with vertical motion
- Two 30 second cycles of air agitated water rinse, then a 90 second post-wash

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

CASR

Field Studies

- Samples dried for 8 minutes at 150ºF
- Drag-through application of developer
- 10 minute development time
- Brightness reading using Spotmeter
- Length reading using UVA and image analysis software

Engineering Studies

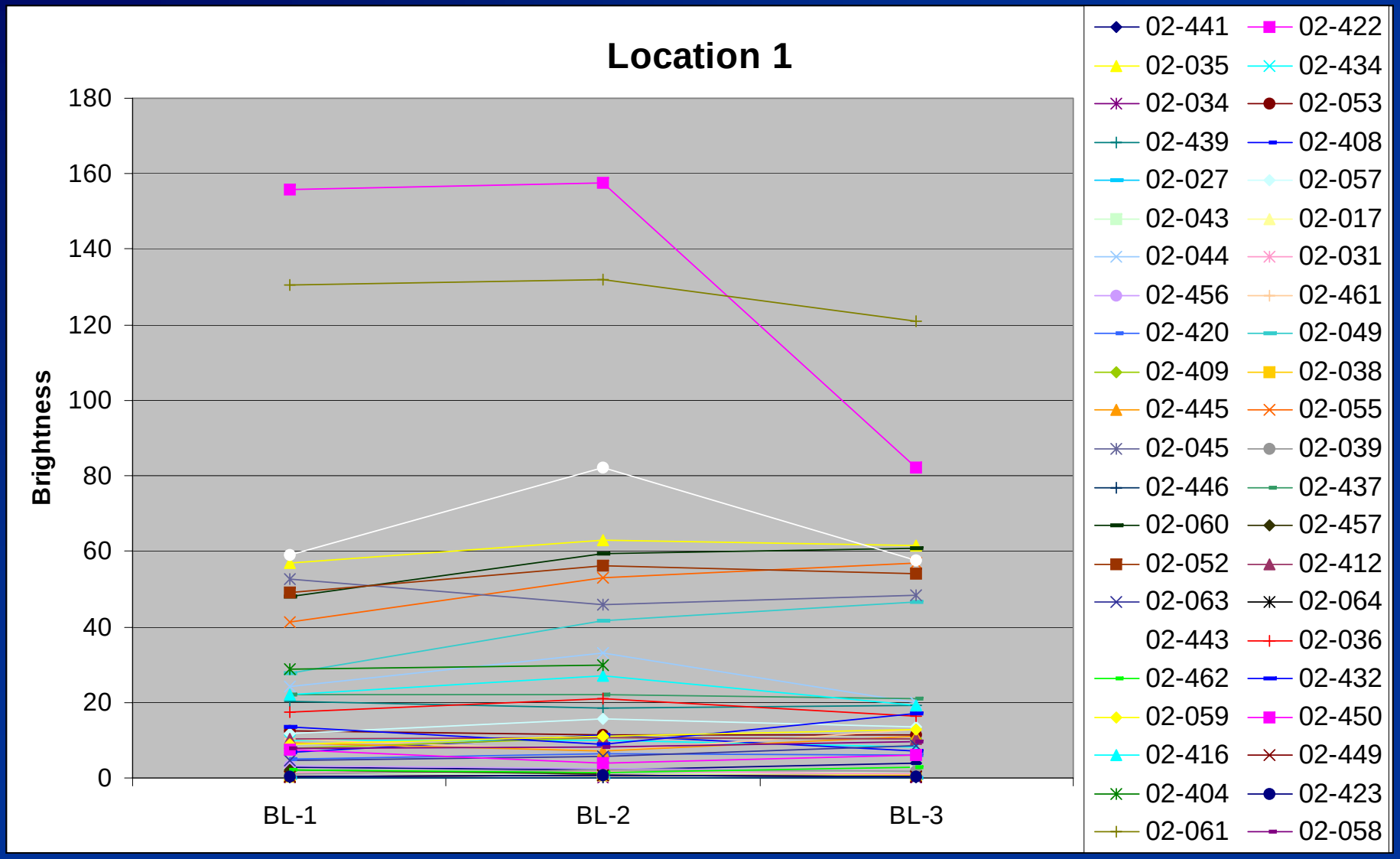
- Topics for engineering studies selected and prioritized by team
- Subteams developed for experimental design with review by the full team
- Experimental efforts to take place at various industry locations
- Definition currently underway

- ES – 1 – Developer Studies
- ES – 2 – Cleaning Studies for Ti, Ni and Al
- ES – 3 – Stress Studies
- ES – 4 – Assessment tool for dryness and cleanliness
- ES – 5 – Effect of surface treatments on detectability
- ES – 6 – Light level Studies
- ES – 7 – Detectability Studies
- ES – 8 – Study of Prewash and Emulsification Parameters
- ES – 9 – Evaluation of Drying Temperatures
- ES – 10 – Part geometry effects
- ES – 11 – Penetrant Application Studies
- ES – 12 – Relationship of part thickness to drying method

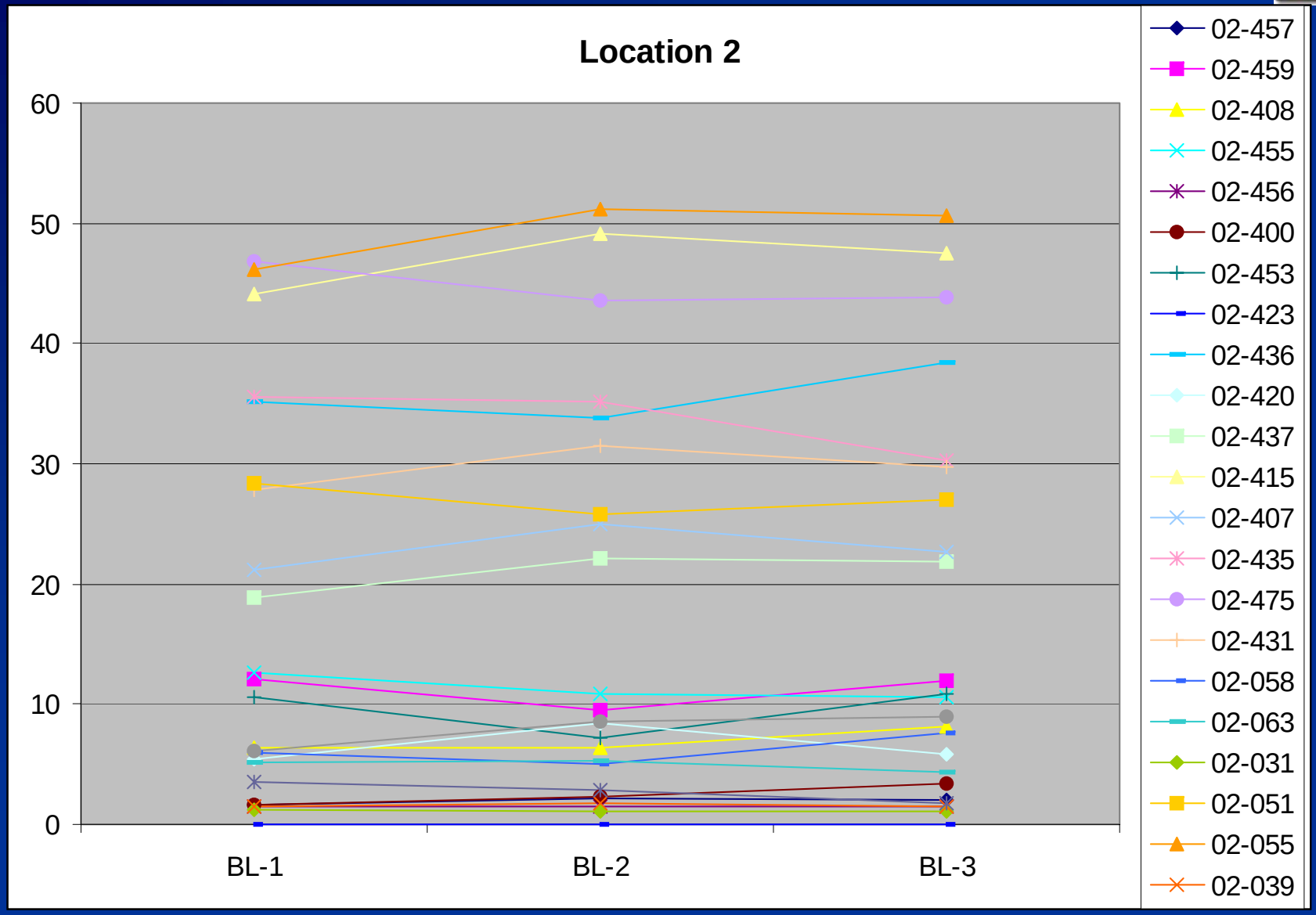
Developer Chamber Characterization

- Utilized standard sample process with baseline established using dip/drag method of developer application
- Evaluated four developer chambers and wand application methods at two locations
- Same penetrant process (level 4 PE) and chemistry use through out

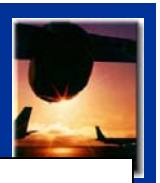
Baseline Characterization

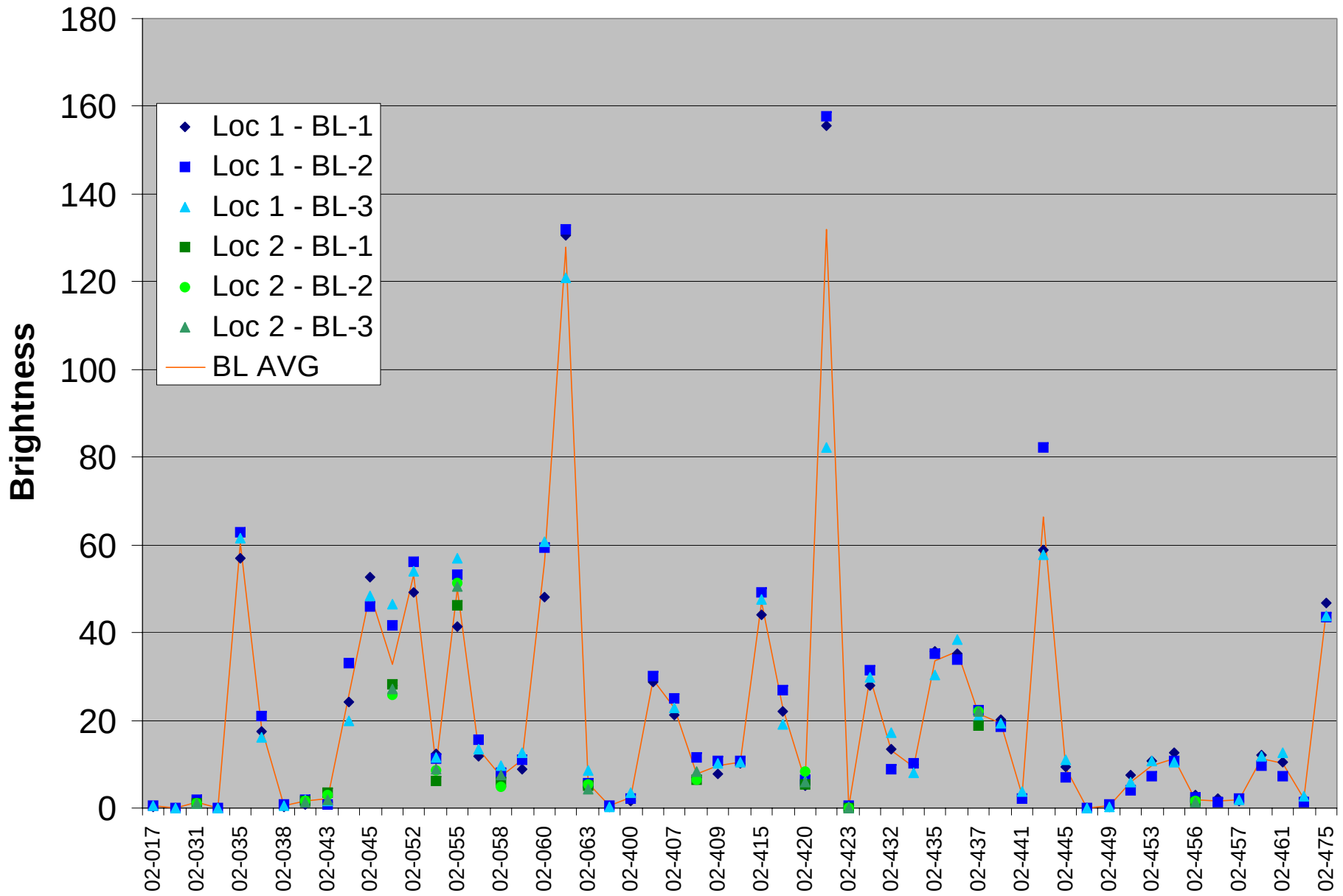


Baseline Characterization

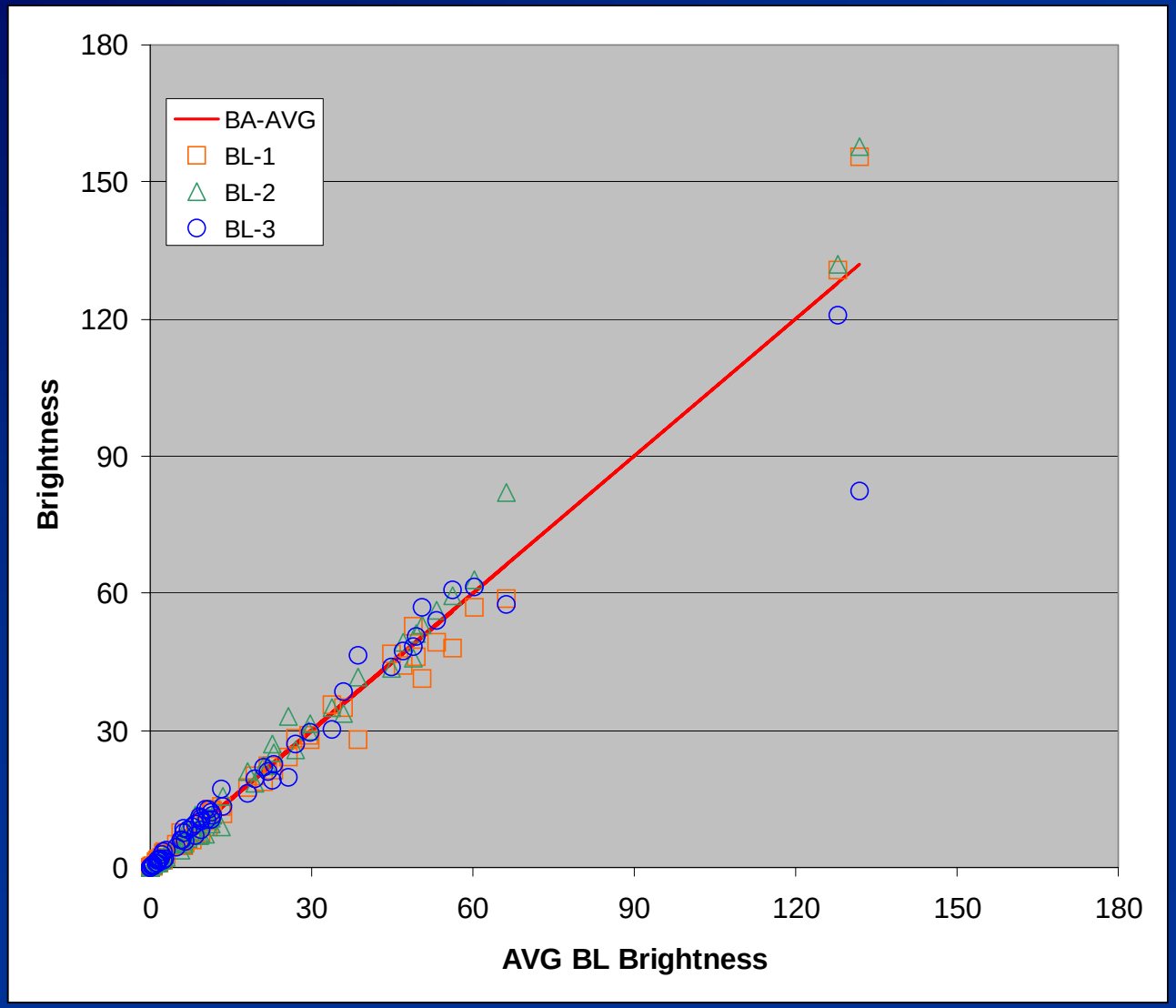


Baseline Characterization





Baseline Characterization



Baseline Characterization

- Samples gave repeatable performance
- Useful for measurement of changes in brightness as function of developer application methods

Developer Application Methods

- Chamber a – Developer applied through linear diffuser located at top and bottom of chamber
- Chamber b – Developer applied from circular diffuser located at top and bottom of chamber
- Chamber c – Developer applied from circular diffuser located at top of chamber
- Chamber d – Developer applied from two nozzle diffusers located at bottom of chamber
- Manual spray – Low pressure, high volume manual application
- Dip/drag – Hand application of individual samples. Used for baseline measurements.

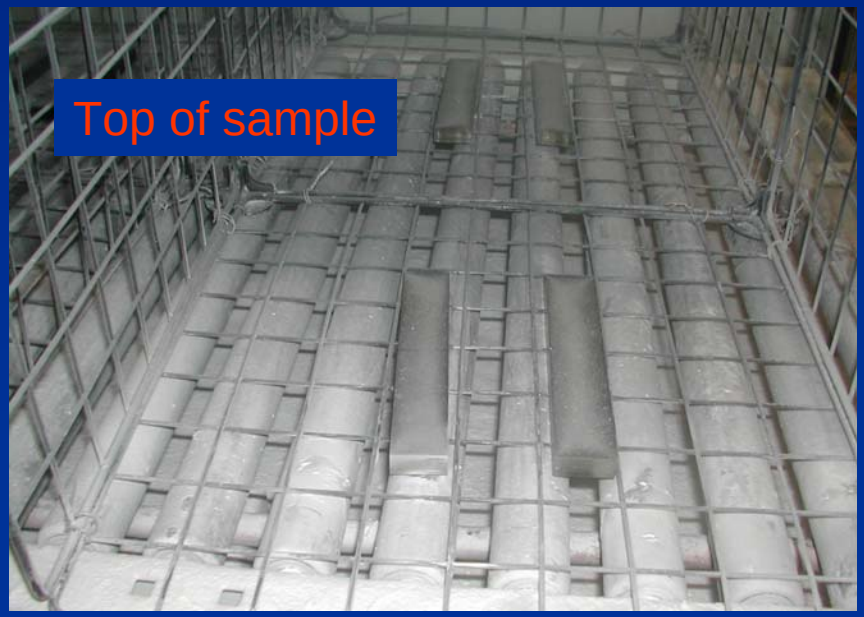
Chamber A Characterization

Chamber A Characterization

- Developer applied through linear diffusers located at top and bottom of chamber
- Developer time of 20 or 60 sec followed by 2 min dwell, 1 min evacuation and removal at 5 min
- Samples placed with cracks in up or down position

Linear diffusers

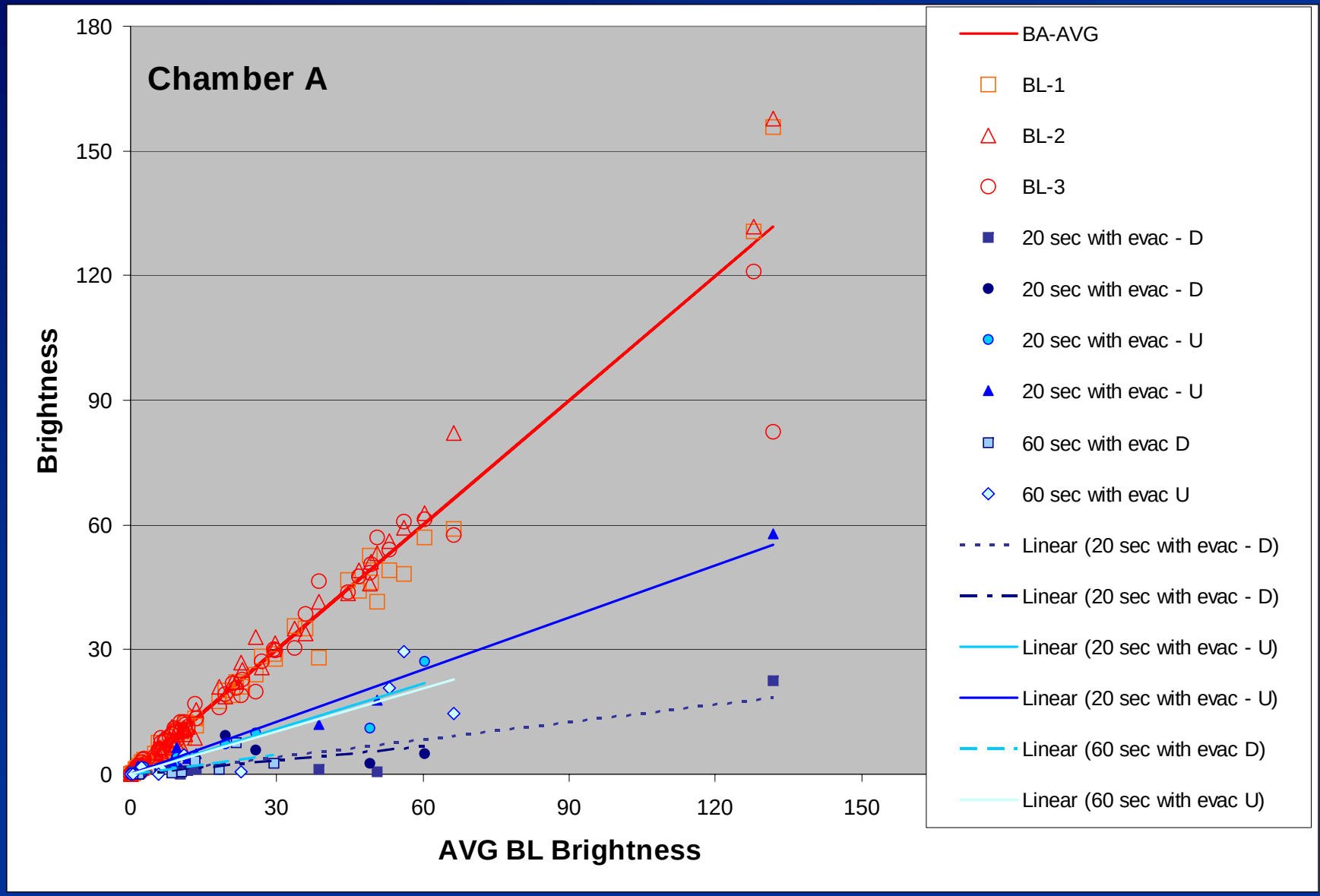
Samples prior to removal



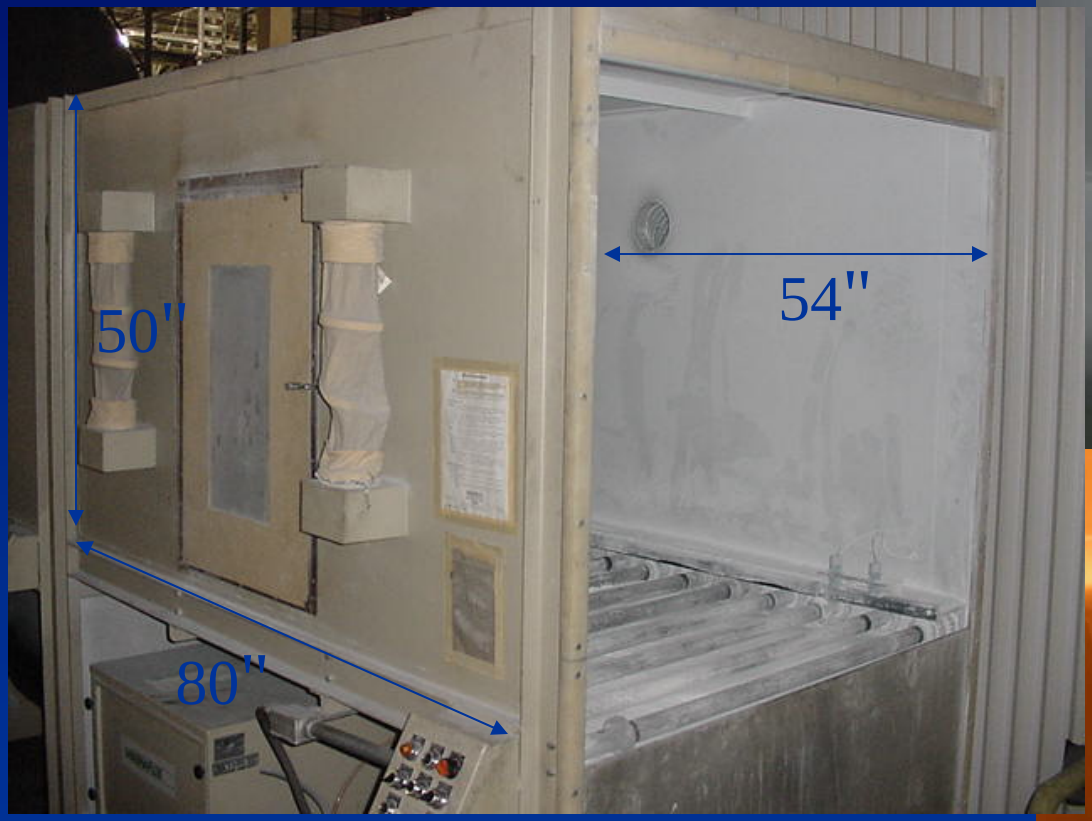
Chamber A Characterization

- New developer added to pot prior to study
- Run 8 – Samples placed in up or down position. Developer application for 20 sec.
- Run 10 – Samples in up or down position. Developer application for 60 sec.
- Run 12 – Samples placed in down or up (opposite of Run 8) position. Developer application for 20 sec.

Chamber A Characterization



Chamber B Characterization



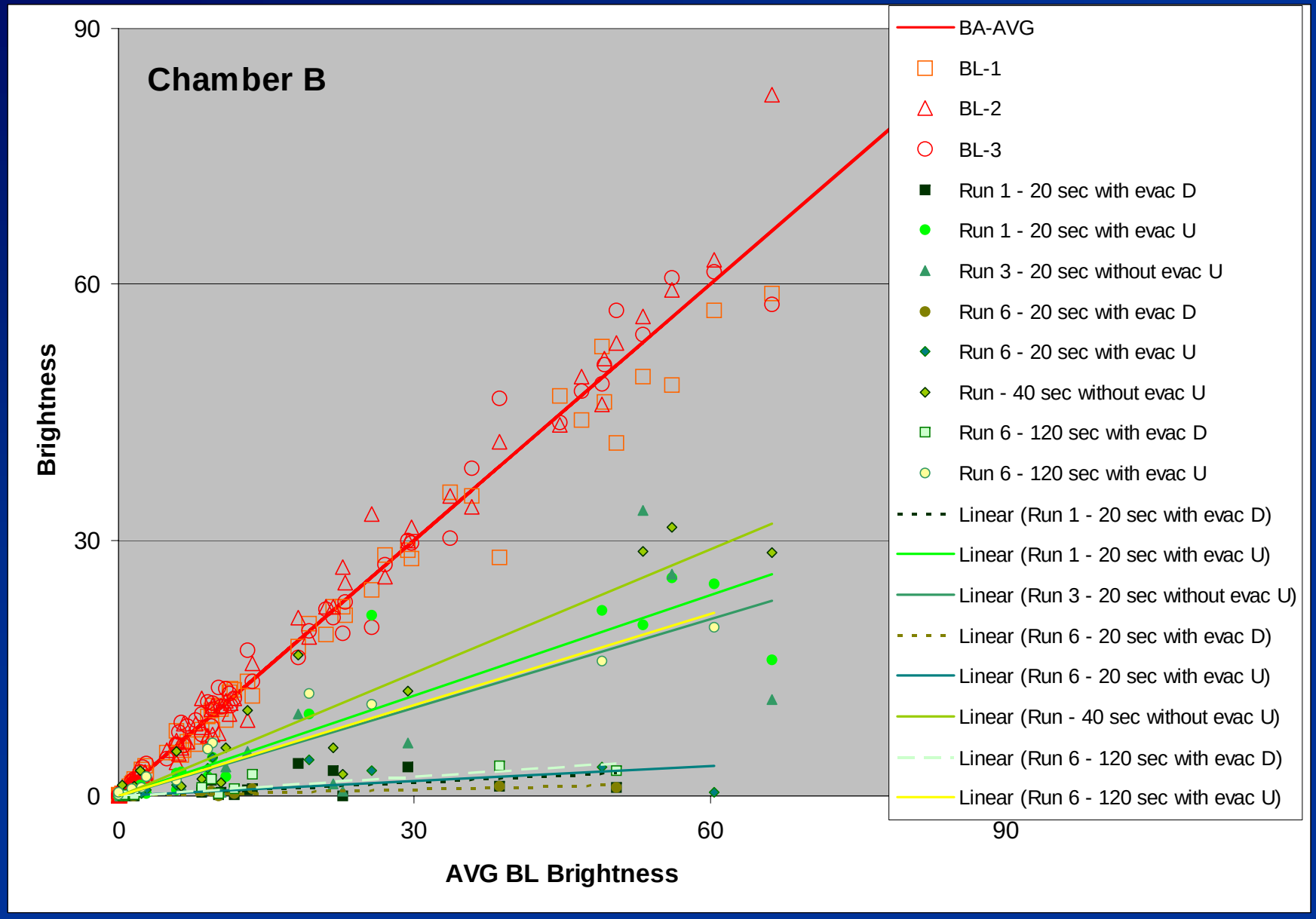
Chamber B Characterization

- Pressure pot with new developer added prior to study
- Circular diffusers at top and bottom of chamber
- Evacuation in upper, center region of chamber

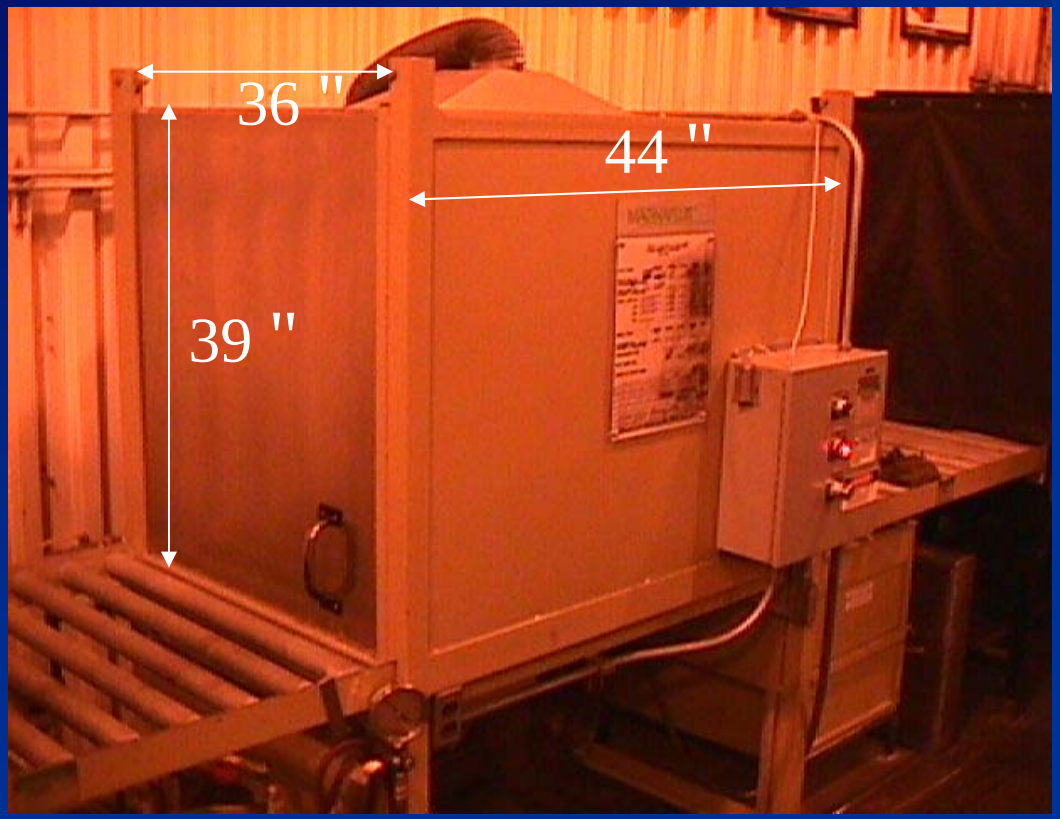
Chamber B Characterization

- 20 sec of developer application followed by 3.5 min dwell and 2 min evacuation
- Other runs included:
  - 20 sec without evac
  - 40 sec without evac
  - 120 sec with evac

Chamber B Characterization

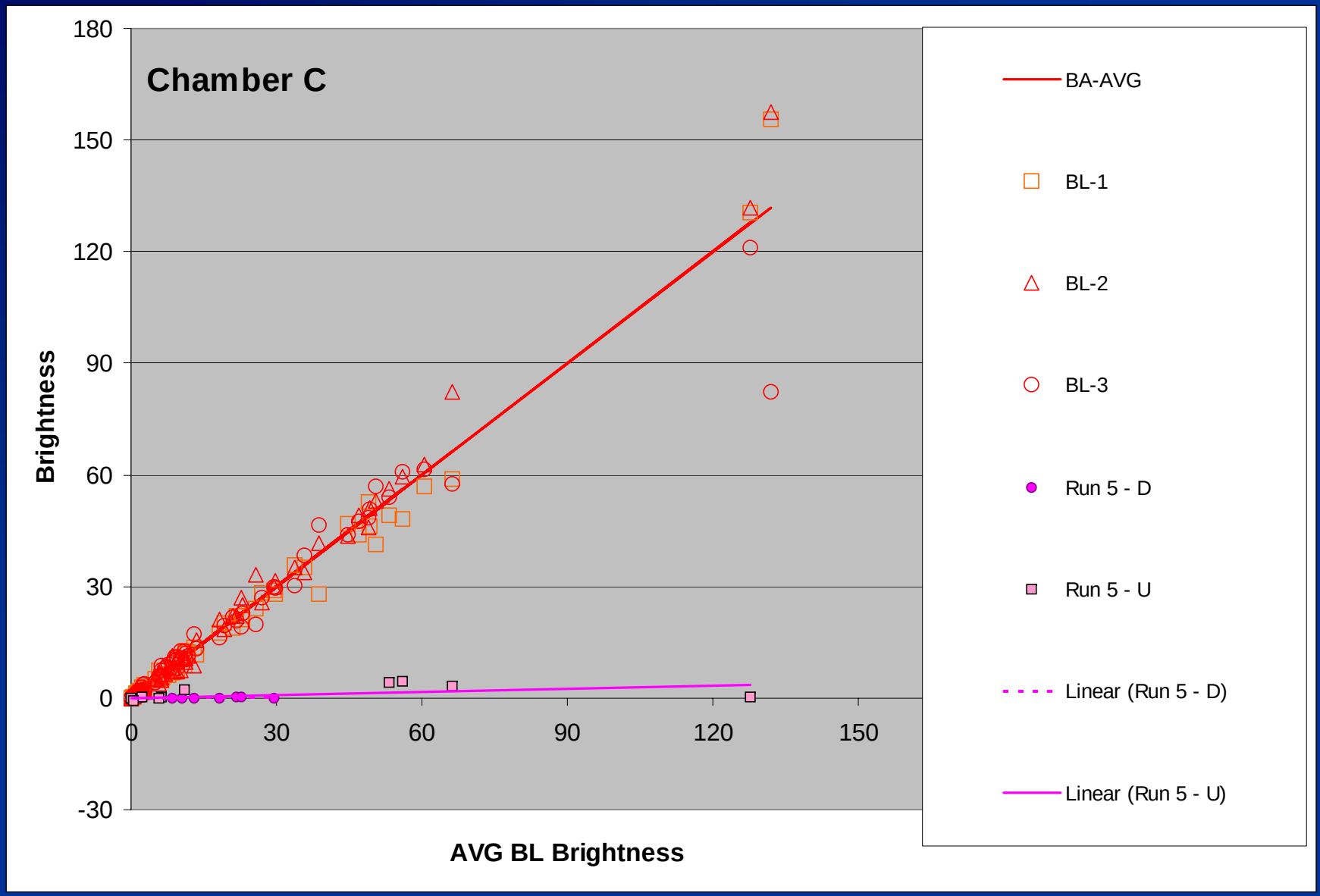


Chamber C Characterization



- Circular diffuser located in top of chamber
- 120 sec of developer followed by 110 sec dwell and evacuation of 60 sec

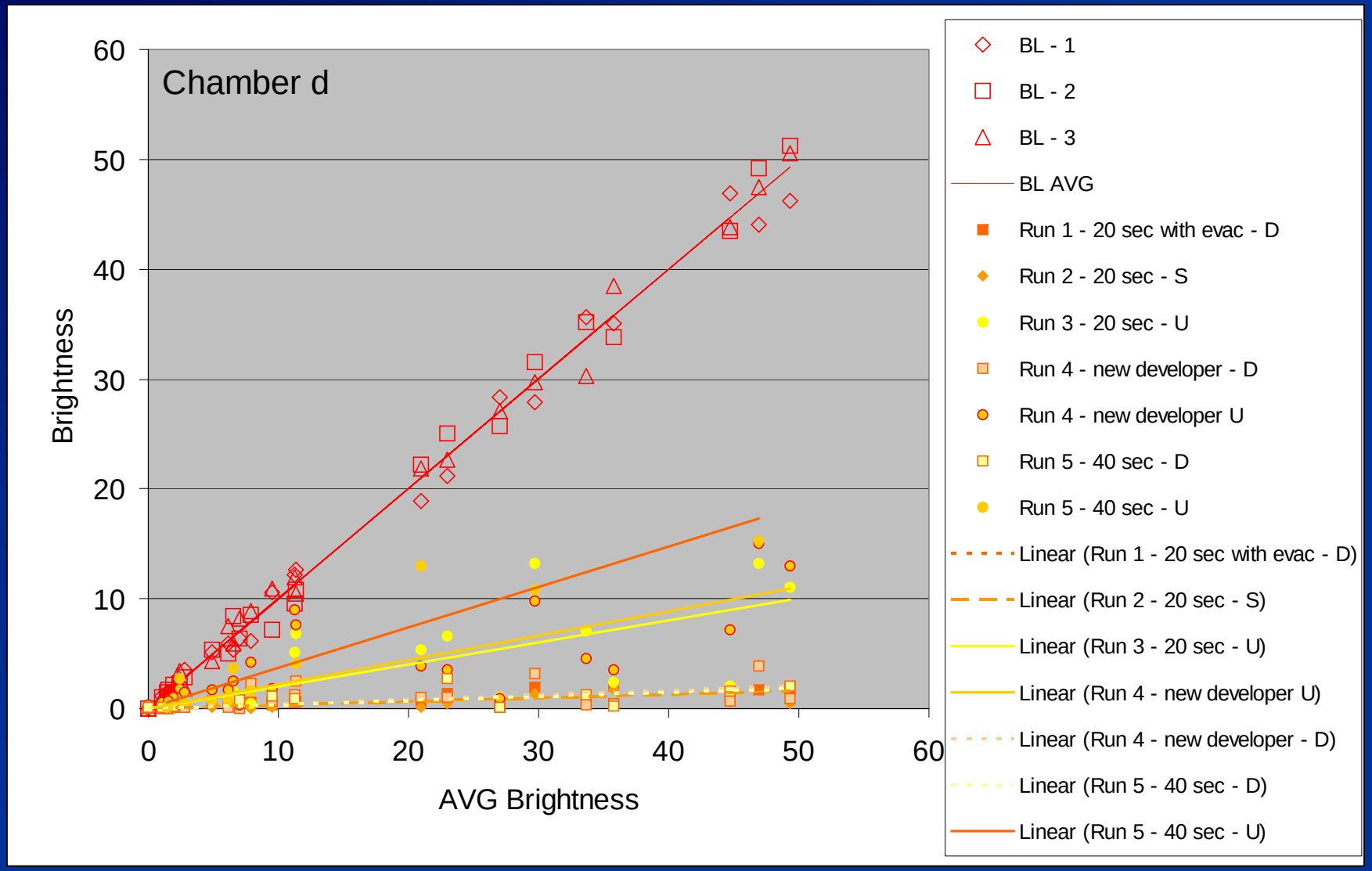
Chamber C Characterization



Chamber D Characterization

- Chamber contains two jets, at approximately ¼ and ¾ of the chamber length
- Jets located below rollers
- Typical operation of 5 sec developer application followed by 10 min dwell in chamber

Chamber D Characterization

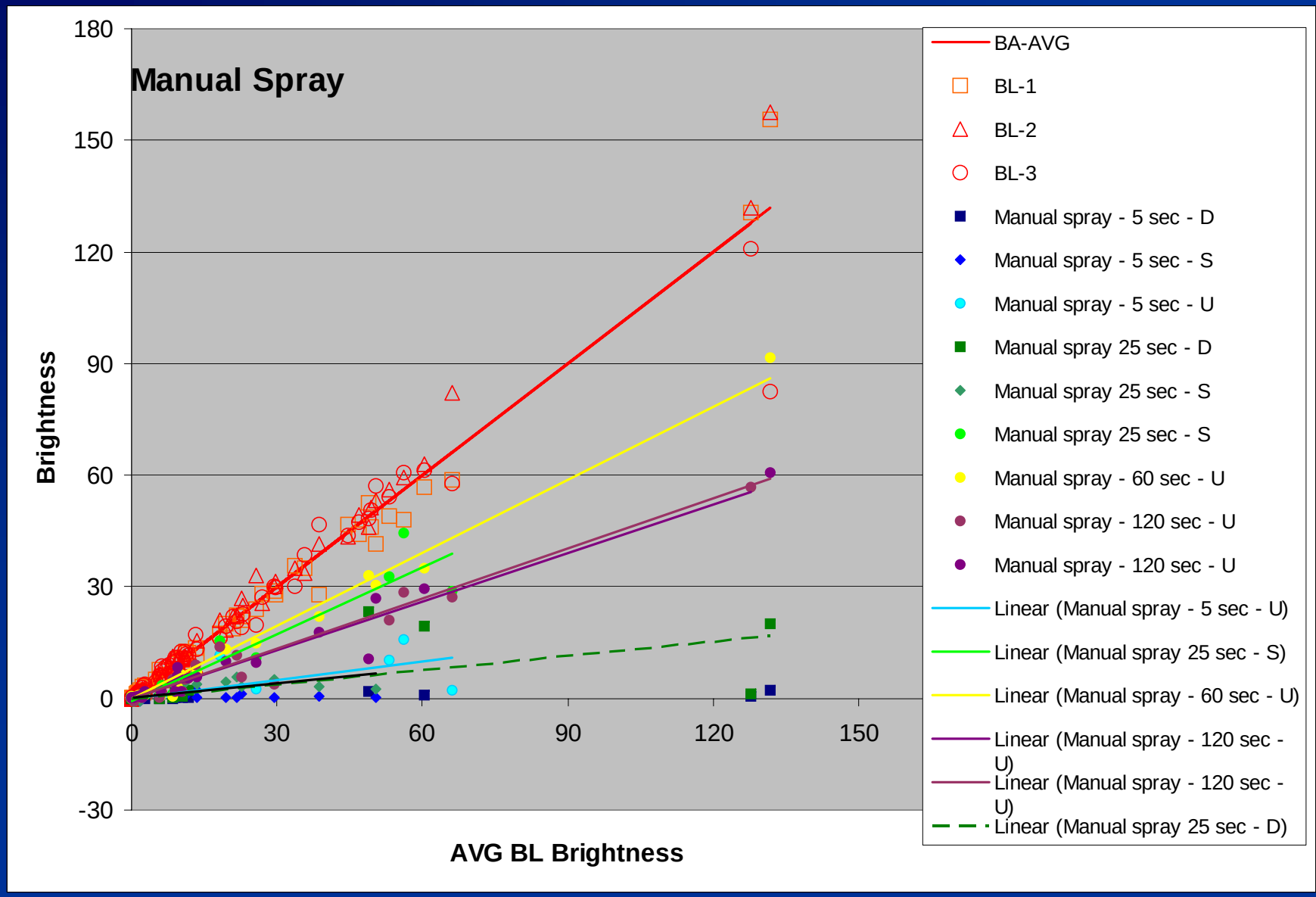


Manual Spray Application

- Low pressure, high volume spray
- 5 and 25 sec runs completed using lobster cage with cracks in D, S or U position
- 60 and 120 sec runs completed with samples all in U position

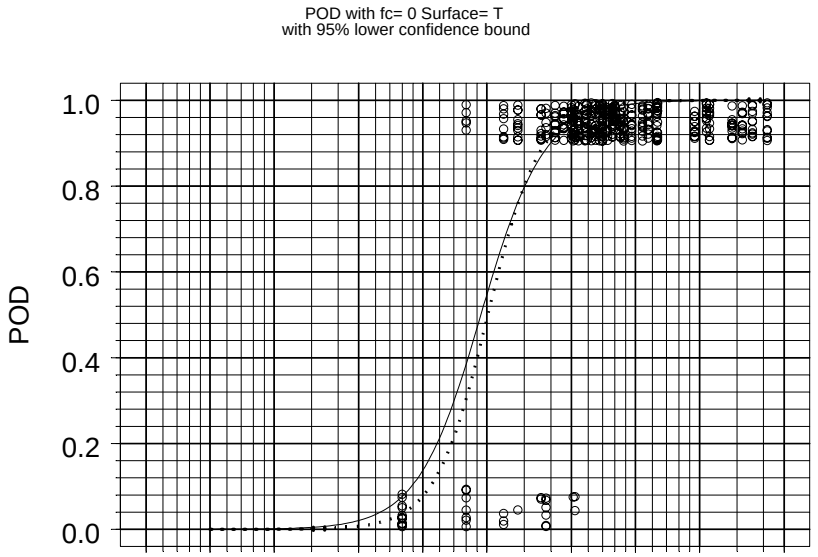
Manual Spray Application

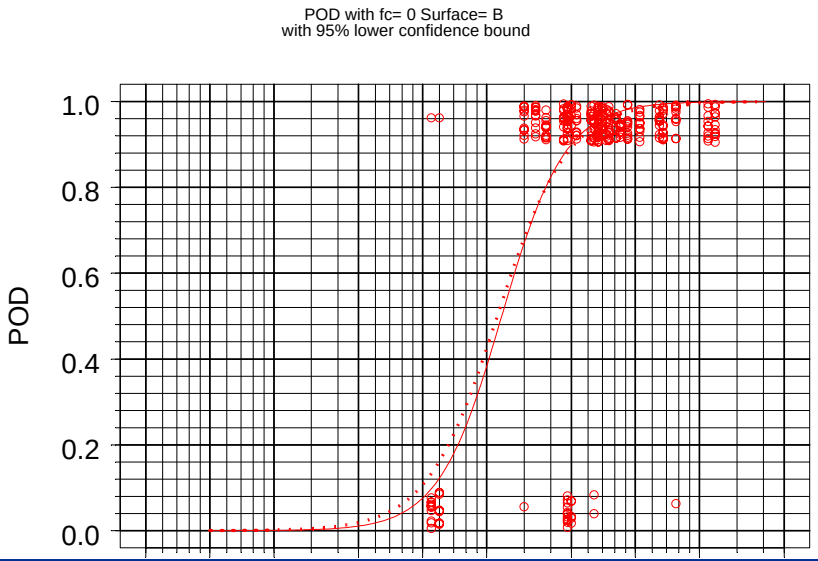
Manual Spray Application



Importance of Sample Orientation

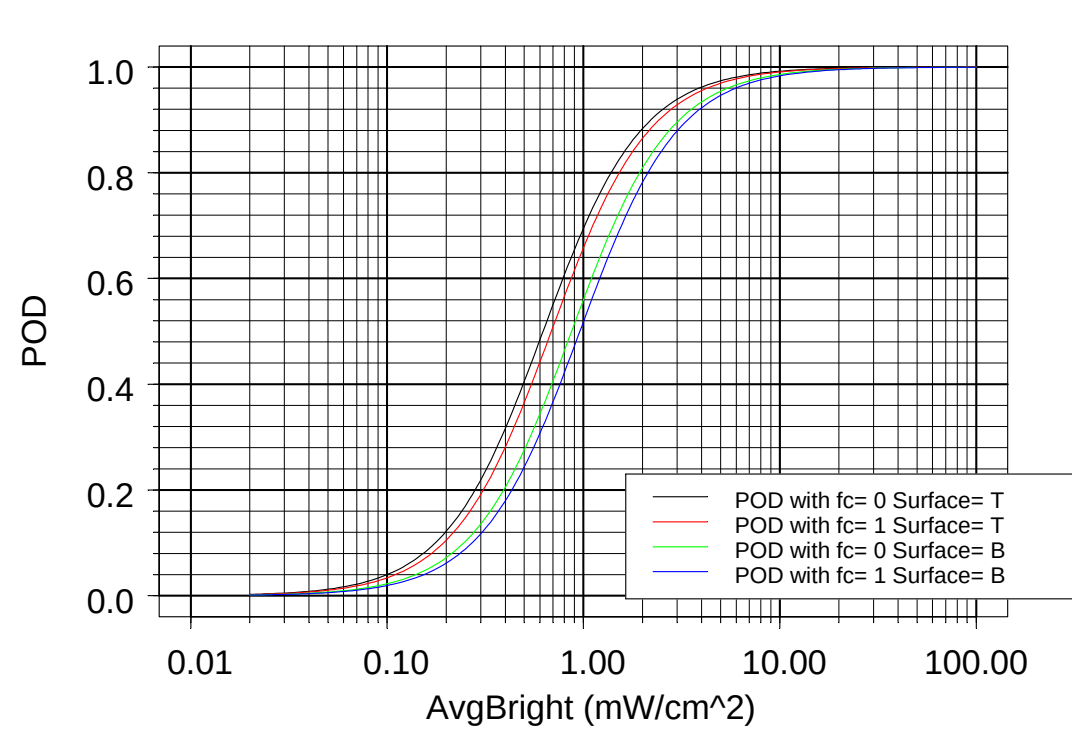
- Completed POD study which correlates brightness to detectability
- Used two sample sets, two inspectors under multiple UV intensity level, white light level combinations
- Evaluated indication location (top or bottom) of panel
- Significant differences can occur





Importance of Brightness

- POD is correlated to brightness
- Increasing intensity from 1000 to 3000 did slightly improve POD but is within statistical error
- Increasing whitelight contamination led to reductions in POD 90/95 point
- Additional studies planned to determine when transition in detectability occurs



Preliminary Conclusions

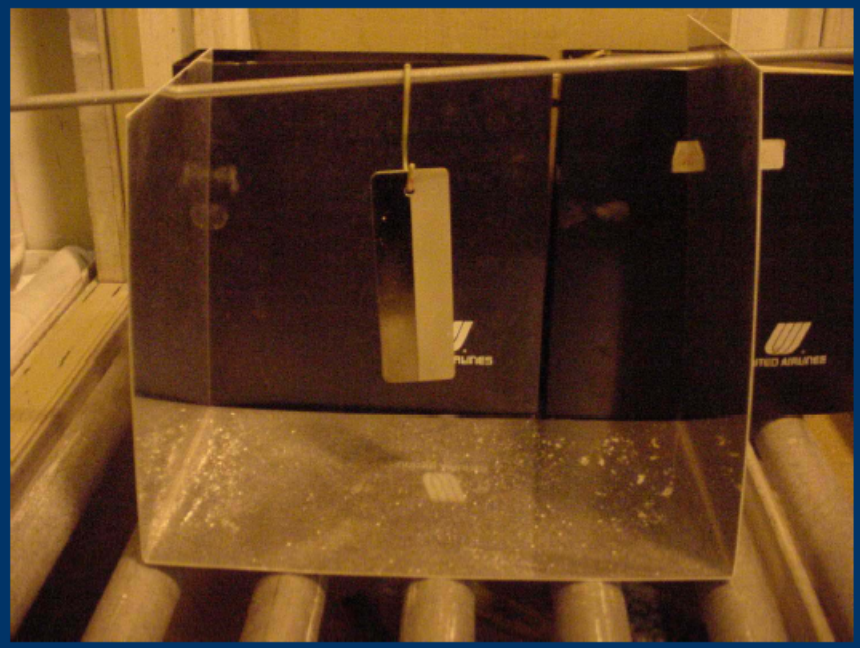
- Developer application by dip/drag yields brighter indication than with any of the developer chamber or wand application methods
- No indications were “lost” but detectability improves with brightness – optimal process will yield bright indications
- Improved understanding of the relationship between brightness and detectability would be beneficial
- Characterization method for typical chamber is needed

Characterization Methods

Ref: Tom Dreher ATA NDT Forum, 2004

- Utilized “worst case” configuration for the sample for comparison to dip/drag
- Digital camera used to record indication response for comparison

Vertical Run Set-up



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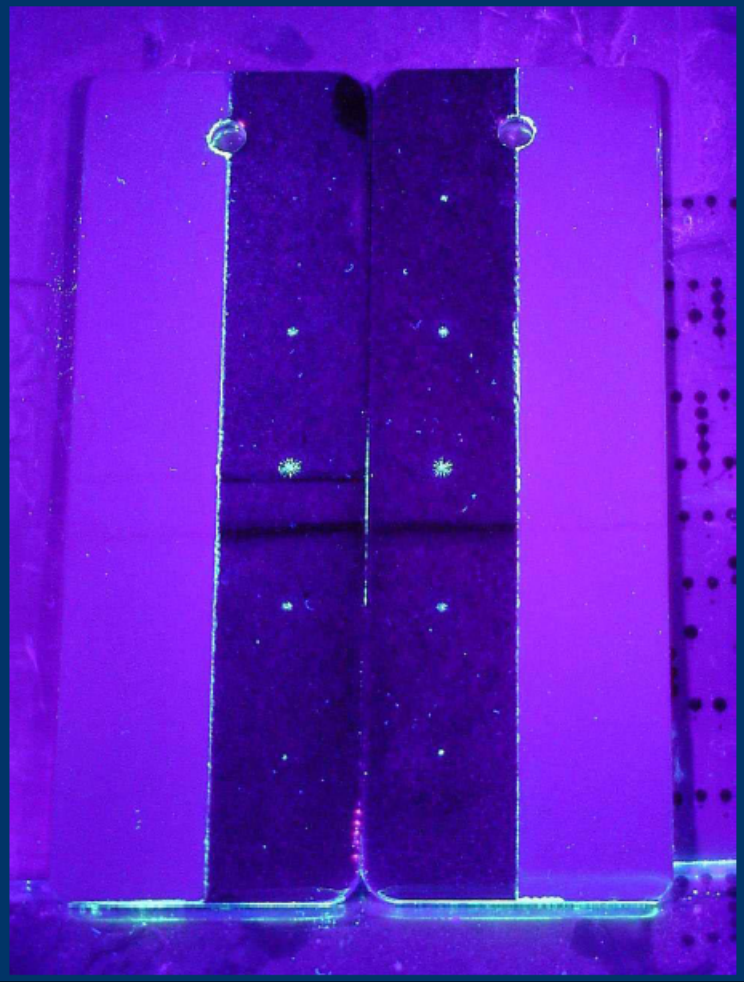
Characterization Methods

Ref: Tom Dreher ATA NDT Forum, 2004

KDS Panel 1st Baseline

Horizontal Cabinet Run



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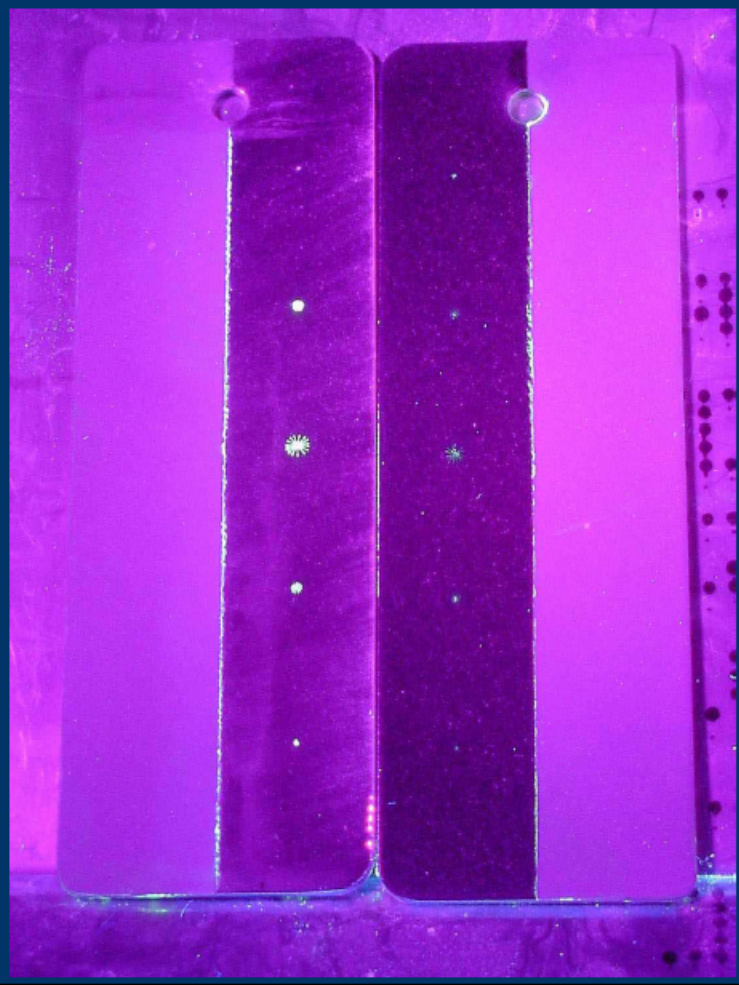
Dip vs. Cabinet 1

After Vertical Run



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Lessons Learned – So Far

- Developer application is critical to overall FPI performance
- Sample orientation matters
  - Avoid barriers that prevent direct application of the developer
  - Ensure chamber configuration or part handling fixtures (rollers, baskets, etc.) don't hamper application
  - No metal-to-metal contact
  - May require multiple trips through the chamber to ensure adequate coverage on all surfaces
- Additional studies underway to understand relationship between developer coverage and indication response