



CASR

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Study of Thermal Mass Effects on Drying Methods in Preparation for Fluorescent Penetrant Inspection

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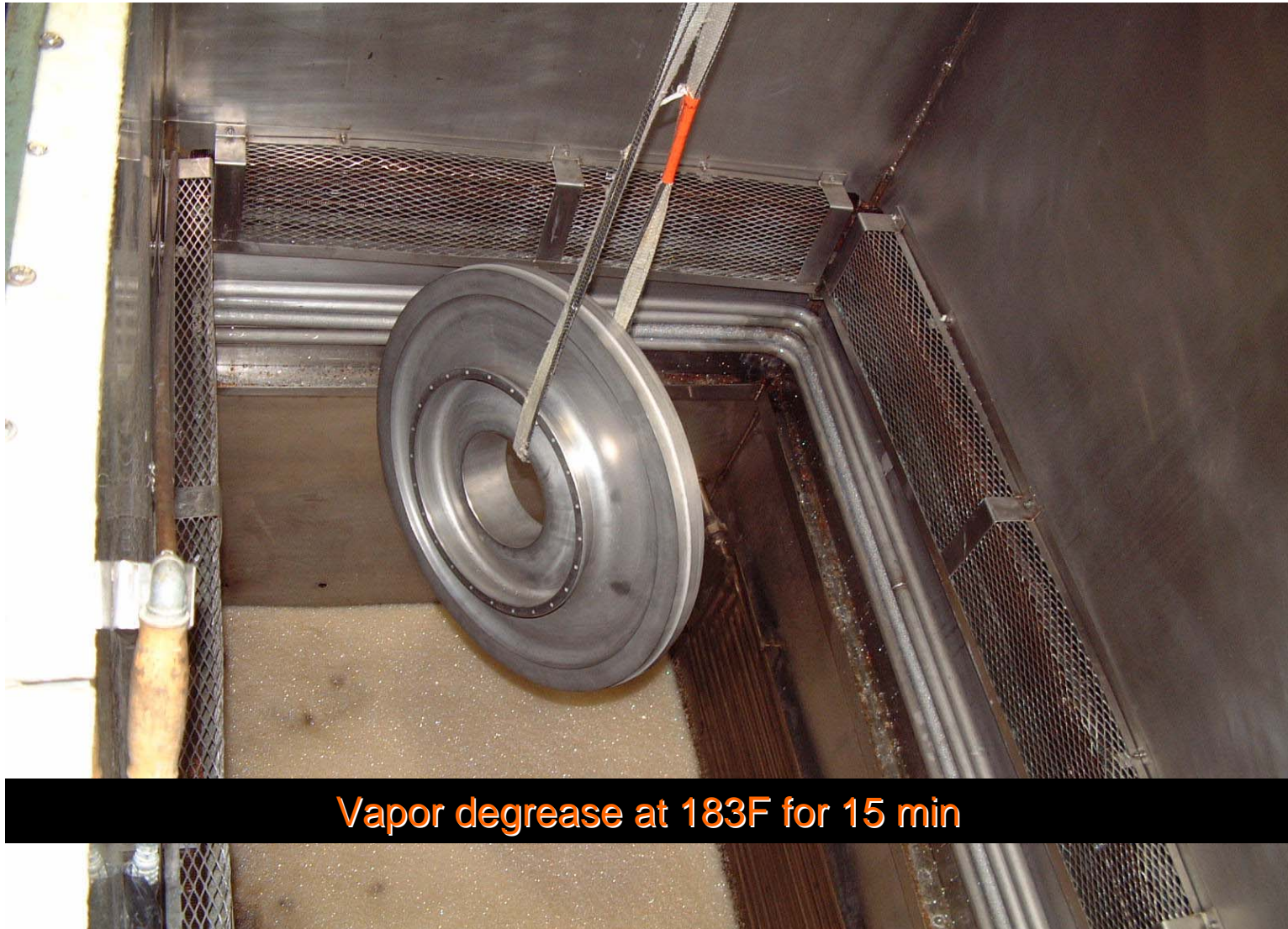


Fluorescent penetrant inspection is widely used to inspect critical rotating components for the presence of surface breaking defects. Typically these components are made of titanium or nickel alloys and can weigh in excess of several hundred pounds. In preparation for FPI, the parts are cleaned to remove contamination and soil from inservice use. The final step in the cleaning process and prior to FPI, is drying. Two methods are commonly used to dry the part, flash dry and oven dry. Prior studies were completed to assess potential differences between the two drying methods in regards to their effectiveness in preparation for FPI and reported at QNDE. However, the earlier studies were limited to coupons and thus, did not take into consideration potential thermal mass effects. The latest study used a 300 pound nickel engine disk which contained fatigue cracks generated during spin pit testing.



- 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





Vapor degrease at 183F for 15 min



Oven dry for 30 min at 225 or 250F



Flash dry for 15 min (150 – 185F)



Oven dry temperature measurement



Flash dry temperature measurement



Level 4, PE Penetrant, 20 min dwell



Spray rinse, 60 sec



Emulsification with agitation, 120 sec



Final spray rinse, 60 sec



Pre-developer, oven dry at 160F for 20 min

Developer application in dust chamber



Hand application by tossing of dry powder



Removal of excess developer powder



Wand application at 3" distance



Wand application at 3" distance



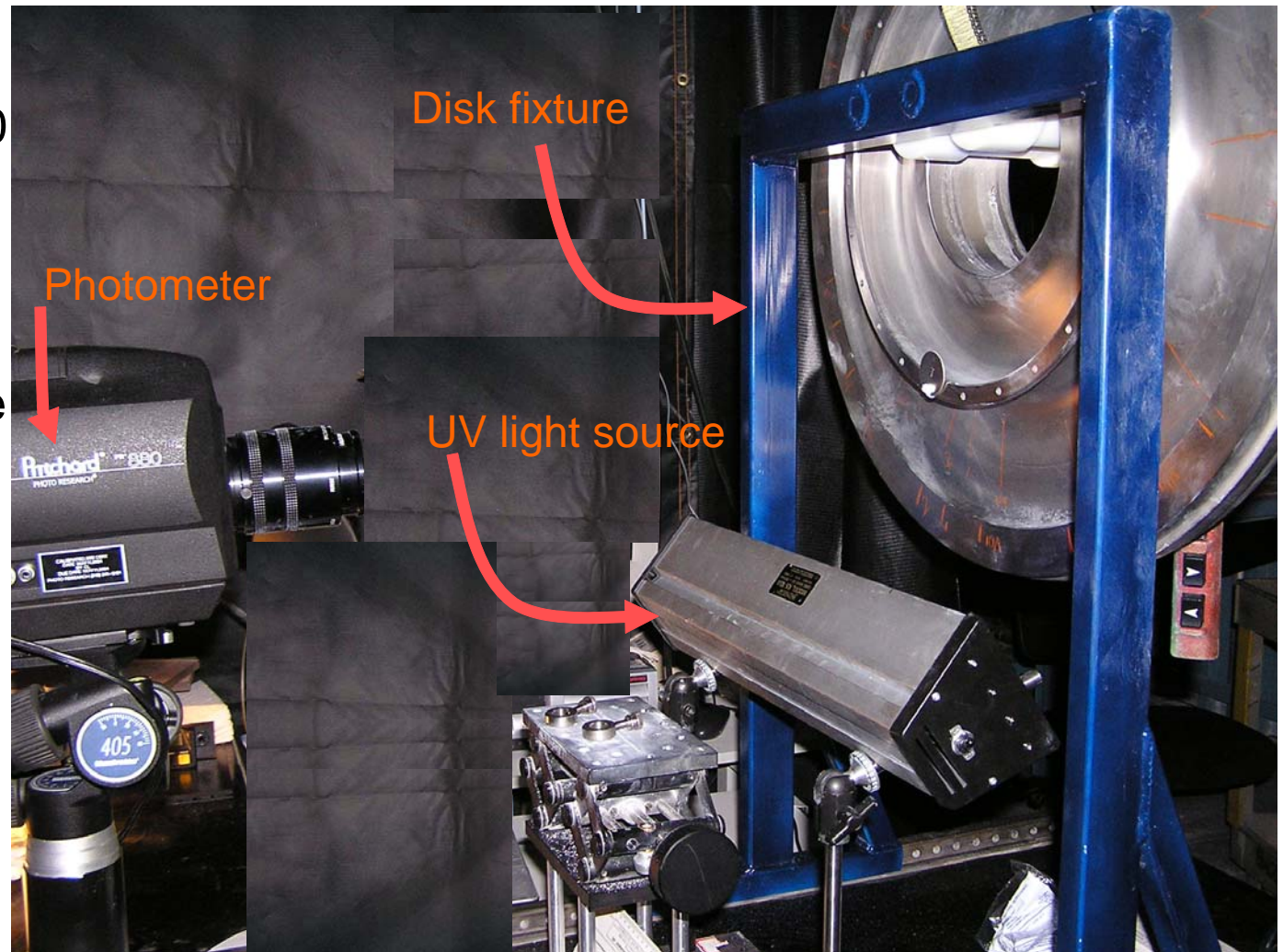
Bulb application of dry powder developer



Dry developer applied with force



- Brightness measurements made with Photo Research PR-880 photometer
- UVP XX-BLB 17" fluorescent UVA source with $850\mu\text{W}/\text{cm}^2$ at the part surface
- Fixtures used to maintain disk position
- Geared tripod head used to manipulate photometer position

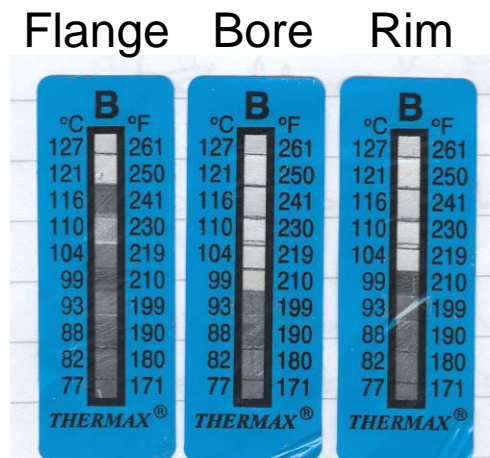
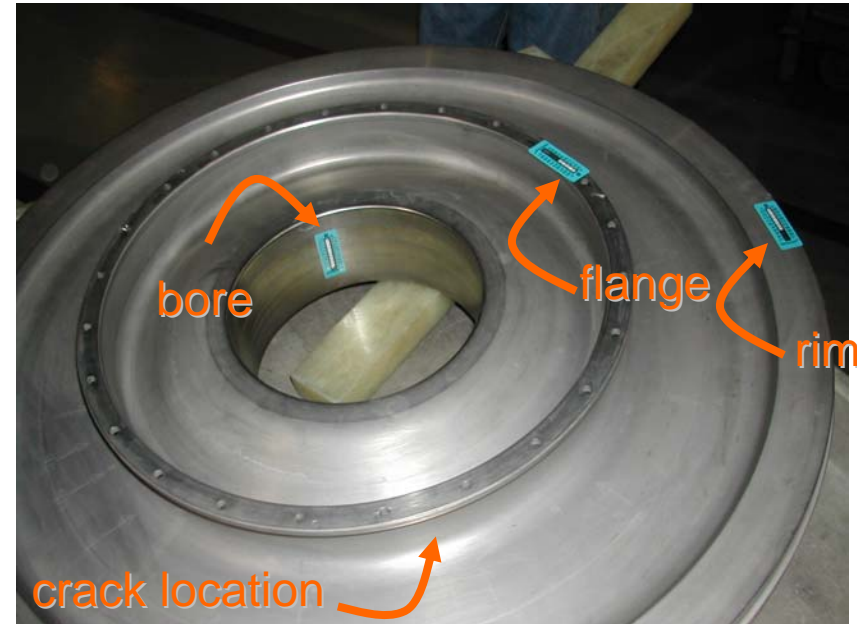


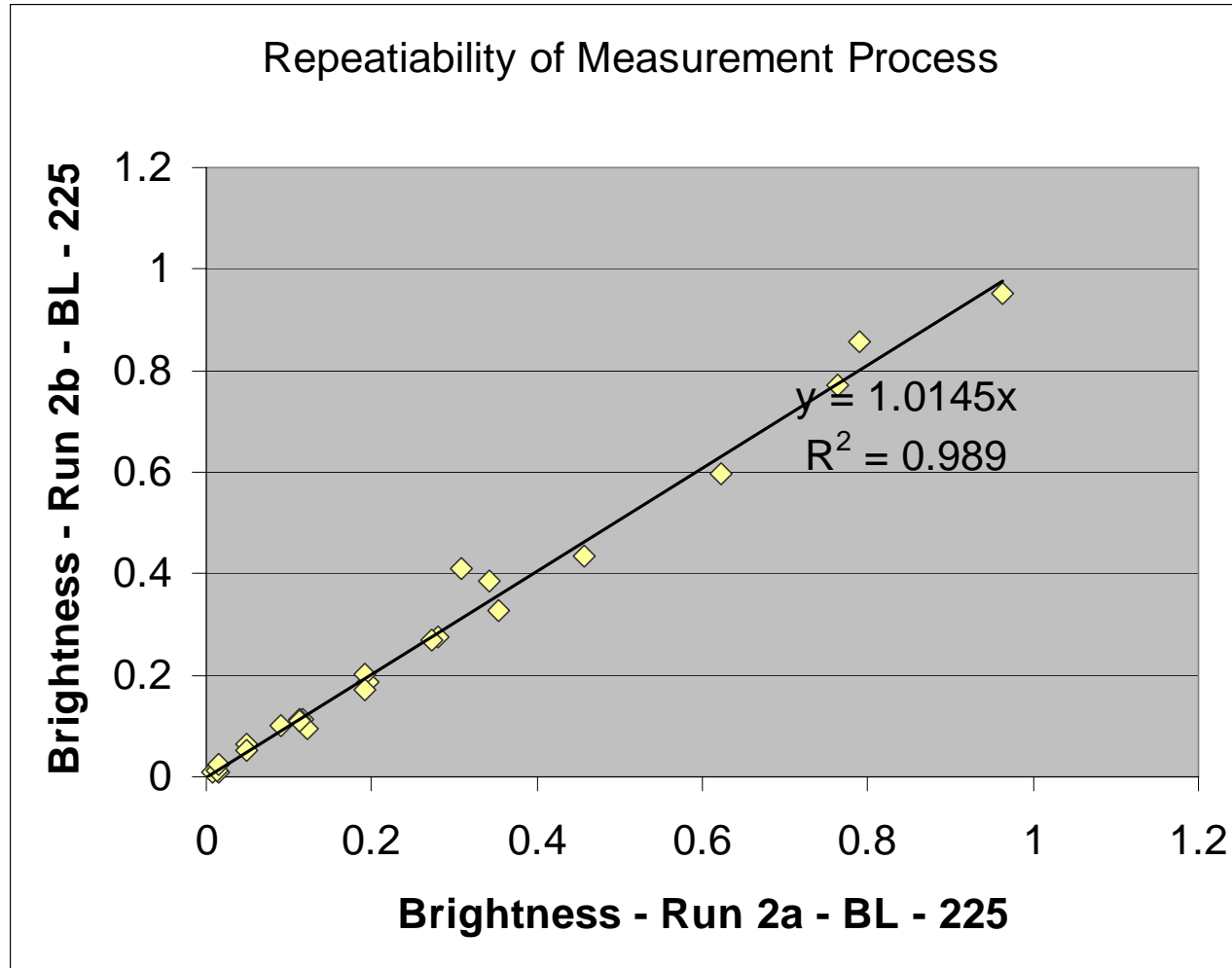


- Vapor degrease 5 mins @ 183F (This increased to default of 20 mins due to persistent FPI indications).
- Oven dry @ 225F for 30 mins
- Cool to 104F (forced air cooled using fan)
- Level 4, PE penetrant (ZL-37), dipped and dwelled for 20 mins
- Wash 60 seconds
- Emulsify using ZR-10B with agitation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

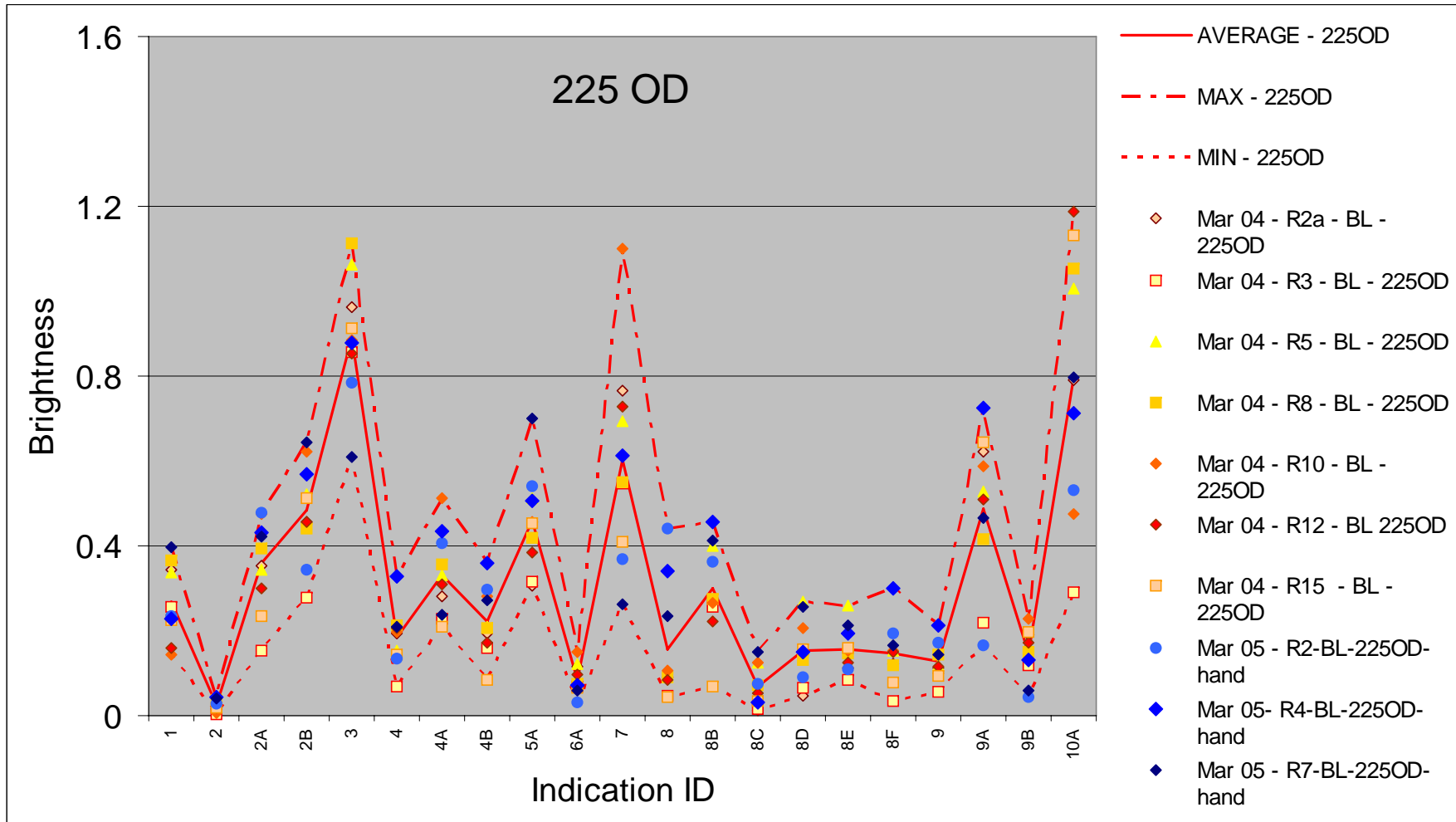


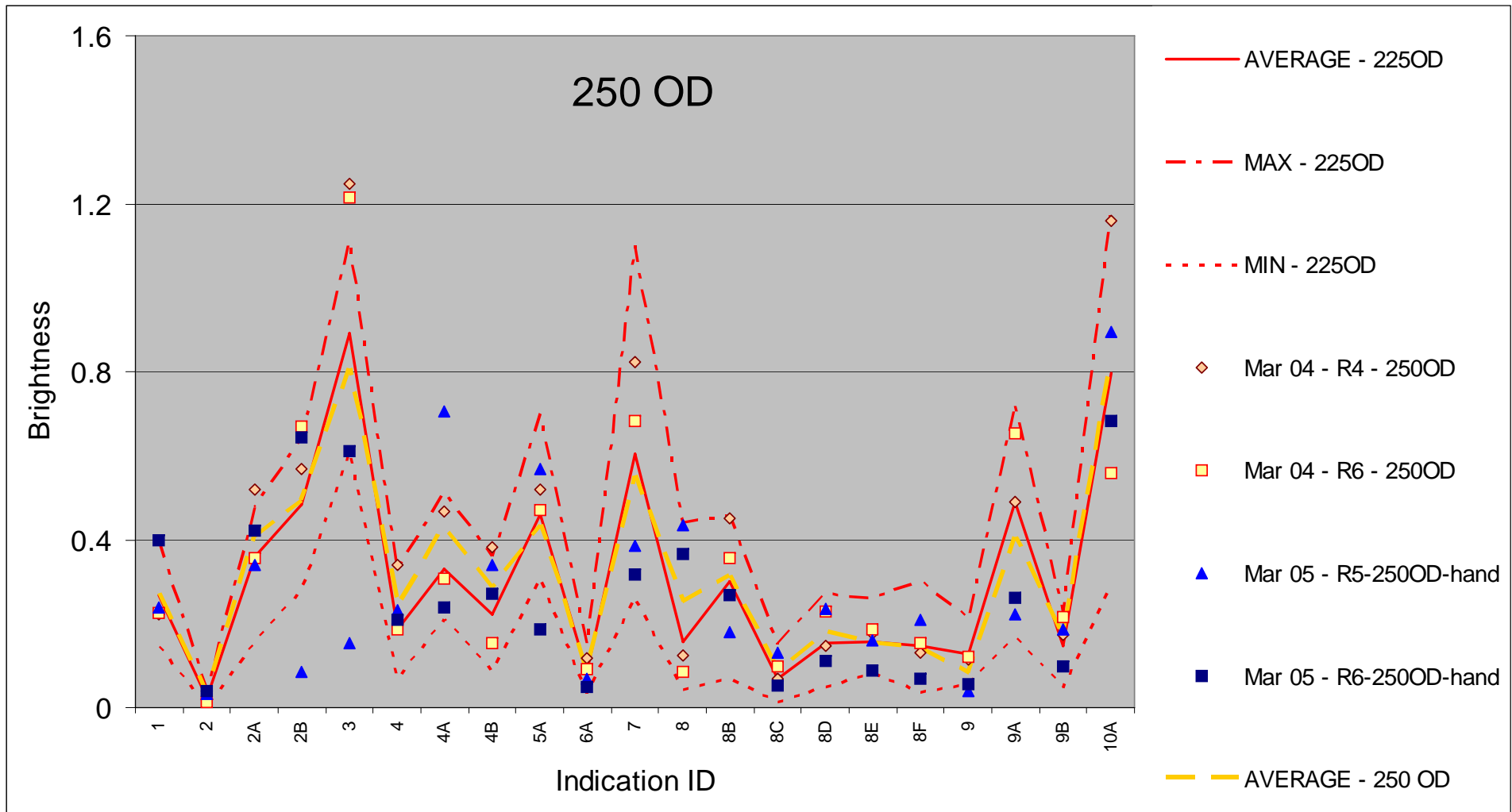
- Temperature gages used to determine variation with part geometry
- Order of increasing temperature:
 - Inner (bore)
 - Outer (rim)
 - Middle (flange)





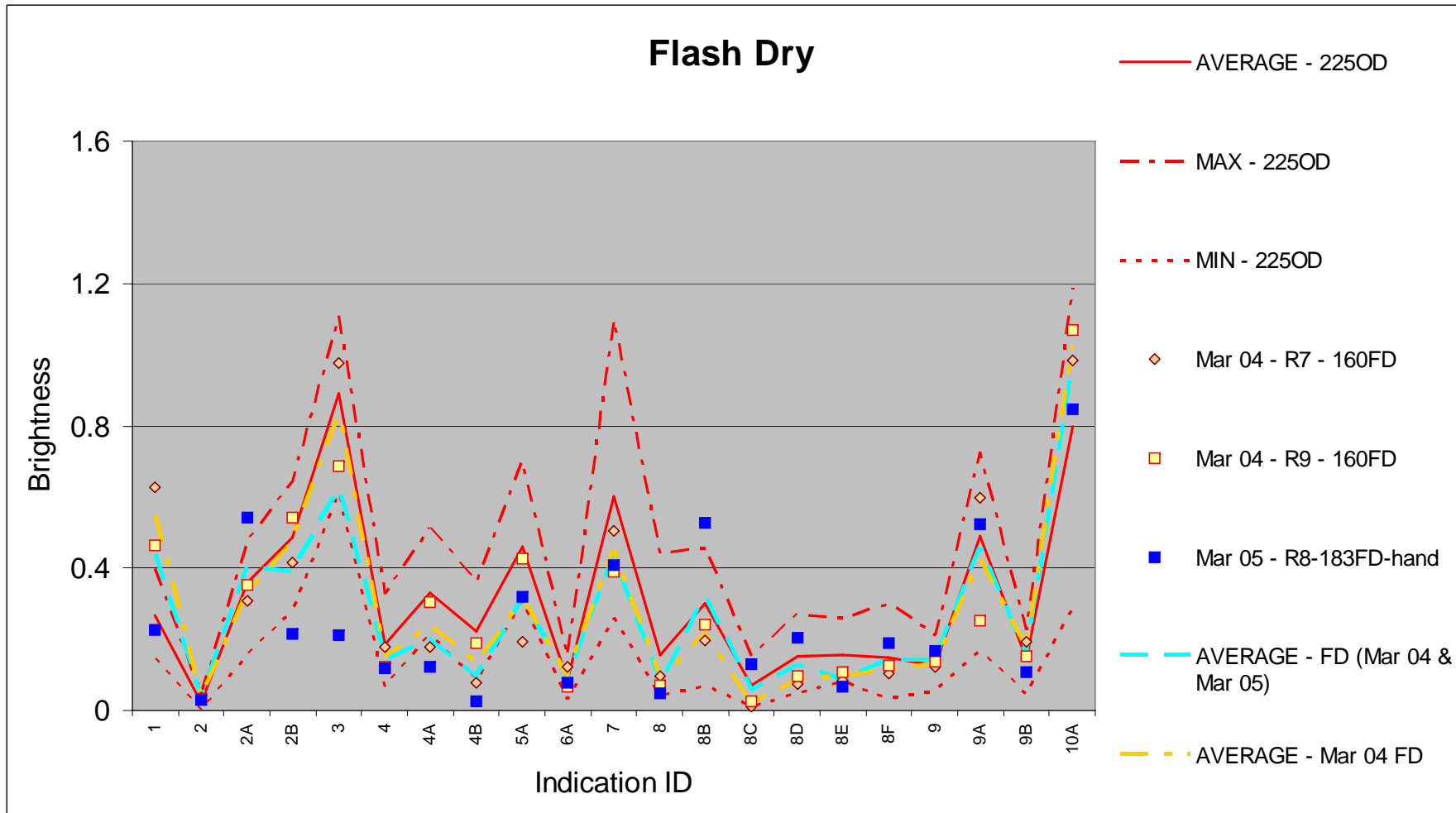
- Brightness measurements were repeated on the same process run to evaluate repeatability of the measurement process





- More variability found with 250OD than 225OD
- Average brightness essentially the same for both OD temperatures

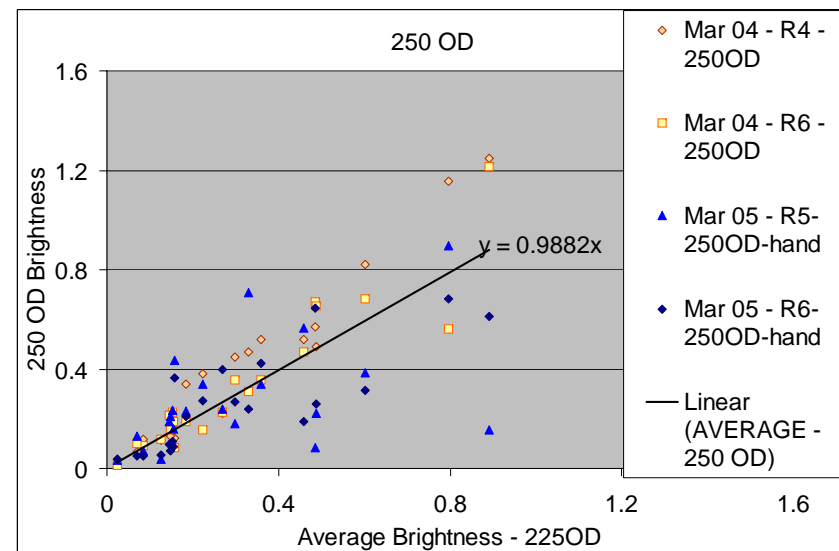
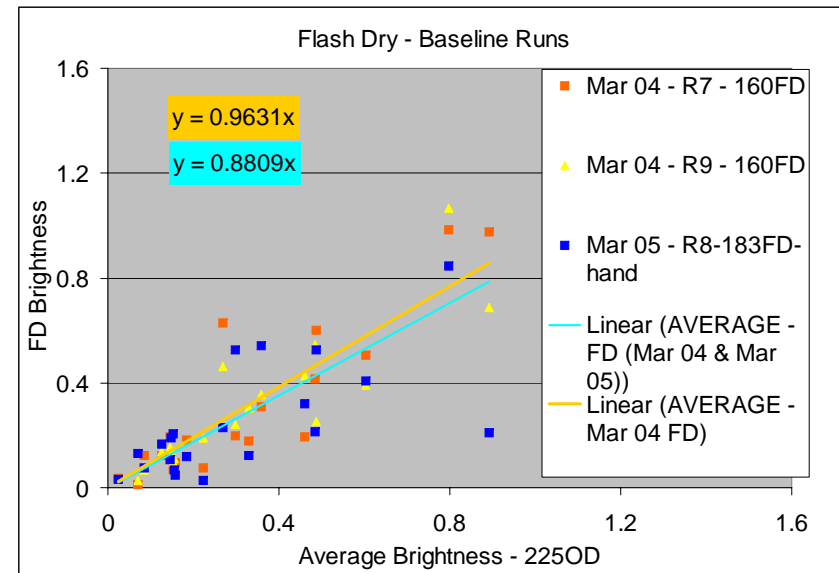
CASR Results of Flash Dry Comparison

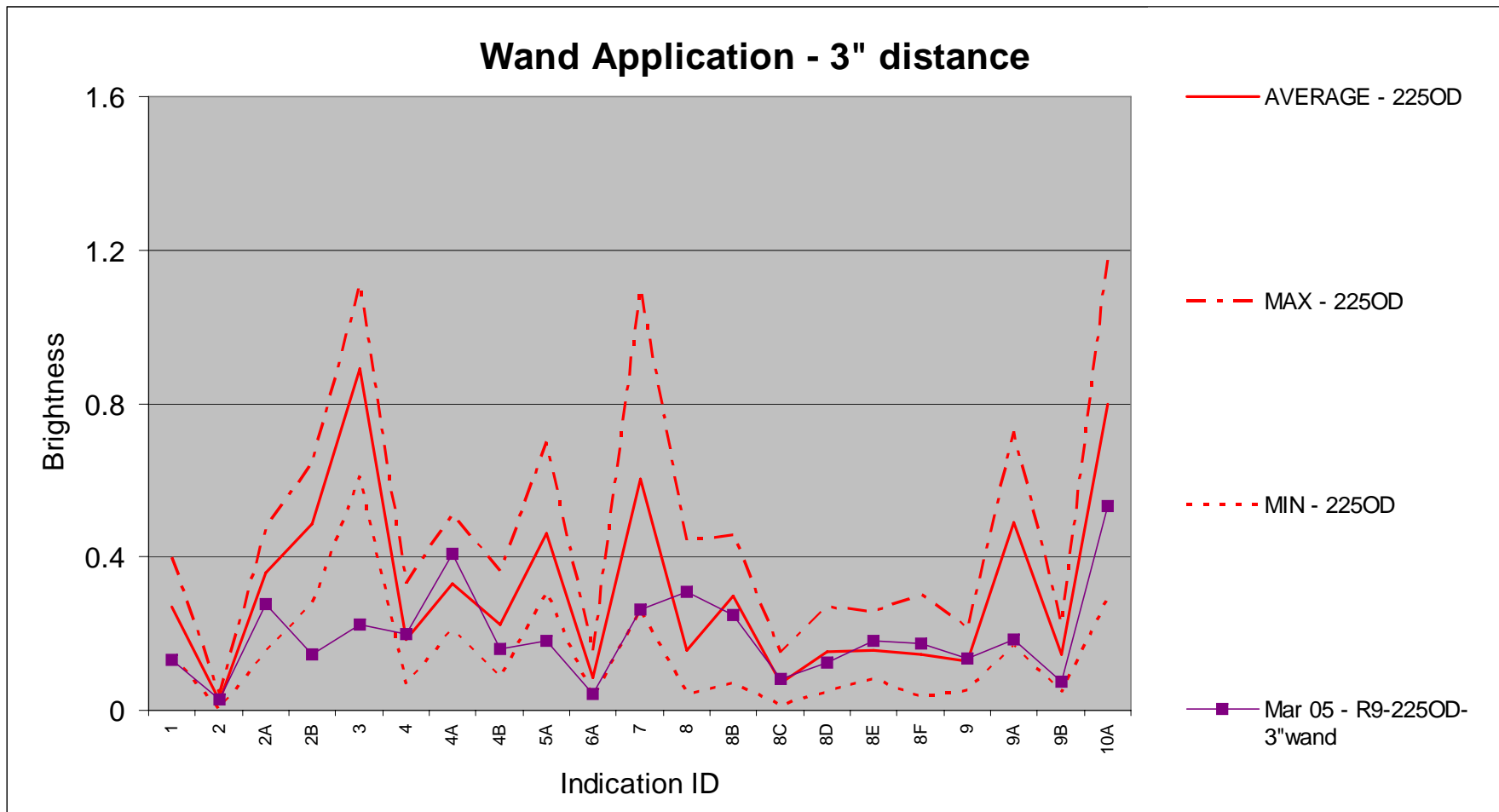


- Similar average brightness between FD and OD in Mar 04
- More variability and lower average brightness found with FD in Mar 05 than 225OD, possibly due to emulsifier effects



- Average brightness of 250 OD very similar to 225 OD (slope = 0.99)
- Average brightness of FD somewhat lower than OD when considering Mar 05 data (slope = 0.88)
- Average brightness of FD very similar to 225OD when consider only Mar 04 data (slope = 0.96)
- Difference between Mar 04 and Mar 05 could be related to emulsifier contamination
- Statistical significance being assessed

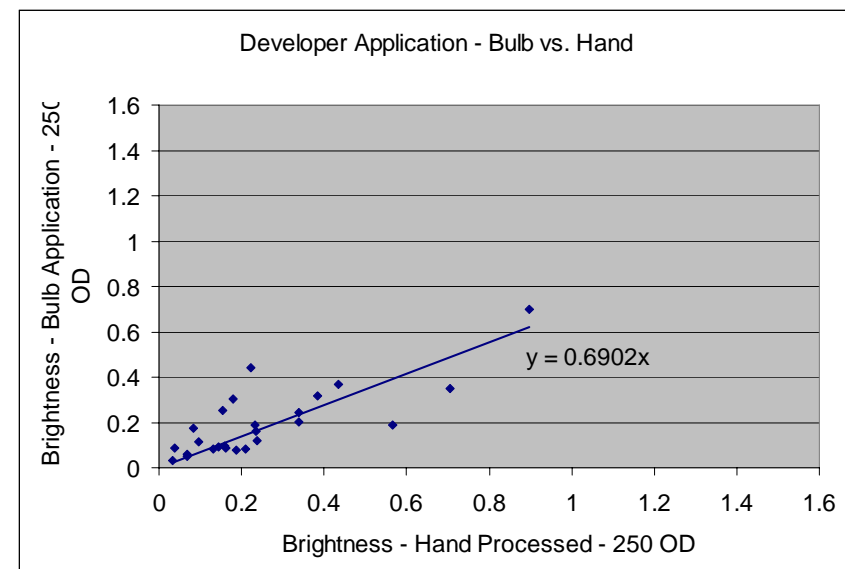
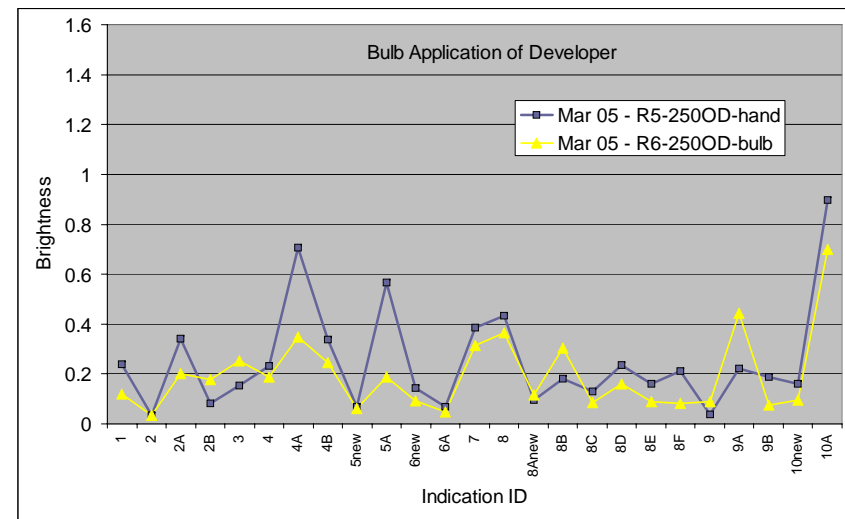


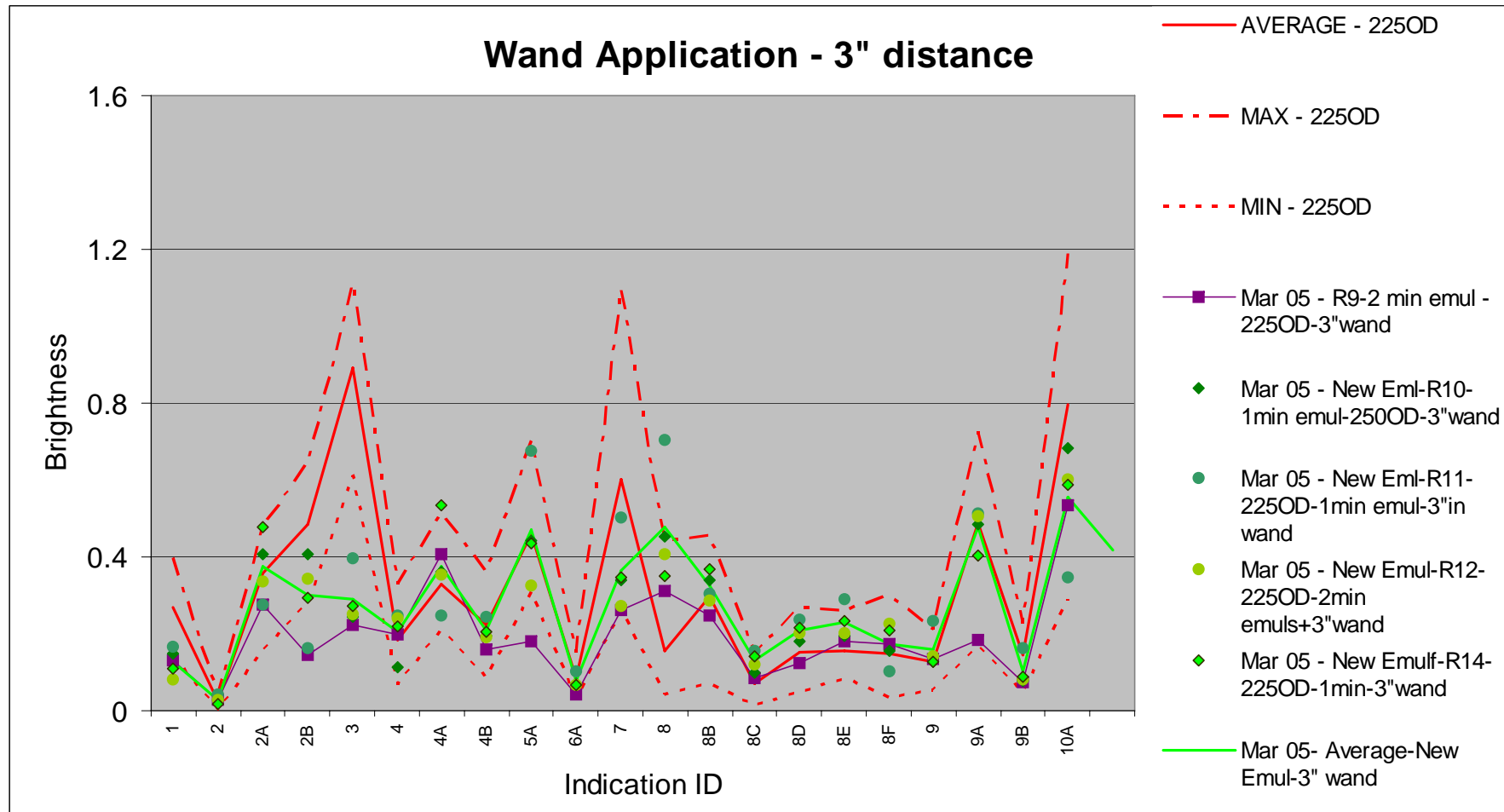


- Use of wand at 3" distance from part led to lower brightness than hand processing with brightness of 30% of the average brightness found with hand-processing

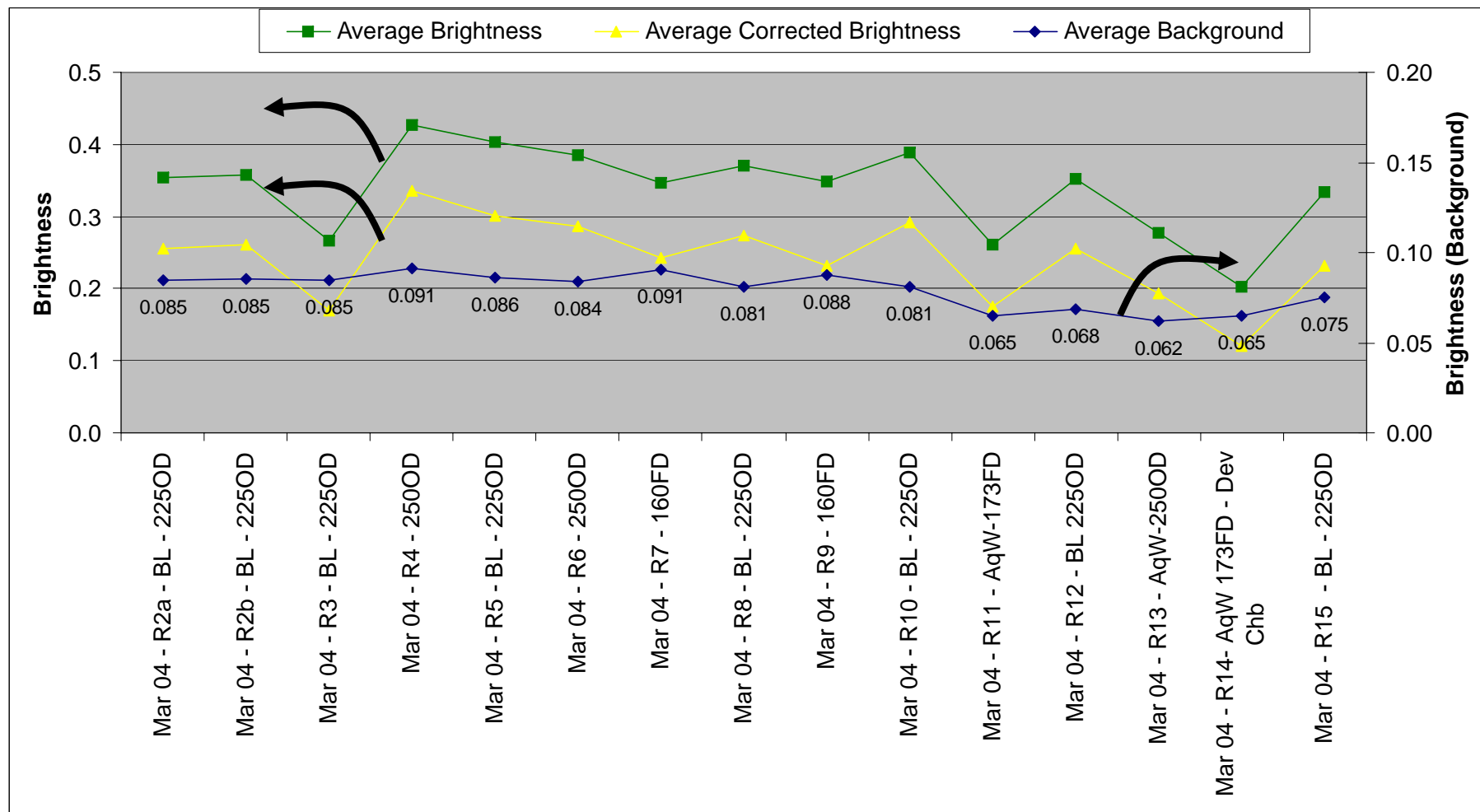


- Comparison of developer application using a bulb led to lower brightness than most hand processed indications
- Linear regression shows brightness values of 69% for the bulb processing compared to hand processing

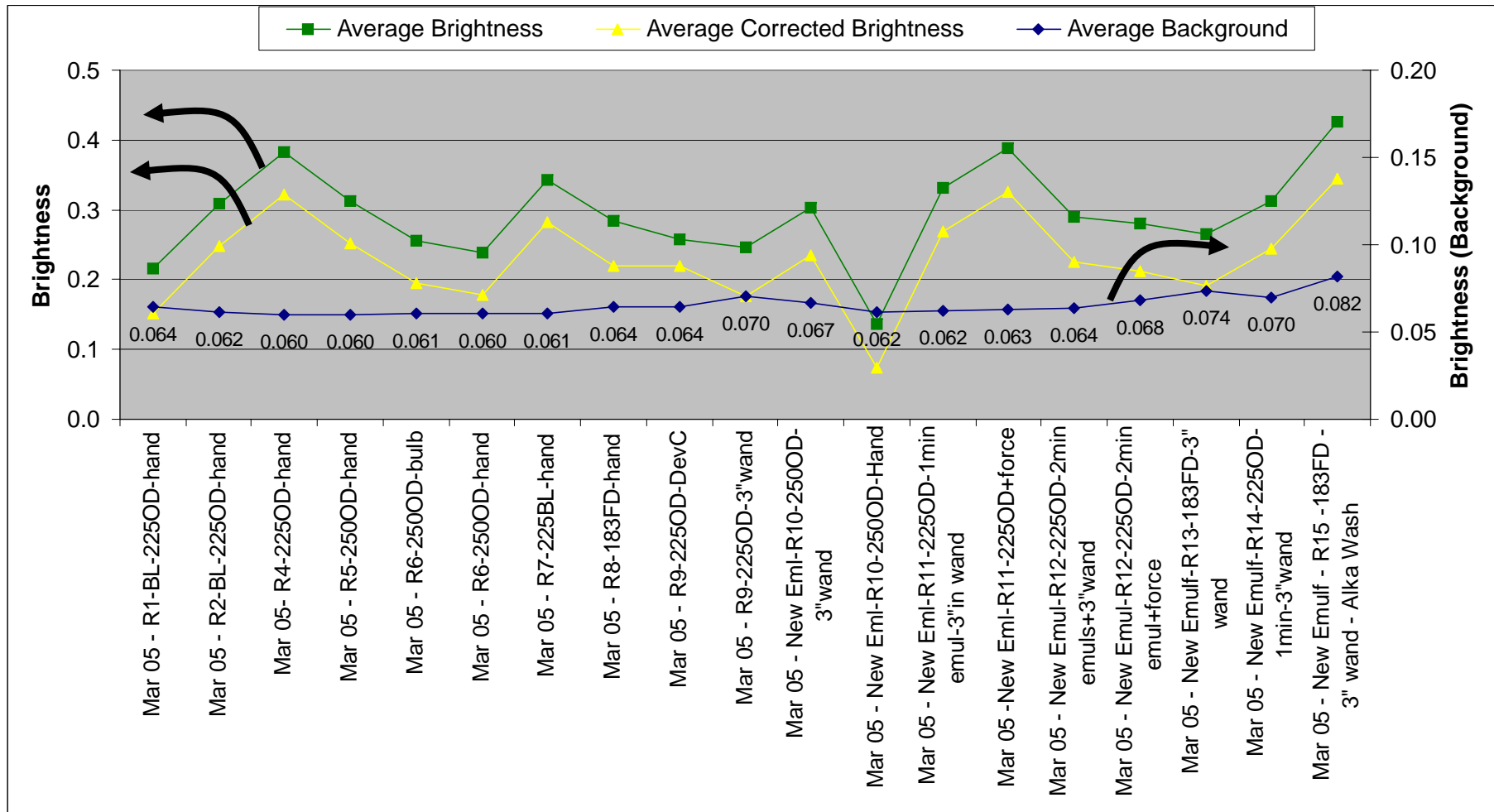




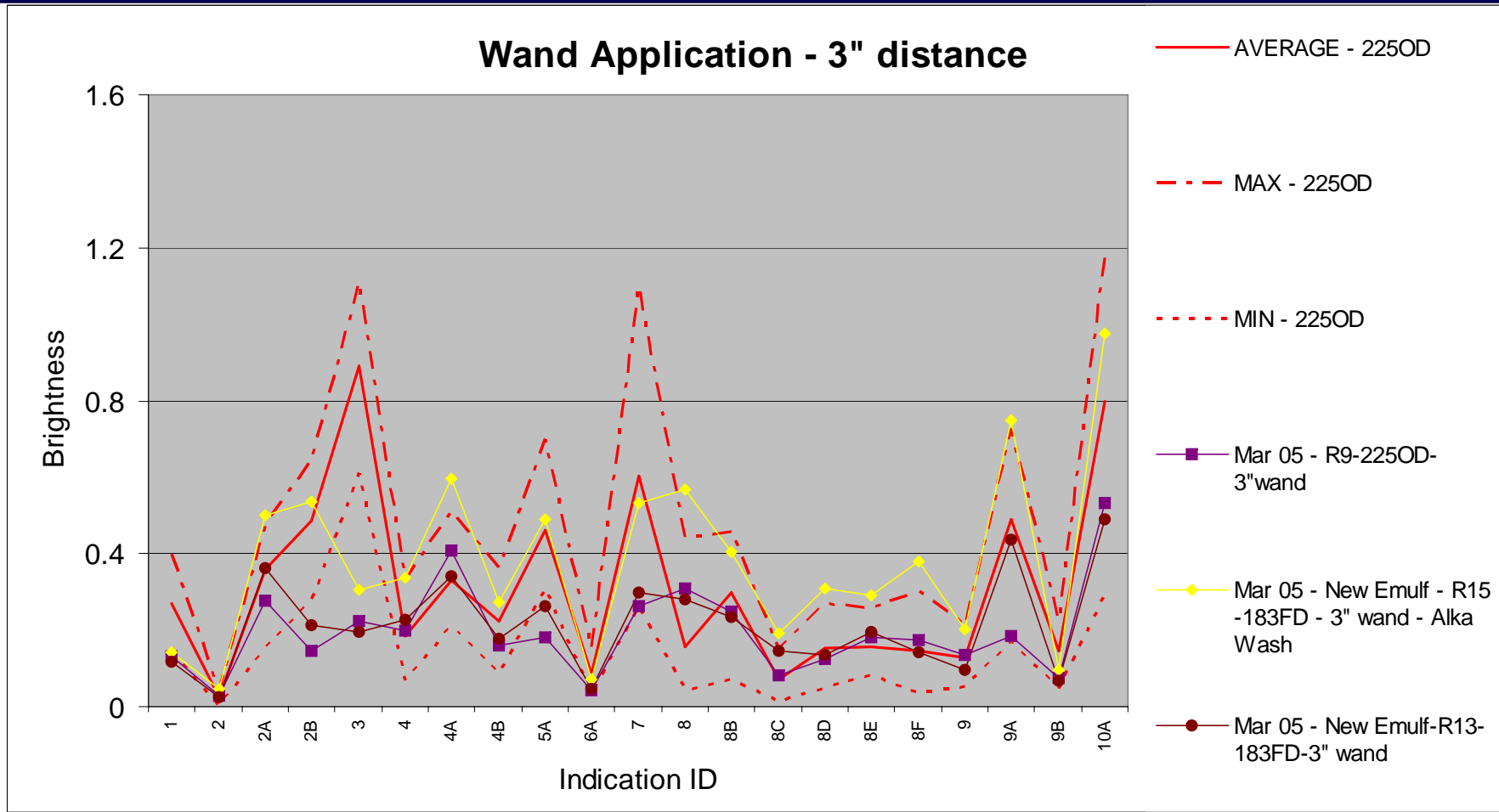
- Brightness increased with new emulsifier compared to original emulsifier
- Use of wand in general led to a reduction in brightness but less variability than with hand processing



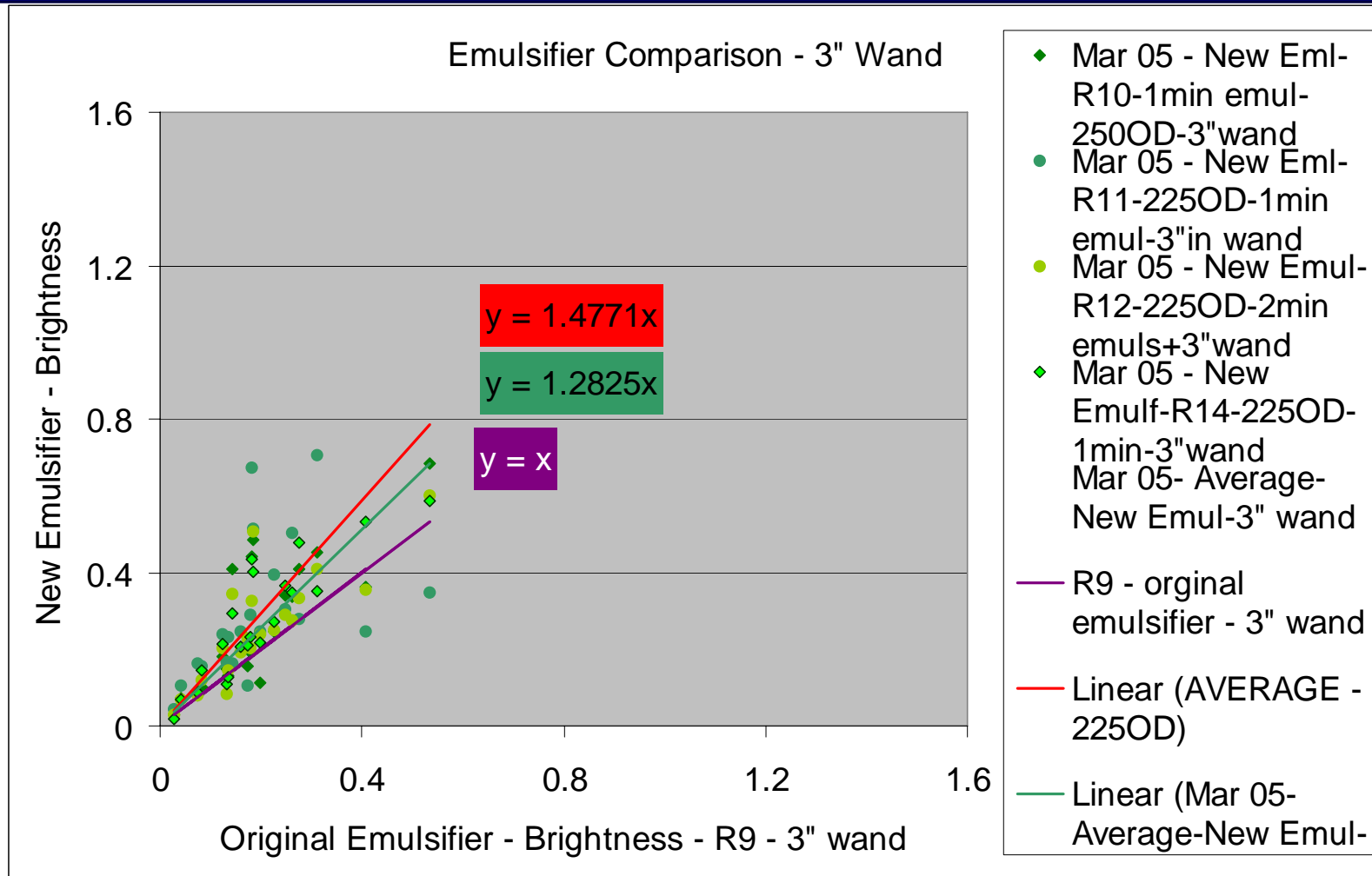
- Background brightness consistent in Mar 04 until R11
- R11 involved aqueous wash which decreased the background from that point forward



- Background brightness consistent in Mar 05 even though a change in emulsifier occurred between R9 and R10



- No difference between OD and FD with new emulsifier and 3" wand
- Brightness increased after heavy duty alkaline clean and FD back to "hand processing conditions"



- New emulsifier gave better performance than the original emulsifier (slope = 1.28 for new emulsifier compared to 1.0 for original emulsifier)
- Hand processing had higher average brightness than wand



- Average brightness similar for both oven dry temperatures, i.e., 225F and 250F
- FD data requires additional statistical analysis
 - More variation found with FD when compared to 225OD, original emulsifier
 - With new emulsifier, FD and OD performed similarly
- Background brightness relatively consistent in Mar05, i.e., not related to changes in emulsifier
- Use of wand showed less variability than hand processing but at a lower average brightness
- Emulsifier change led to improvements in brightness
- Dust chamber application shows similar brightness debits to those found using lcf samples
- Use of heavy duty alkaline clean led to improvements in brightness
- Recommend final study to establish minimum acceptable drying temperature for parts, i.e., energy savings benefits