

Rapid Thermal Processing DOE And Simulation

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2014 Execute and gain share



Building a stronger TI

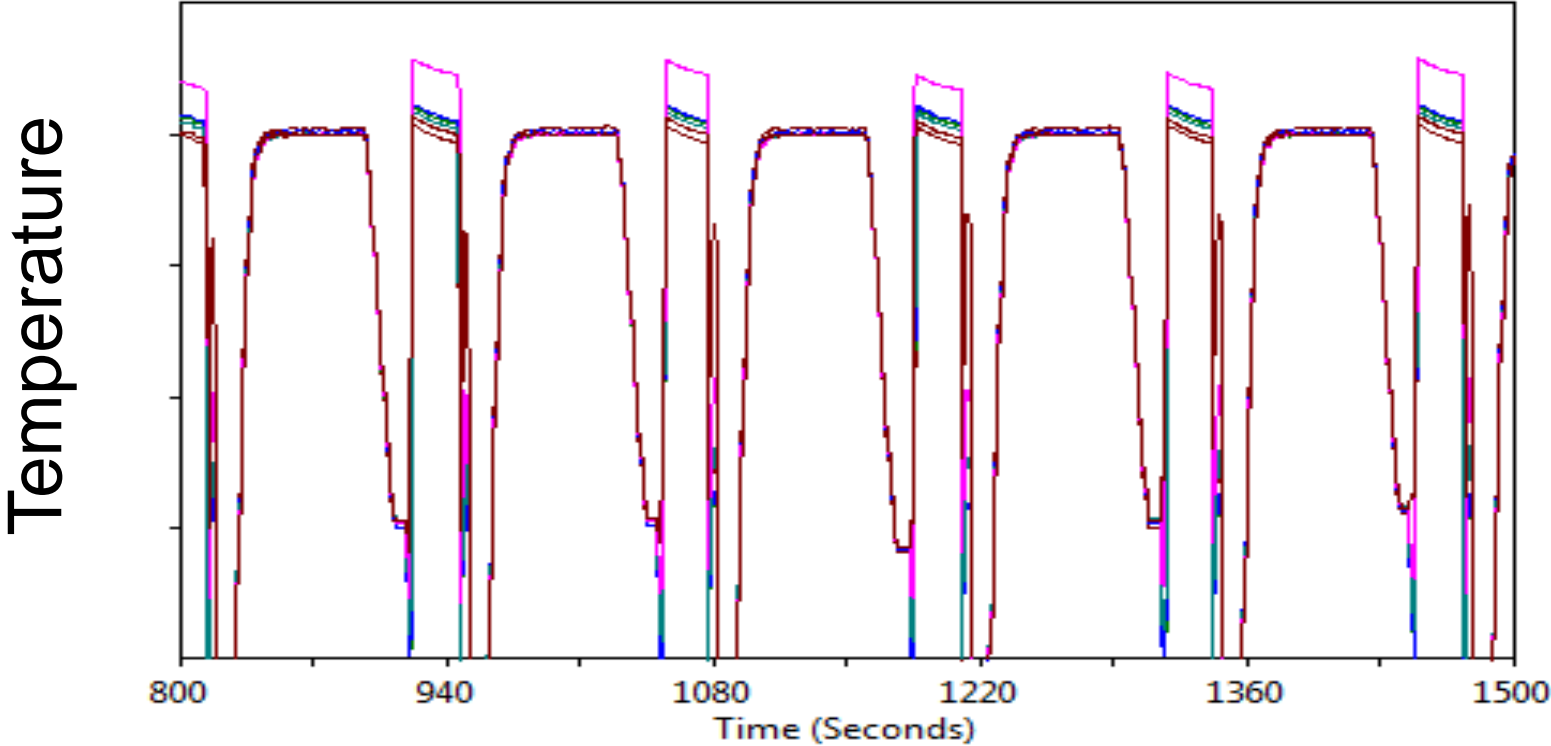
Rapid Thermal Processing (RTP)

- Semiconductor Manufacturing
- Technical Challenges
- Design Experiment
- Simulate Response



Rapid Heat and Cool Cycles

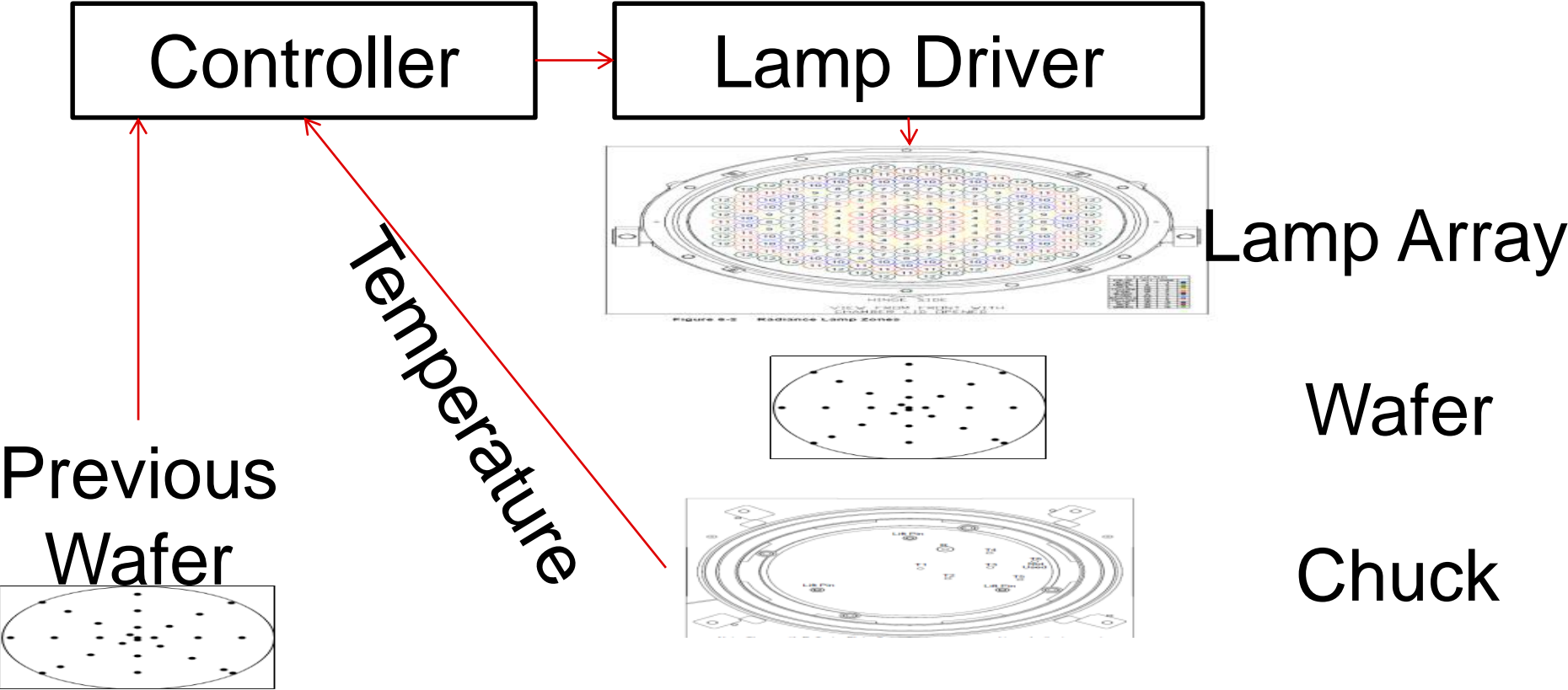
FILE: L:\amtc02\data\13112200.57 (data)



(L)3101_A_Temp_Probe_1 (L)3102_A_Temp_Probe_2 (L)3103_A_Temp_Probe_3
(L)3104_A_Temp_Probe_4 (L)3106_A_Temp_Probe_6 (L)3107_A_Temp_Probe_7

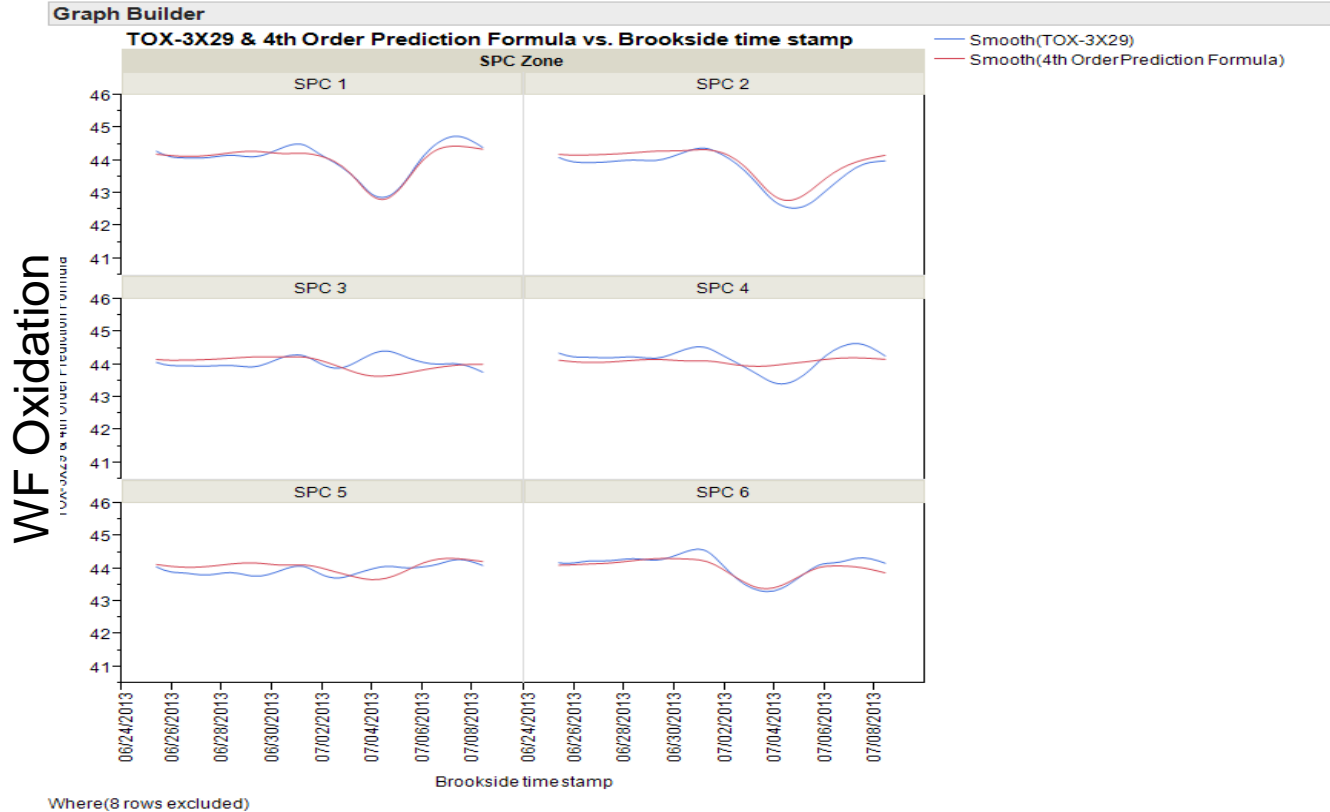
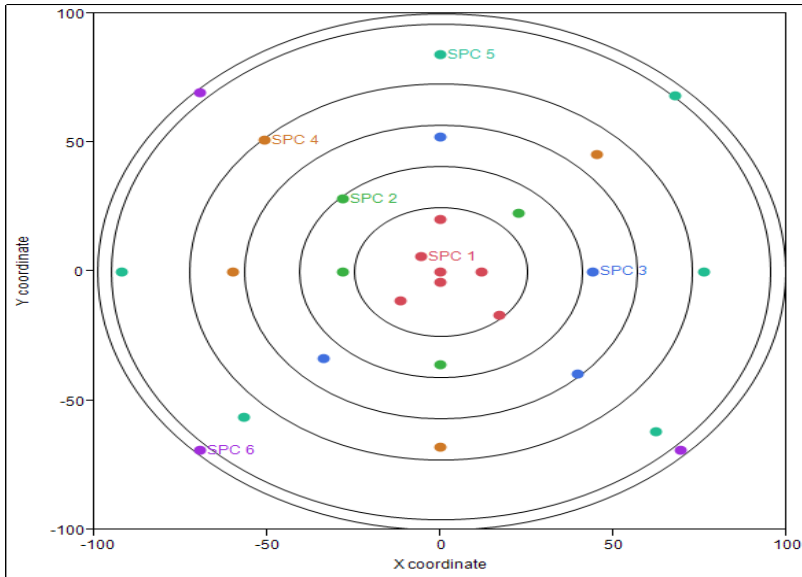
Time

Dynamic Feedback



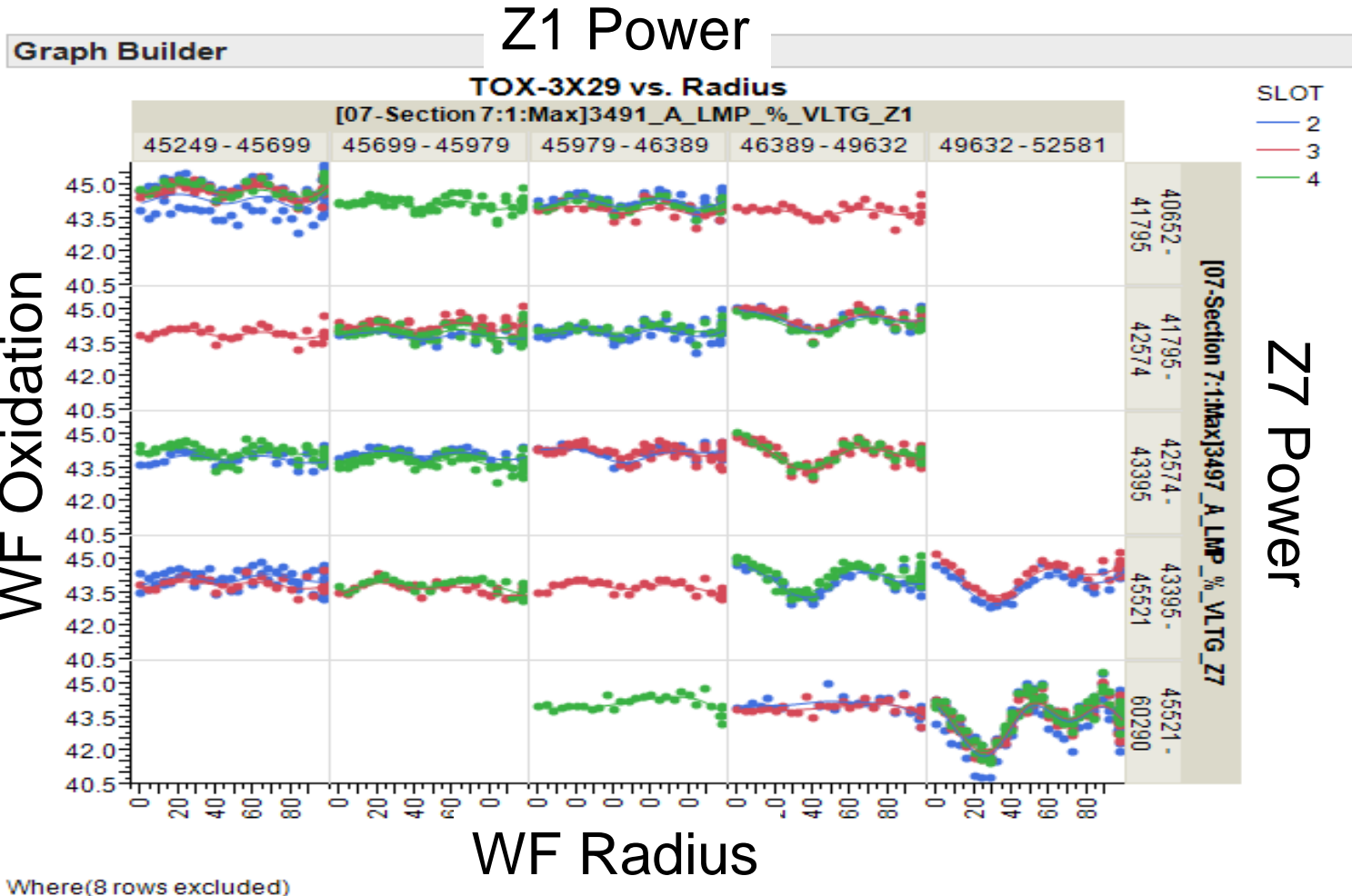
Unstable Variation Over Time

- Control systems work for some zones, but not all!

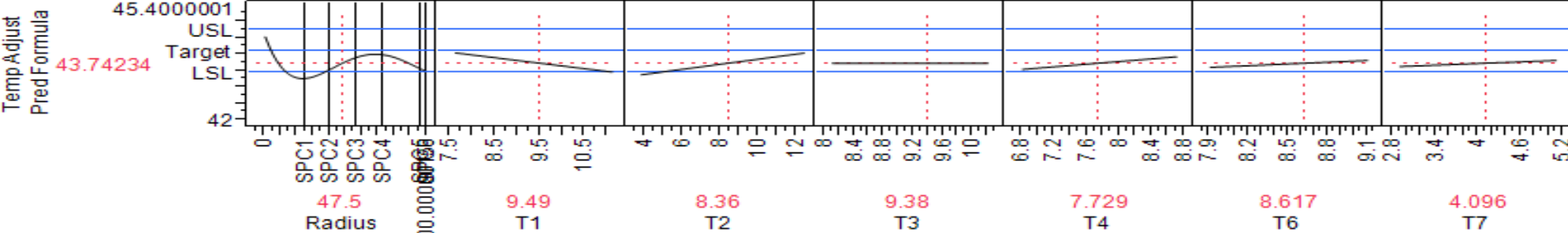


Multiple runs over time

Complex Interactions

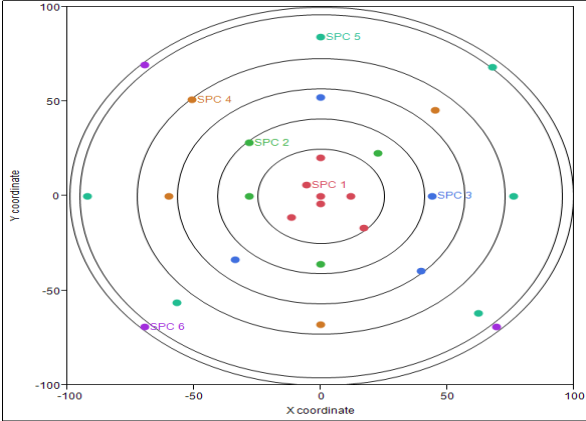


Complex Temperature Zone Response



$$\text{New temp offset} = \text{Old temp offset} + \frac{(\text{target} - \text{measured TOX})}{0.6}$$

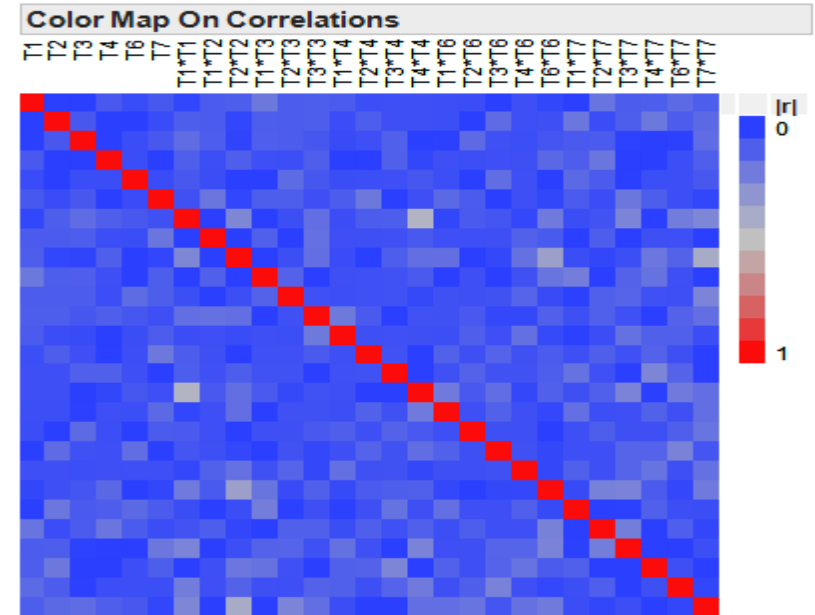
- $\text{RTO} = f(\text{R}, \text{T1}, \text{T2}, \text{T3}, \text{T4}, \text{T6}, \text{T7})$
- Significant interaction between zones
- Response is not linear



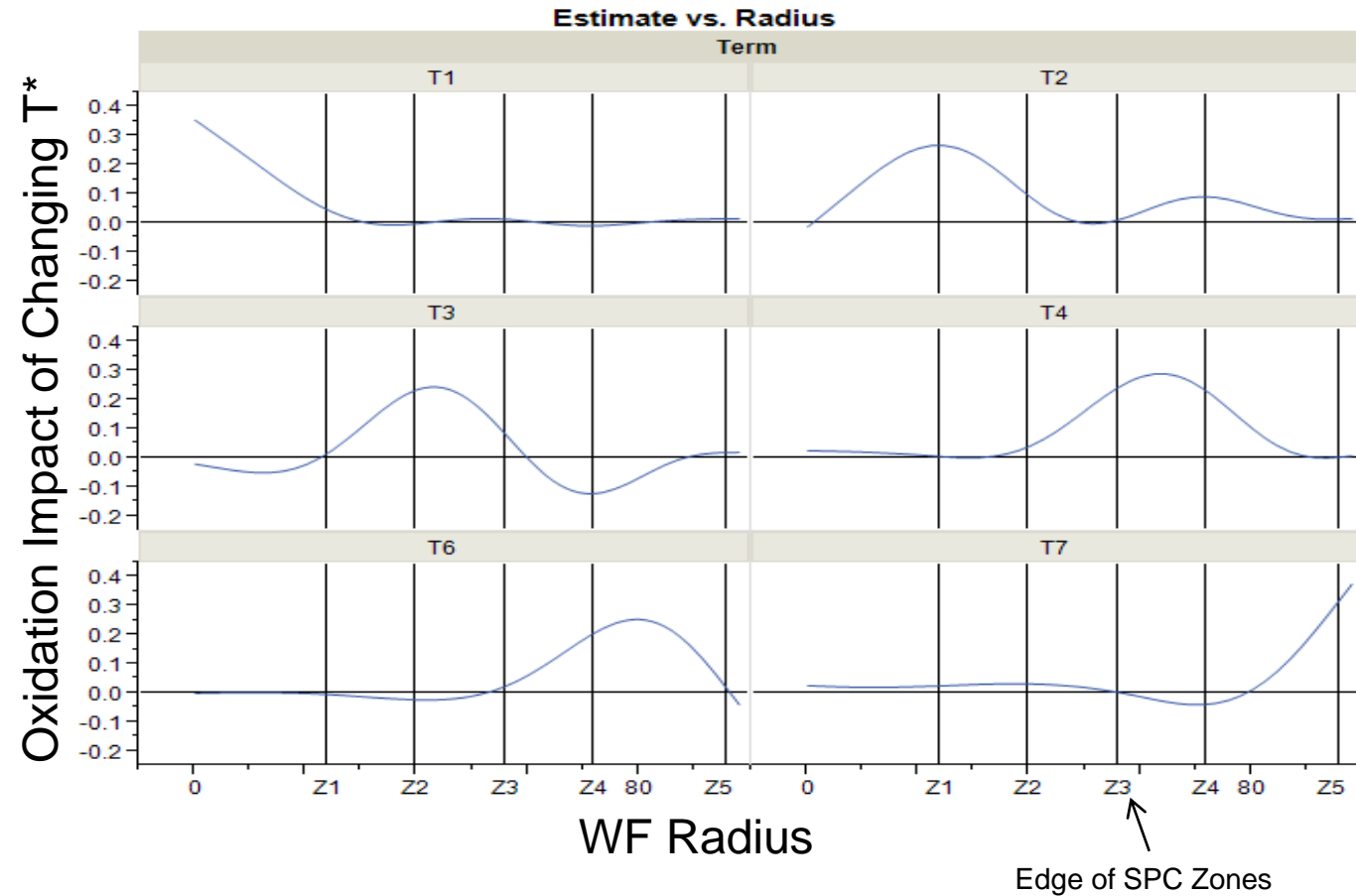
Run Response Surface DOE

Model	
Main Effects Interactions RSM Cross Powers Remove Term	
Name	Estimability
Intercept	Necessary
T1	Necessary
T2	Necessary
T3	Necessary
T4	Necessary
T6	Necessary
T7	Necessary
T1*T1	Necessary
T1*T2	Necessary
T2*T2	Necessary
T1*T3	Necessary
T2*T3	Necessary
T3*T3	Necessary
T1*T4	Necessary
T2*T4	Necessary
T3*T4	Necessary
T4*T4	Necessary
T1*T6	Necessary
T2*T6	Necessary
T3*T6	Necessary
T4*T6	Necessary
T6*T6	Necessary
T1*T7	Necessary
T2*T7	Necessary
T3*T7	Necessary
T4*T7	Necessary
T6*T7	Necessary
T7*T7	Necessary

- I-Optimal design
- 34 runs



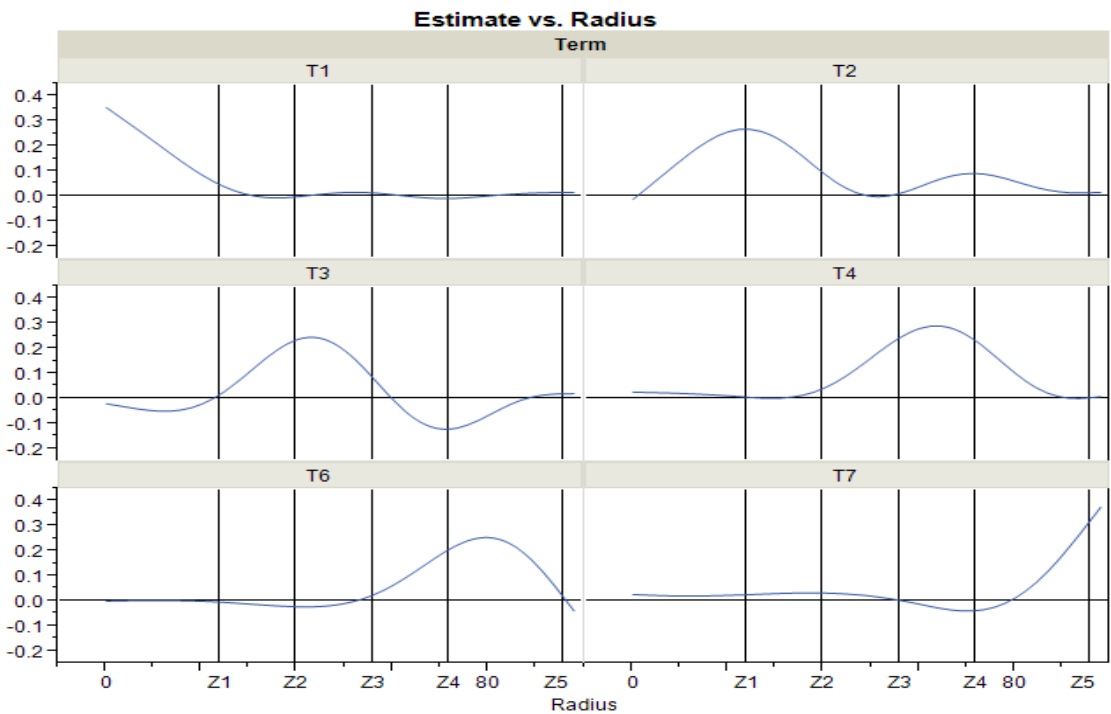
DOE Results Show The Problem



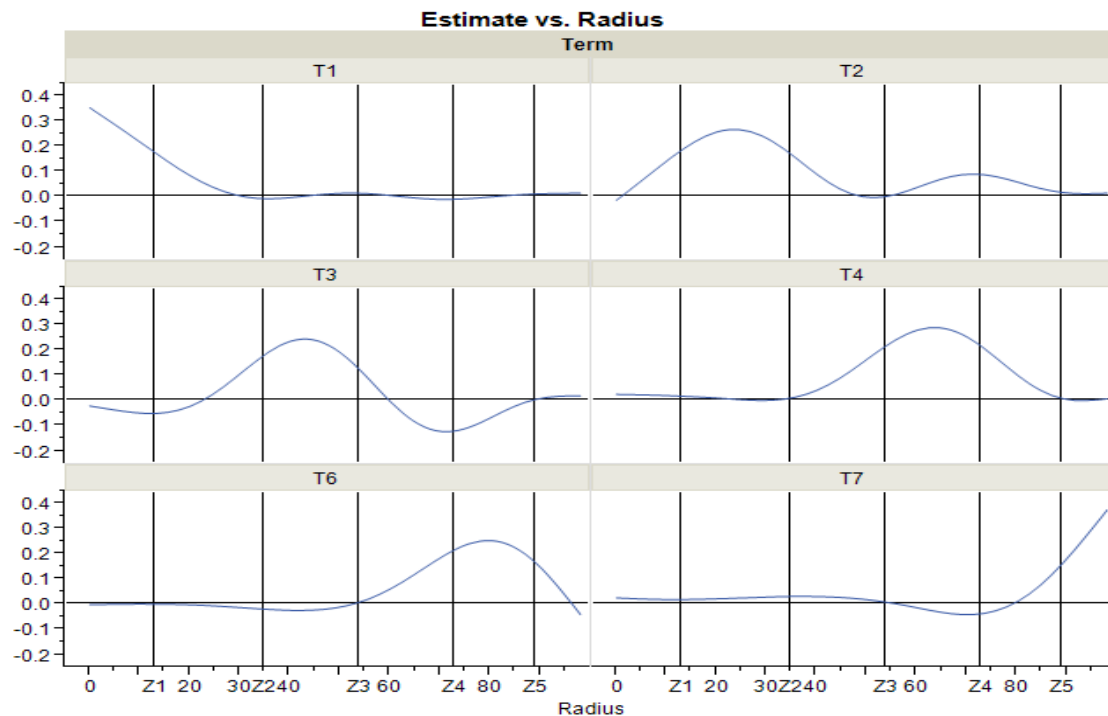
- Primary Findings:
 - Current zone groupings for measurement sites are not optimal
 - Zones not independent
 - T1 and T2 offsets both influence Z1
 - T2 also influences Z4 and Z5
 - T3 influences Z2 and inversely affects Z5 and Z5
 - Adjustment factor of 0.6 should be different for some zones

Optimizing SPC and Temperature Zones

Original Zones

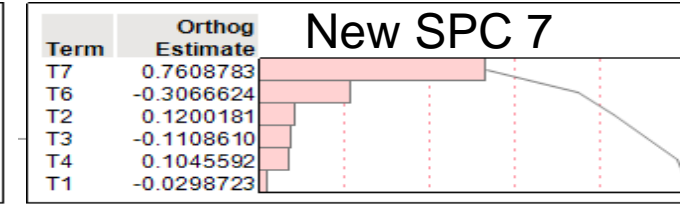
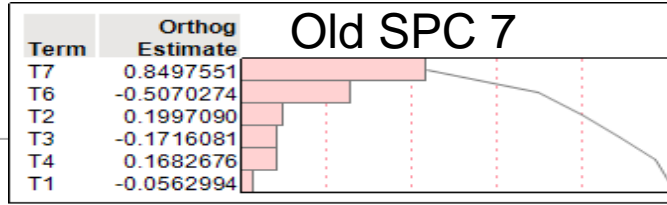
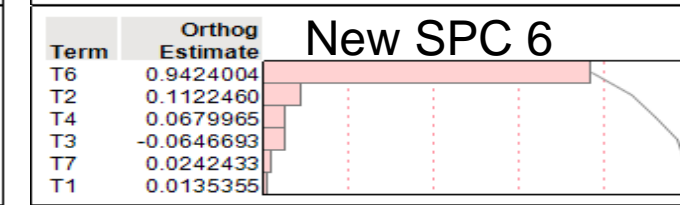
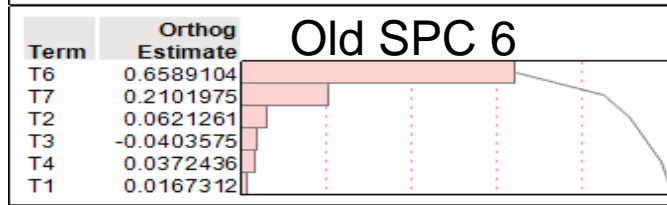
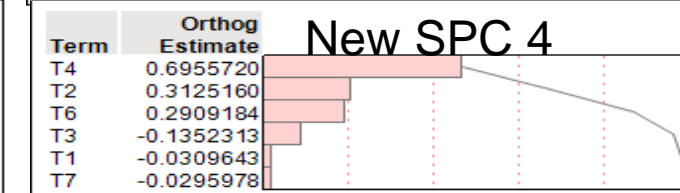
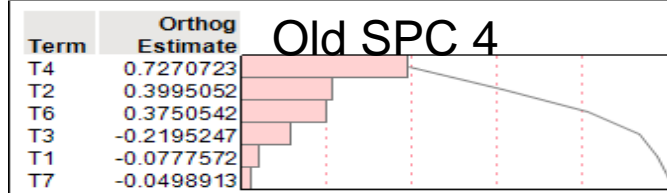
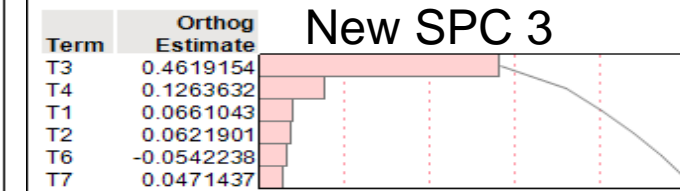
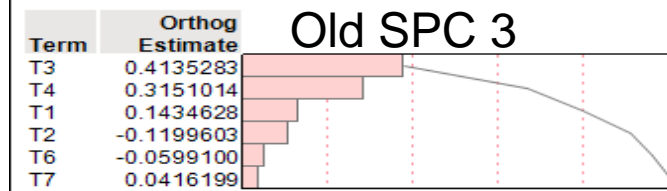
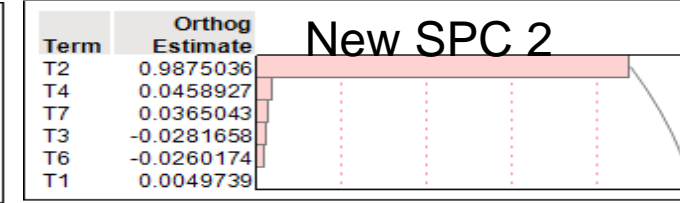
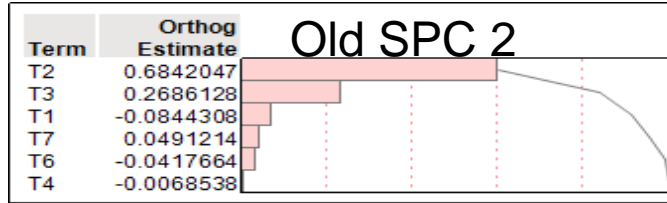
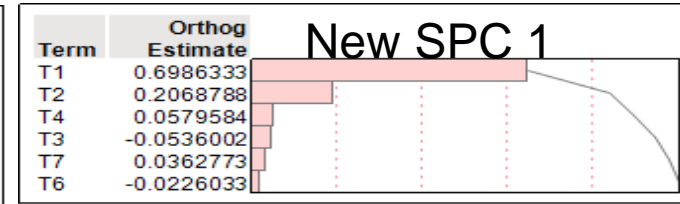
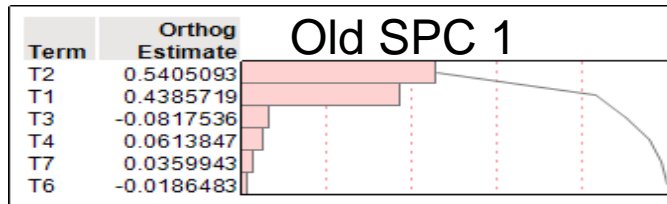


Proposed Zones



New SPC Zones have Less Crosstalk

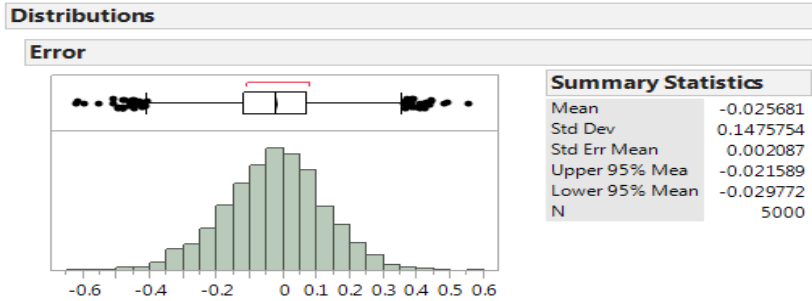
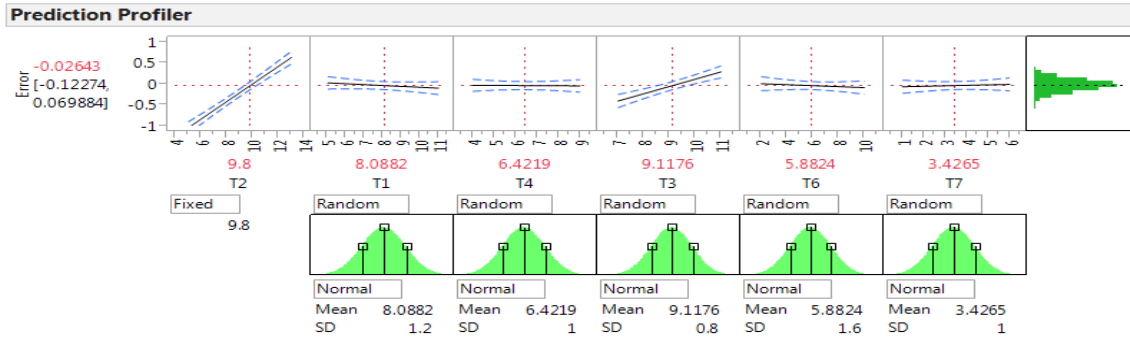
- New SPC zones are not influenced by changes in other Temperature Zones
- Pareto's show impact of each offset factor on oxidation rate of each zone



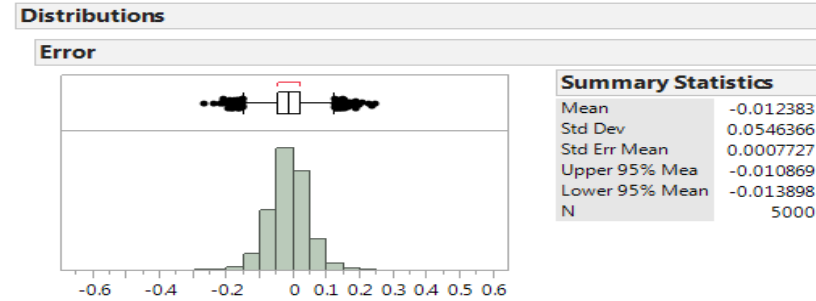
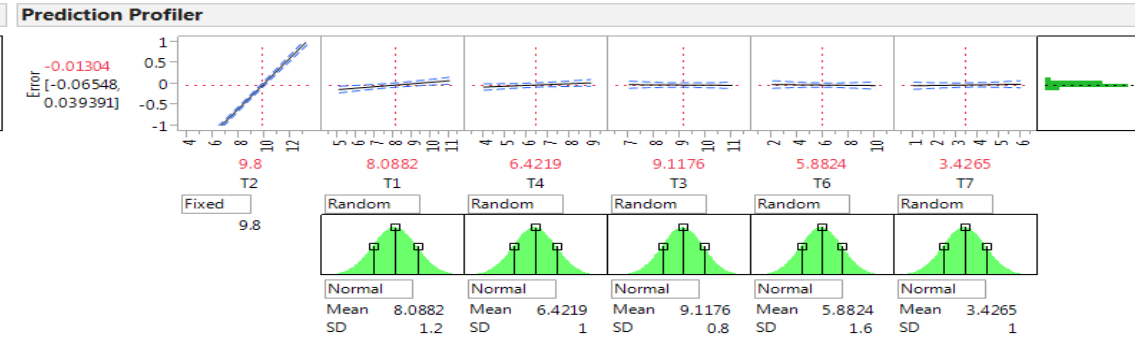
Simulating Impact

- Modeled impact to SPC Zone 2 when setting Temperature Zone 2
- Proposed Zones reduce interaction of all zones

Original Zones



Proposed Zones



Conclusions

- Modeled complex RTP interactions
 - Current system sub-optimal
 - External feedback loop is the problem: Tool internal feedback works
 - No need to completely change system: Need to fine-tune feedback loop

- Challenge with communicating and using models
 - Practical vs. theoretical
 - Interpretable models
 - Actionable model

- Learning cycle to build a model that makes sense with equipment
 - Knowledge of the hardware helped shape the form of the model