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Ceria Slurry Reclamation and Recycling Systems used in High Volume, Semiconductor Manufacturing

GREEN AND EFFICIENT

Slurry Recycling:

- **Why?**
- **When?**
- **Where?**
- **How?**
- **How Well? (Performance)**

Slurry Recycling: Why?

- **Costs - Consumables are a large percentage of semiconductor manufacturing costs**

- **Environmental Impact - an ever growing concern and in most cases a growing expense as well**

- **Slurry Performance – CMP slurries (especially Ceria slurries) are chosen because of unique polish performance, selectivity and low defect levels. To find new slurries with comparable results is difficult, time consuming and expensive.**

Slurry Recycling: When?

- **2000 – 2004** Research and Development
- **2004 – 2006** Concept and Design Testing
- **2006 – 2009** Application Testing (CMP processes using recycled oxide slurry
- **2009 – 2010** Pilot systems installed and qualified (oxide slurry)
- **2010 – Present** High volume manufacturing systems in production (oxide slurry)
- **2013 – 2014** Pilot systems installed and qualified (ceria & tungsten slurries)
- **2014 – Present** High volume manufacturing systems in production (ceria & tungsten slurries)

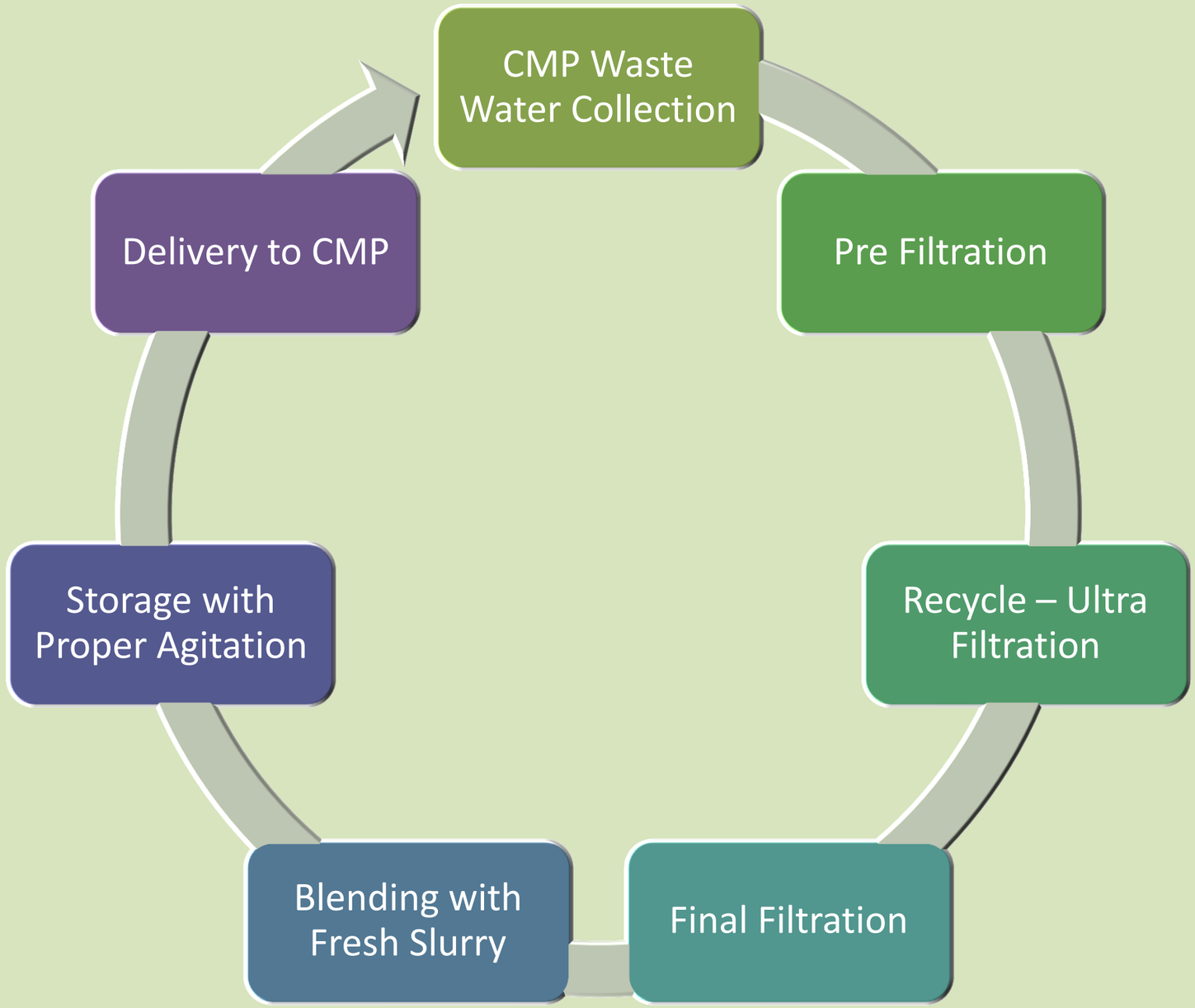
Slurry Recycling: Where?

- **Europe**
  - **Germany** **Oxide-Silica, Tungsten, Li Ta**
  - **France** **Oxide-Silica**

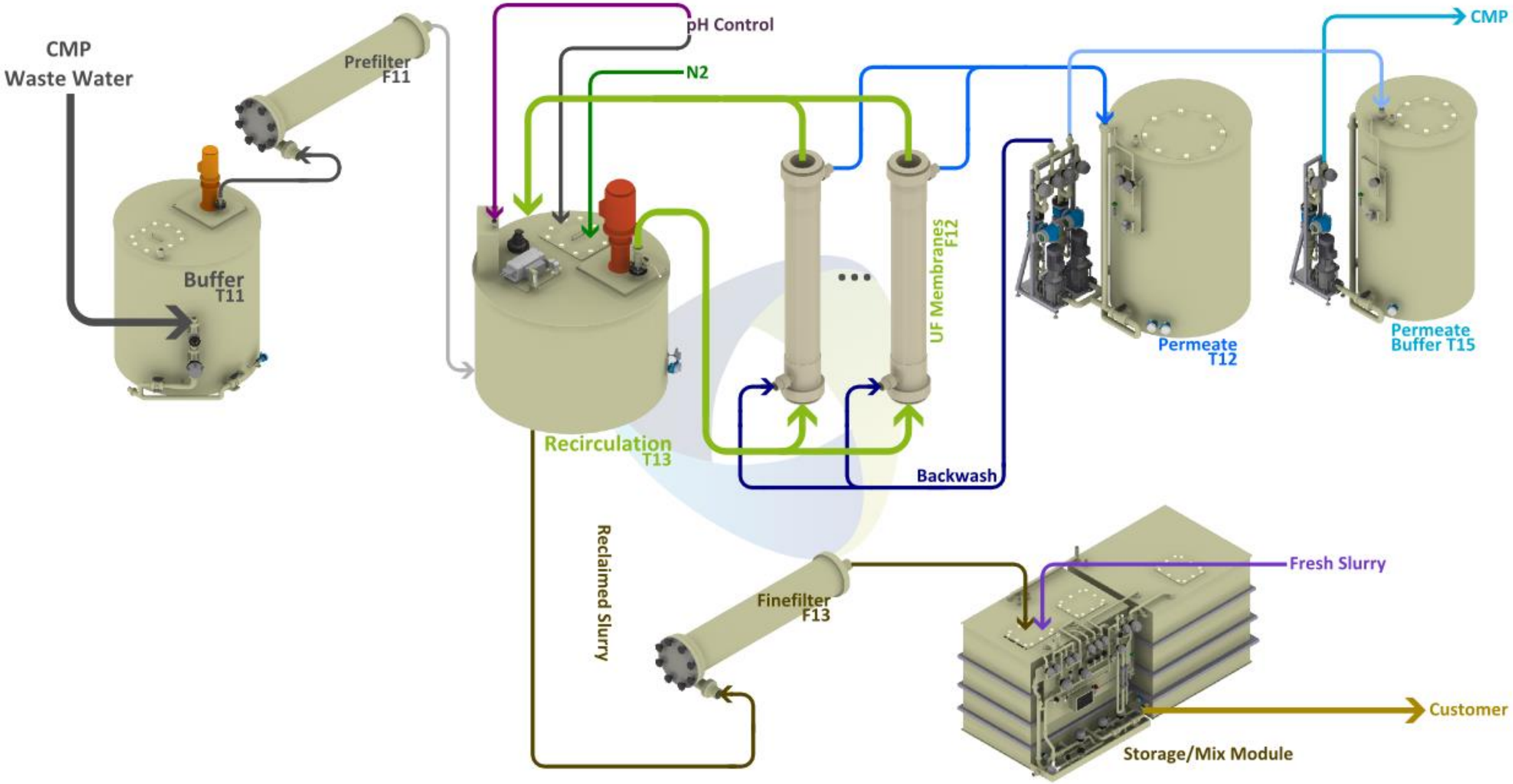
- **South East Asia**
  - **Malaysia** **Oxide-Silica**
  - **Korea** **Oxide-Silica**
  - **Japan** **Oxide-Silica**

- **North America**
  - **United States** **Oxide-Silica, Oxide-Ceria**

Ceria Slurry Recycling: How?



Ceria Slurry Recycling: Process Flow



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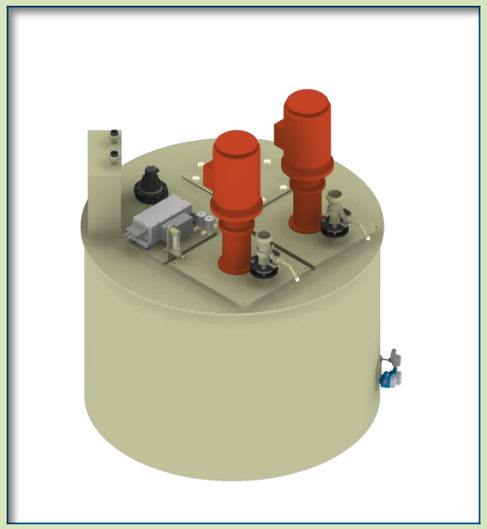
Ceria Slurry Recycling: Modular Design

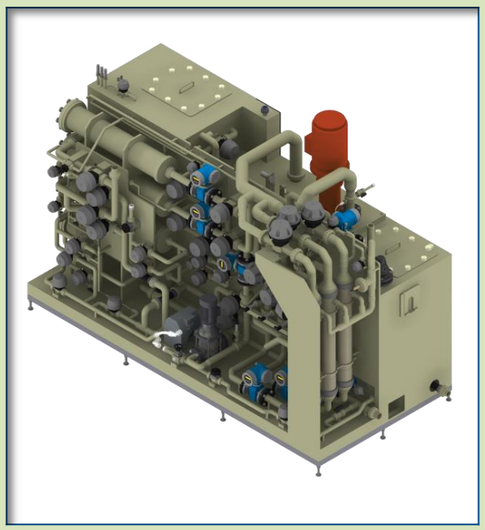
Buffer Tank

Permeate Tank

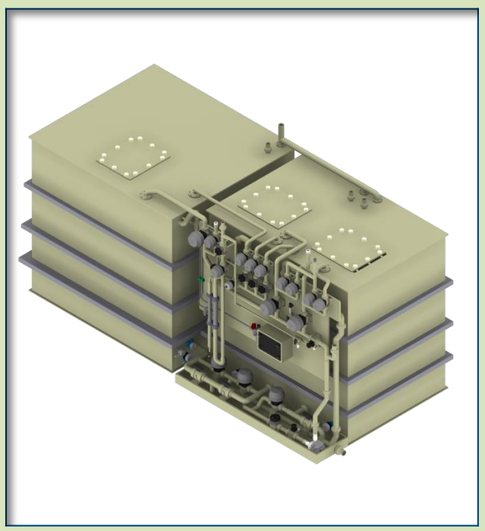


Recirculation Tank

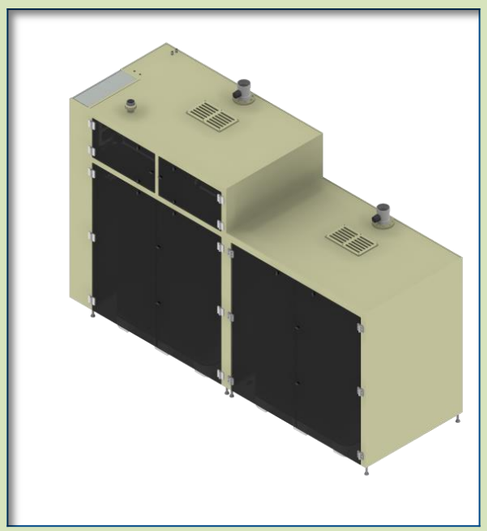
Redundant Filters



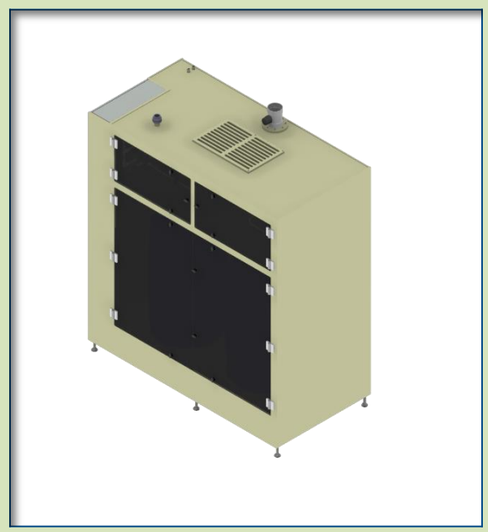
Recycle Skid Module



Storage/Mix Module



Fresh Slurry Module



Chemical Supply Module

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Ceria Slurry Recycling: Modular Design

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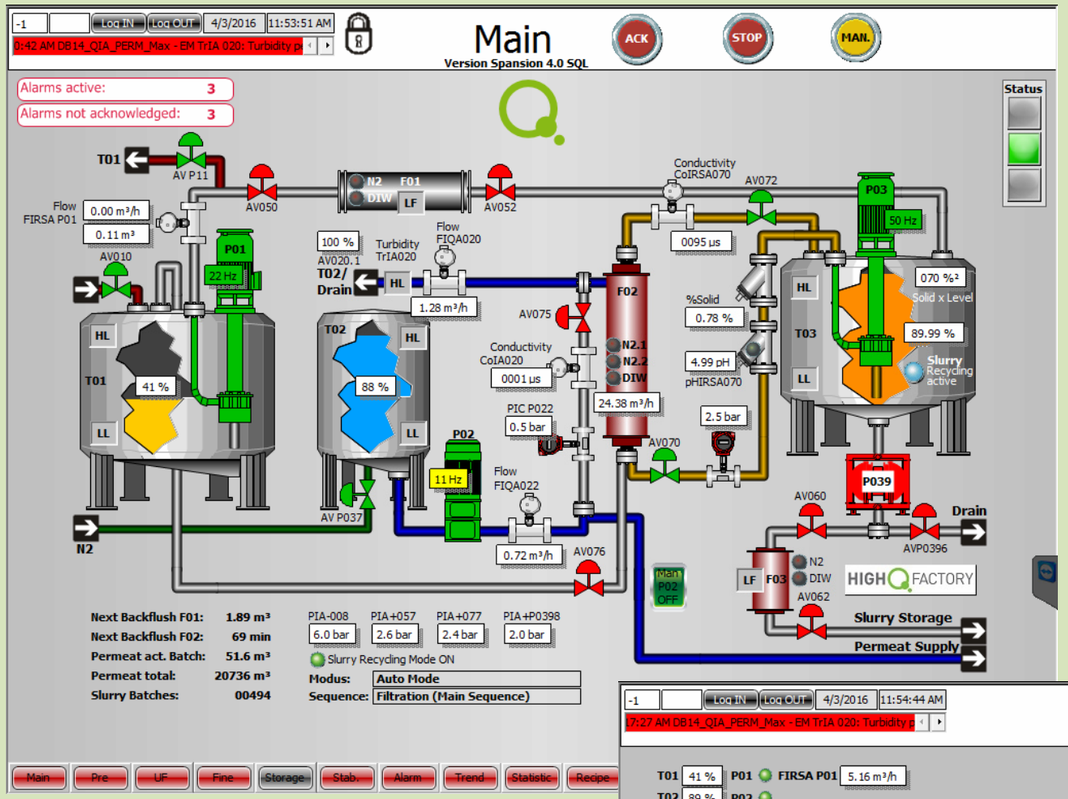
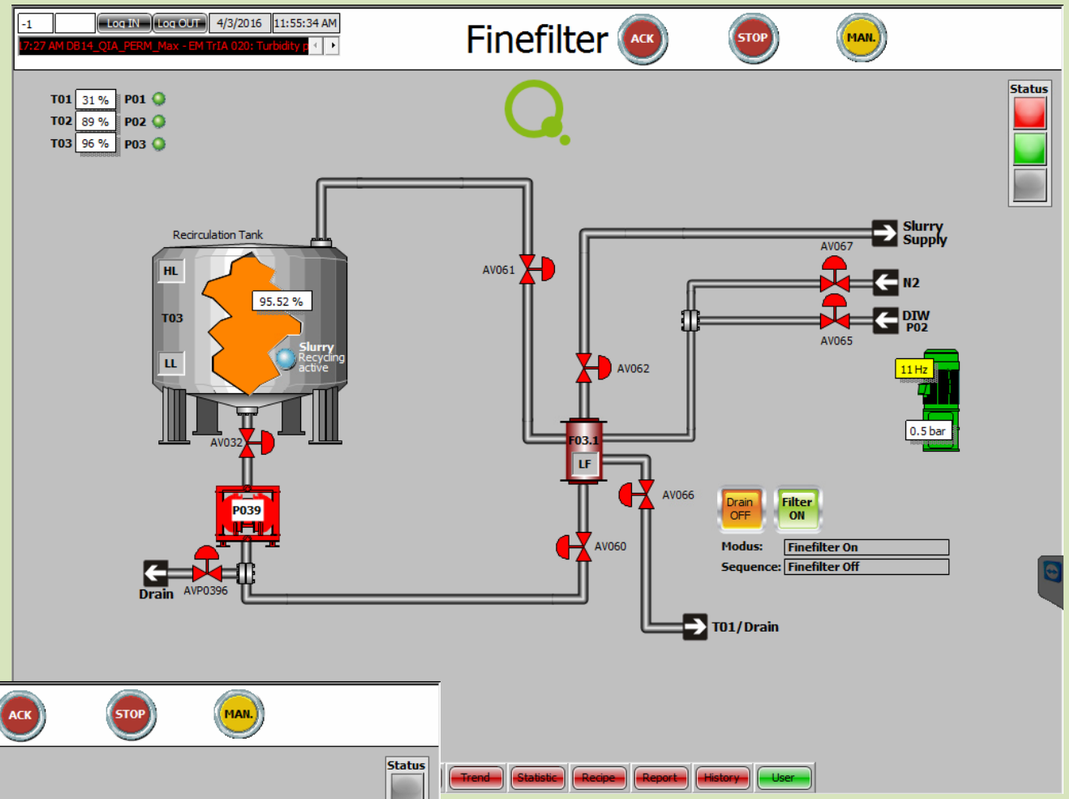
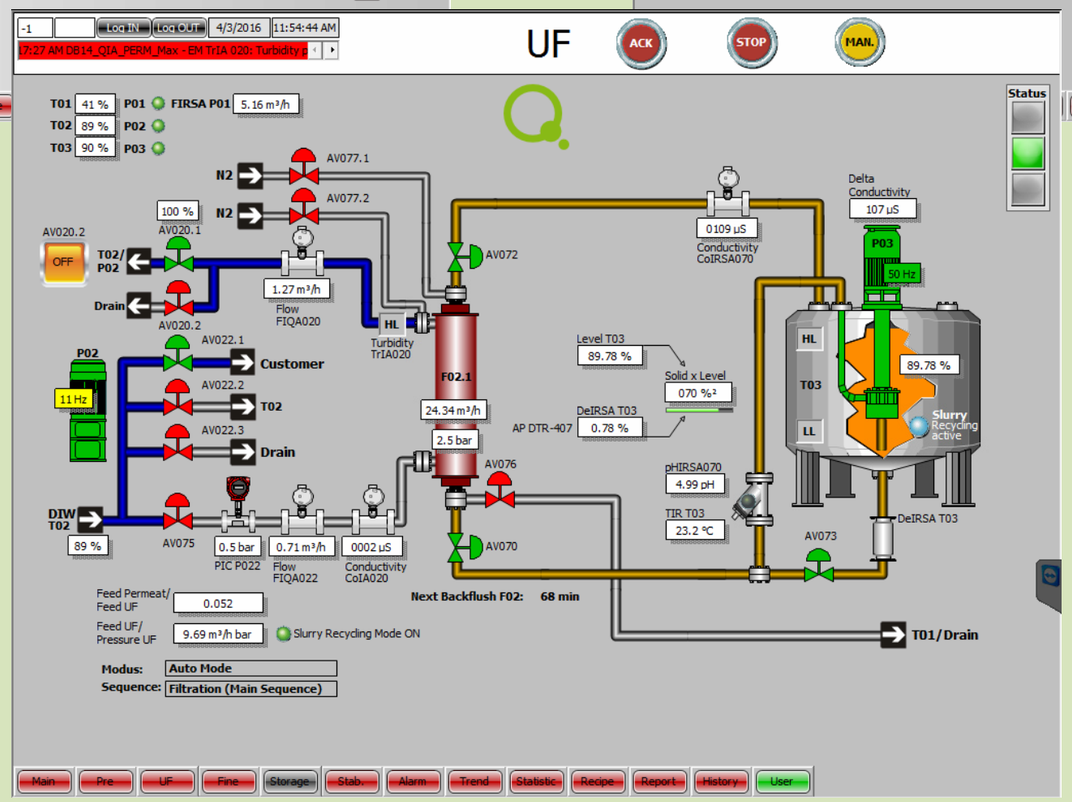
Ceria Slurry Recycling: Quality Control-Operations







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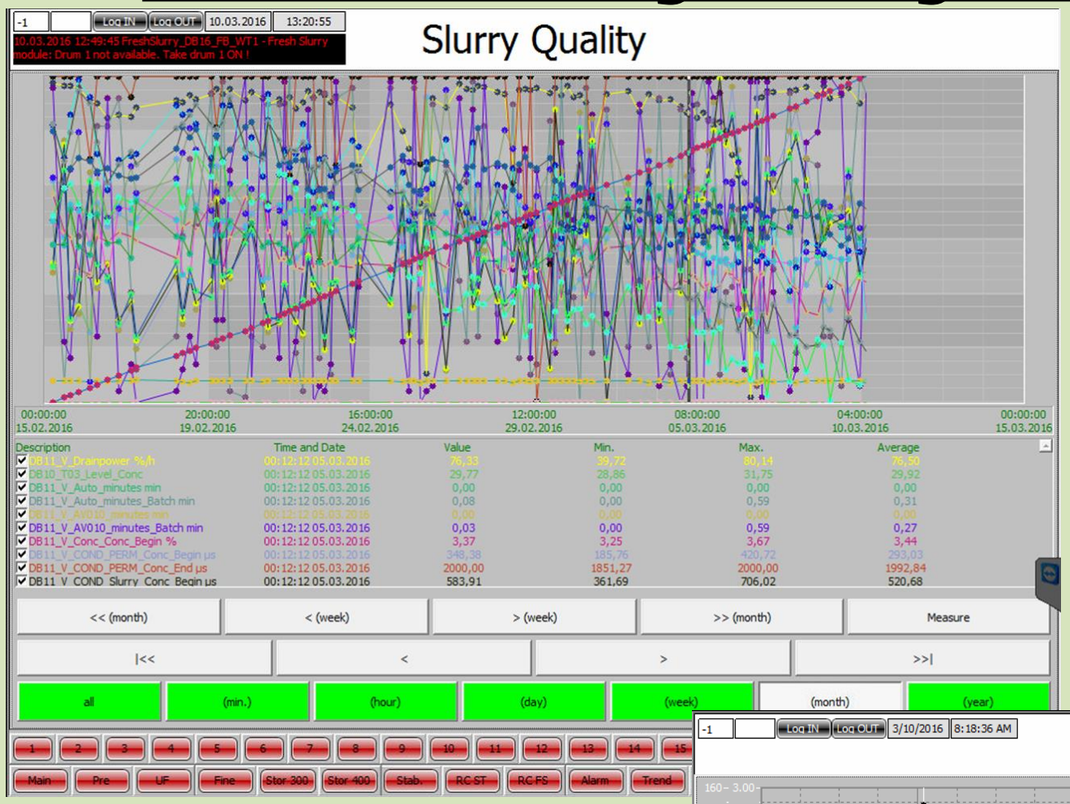
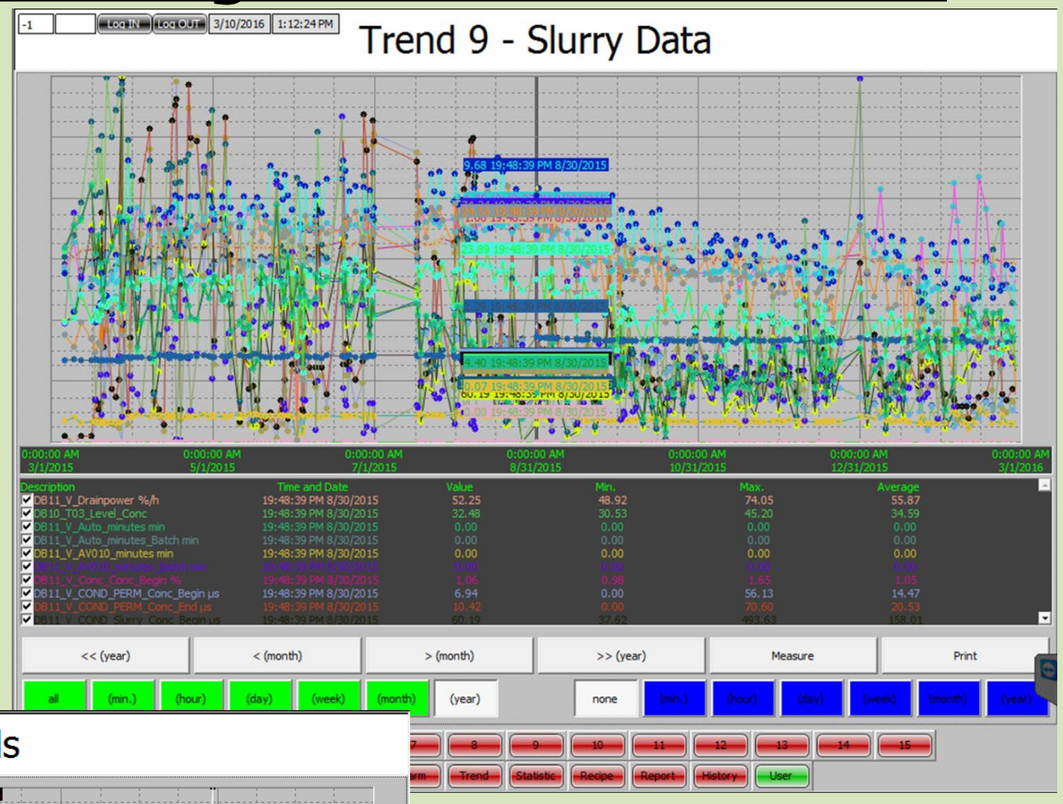
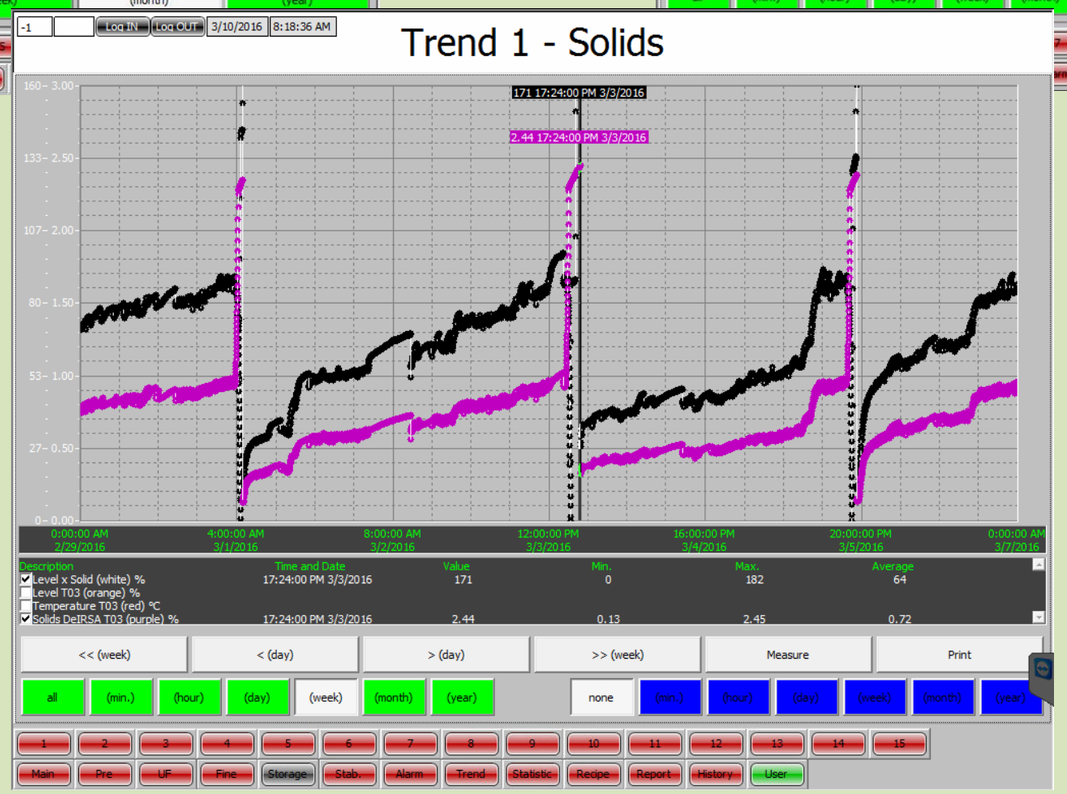
Ceria Slurry Recycling: Quality Control - Data



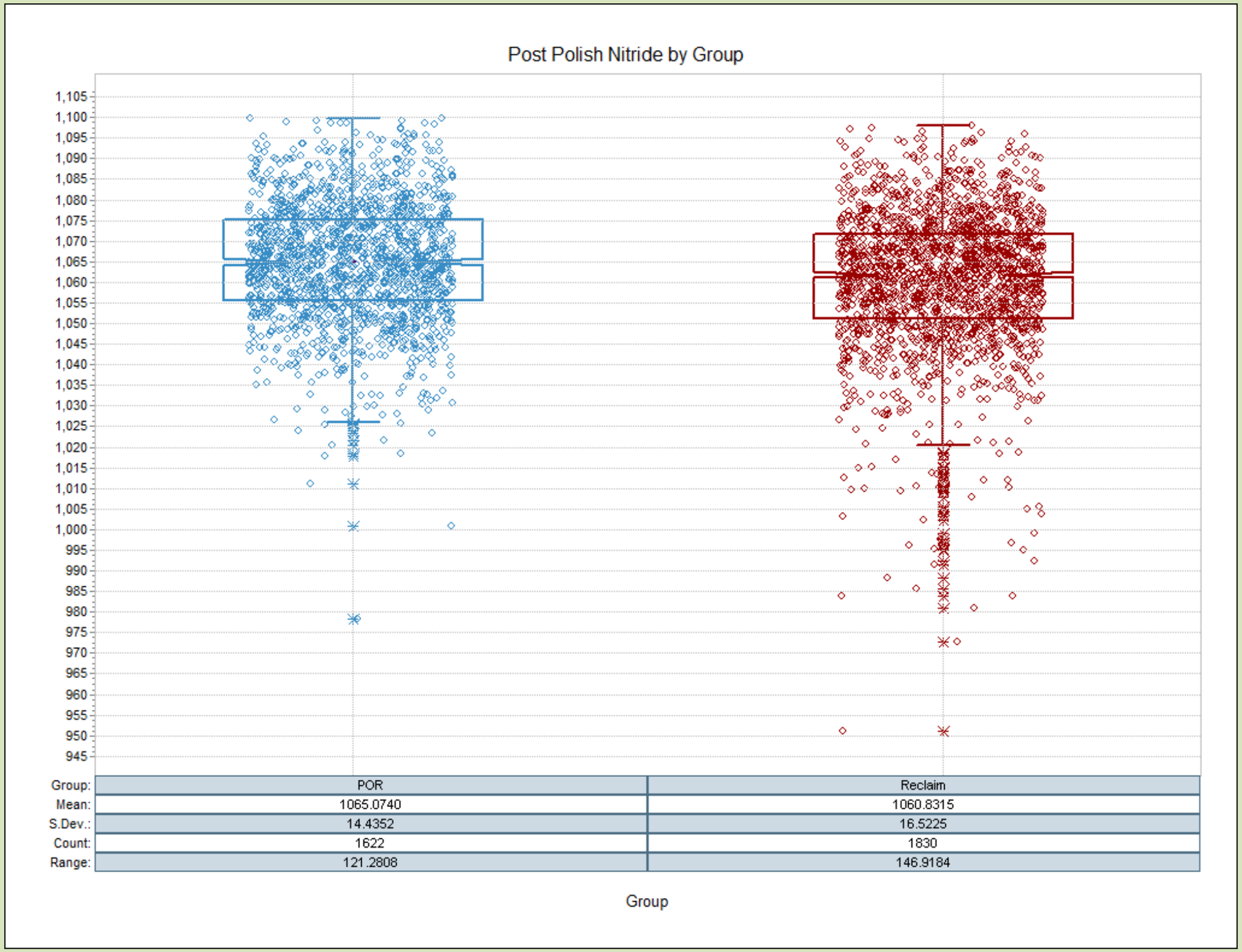




Ceria Slurry Recycling: How Well?(Performance)

- **Polish Removal**
- **Defectivity, Micro-Scratching**
- **Long Term Stability**

Ceria Slurry Recycling: Removal



Post polish silicon nitride thickness comparison on 65nm production wafers.

- **The POR (2-step, 2-slurry) process mean was 1065Å (left) and the Reclaim (recycled ceria) was 1061Å (right).**
- **Customer reported result: “The difference is not significant.”**

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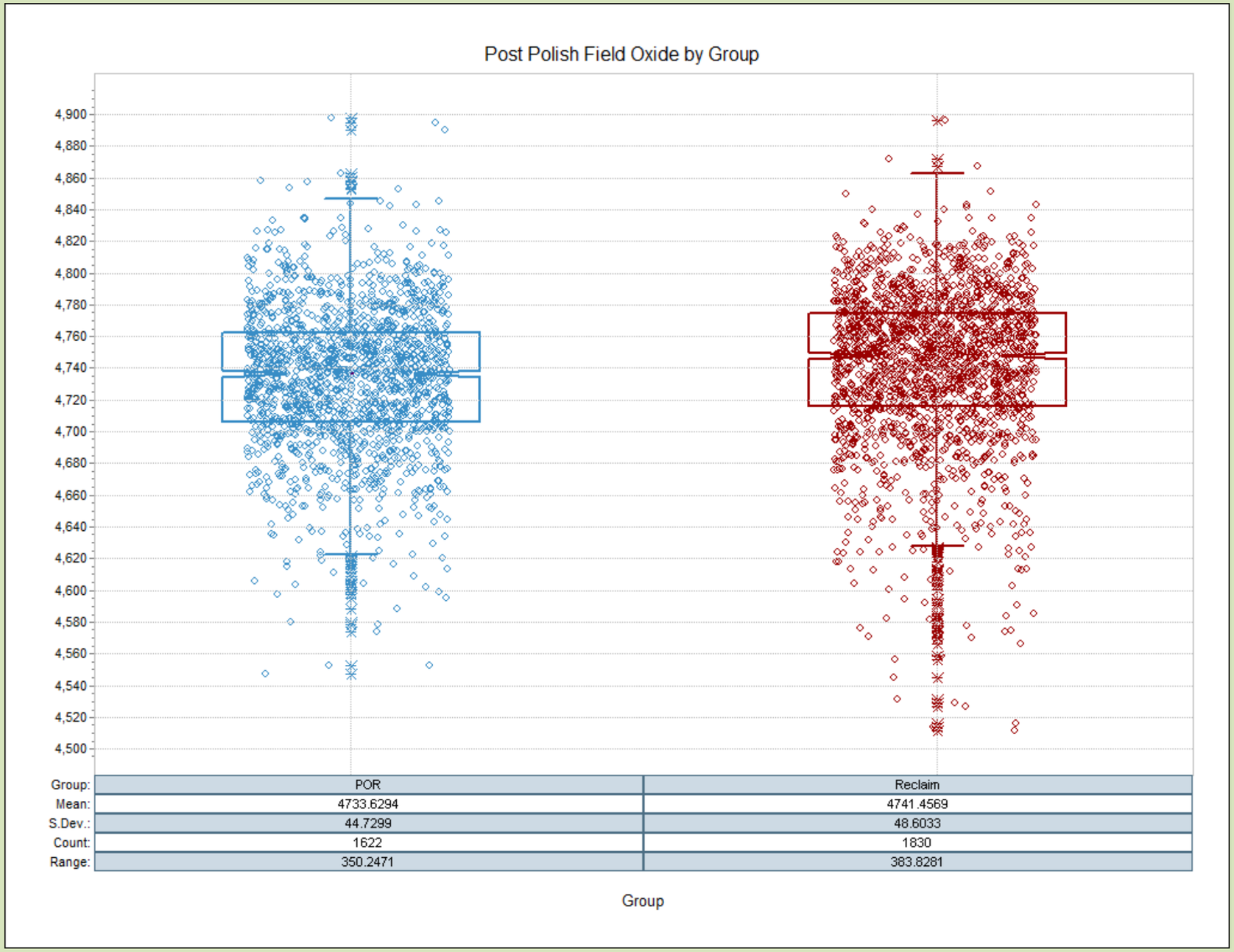
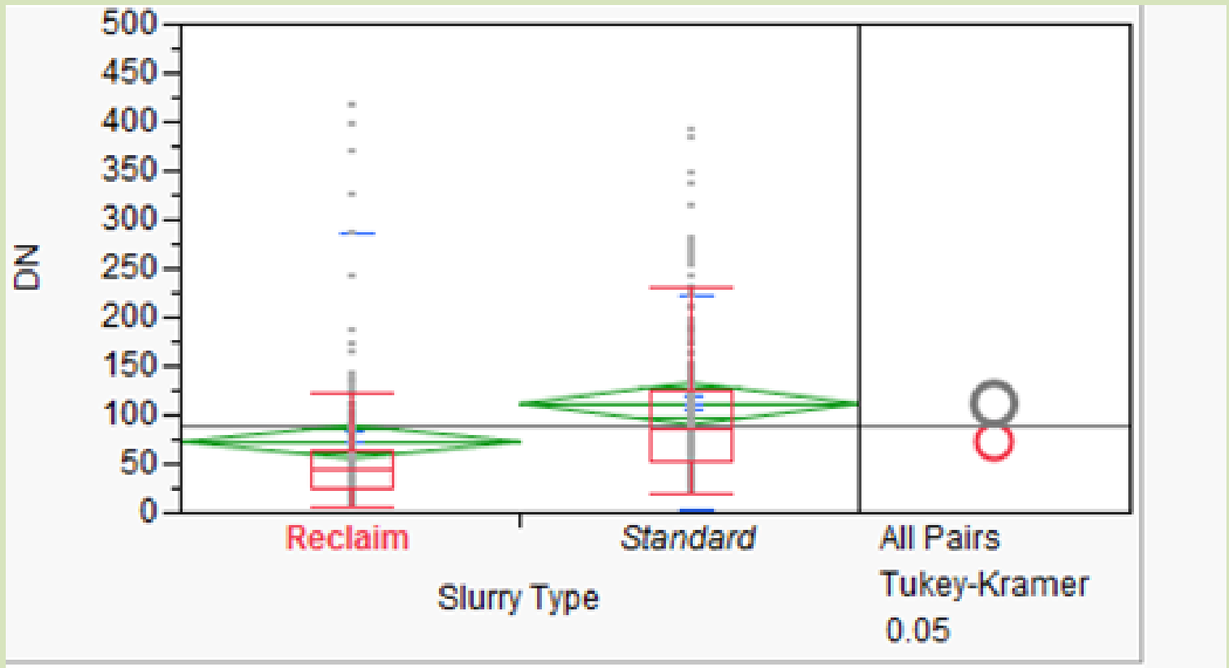
Ceria Slurry Recycling: Removal



Post polish trench or field oxide thickness comparison on 65nm production wafers.

- **The POR (2-step, 2-slurry) process mean was 4734Å (left) and the Reclaim (reclaimed ceria) was 4741Å (right).**
- **Customer reported result: “The difference is not significant.”**

Ceria Slurry Recycling: Defectivity



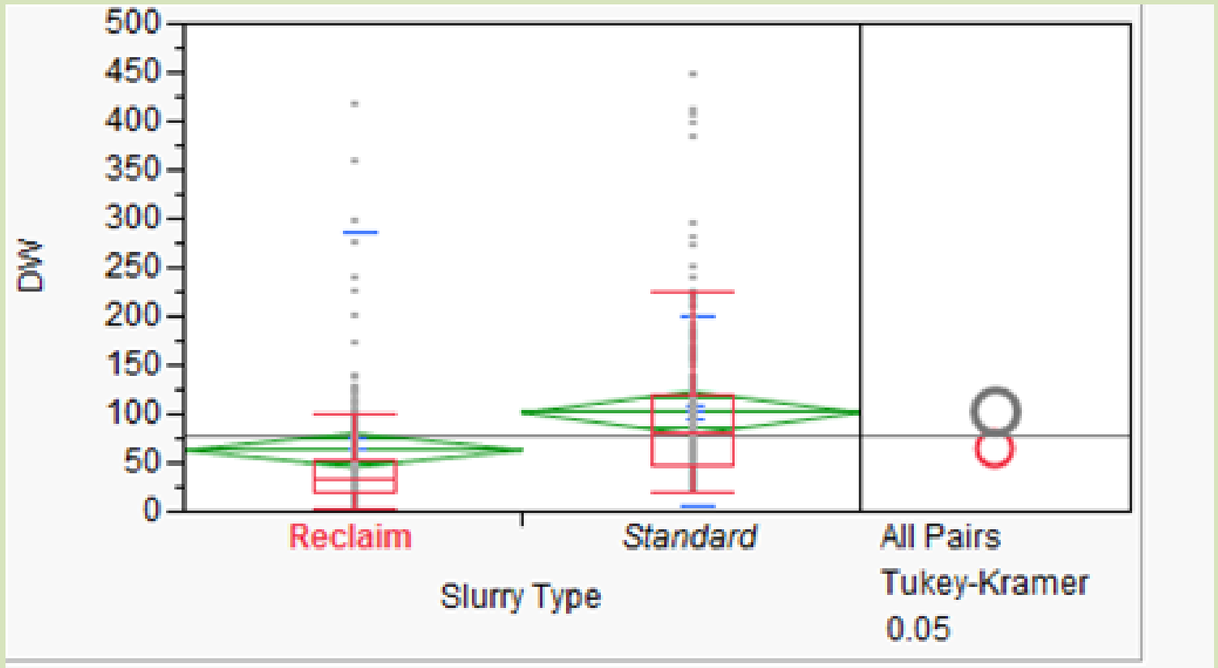
Excluded Rows 3

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Reclaim	440	73.261	212.760	10.143	53.327	93.20
Standard	274	112.245	109.830	6.635	99.182	125.31

KLA-Tencor DN defect counts were statistically lower by 35% for the reclaimed slurry over the Standard (2-step) STI process.

35% Improvement



Excluded Rows 3

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Reclaim	440	63.377	221.626	10.566	42.612	84.14
Standard	274	101.668	97.329	5.880	90.092	113.24

KLA-Tencor DW defect counts were statistically lower by 38% for the reclaimed slurry over the Standard (2-step) STI process.

38% Improvement

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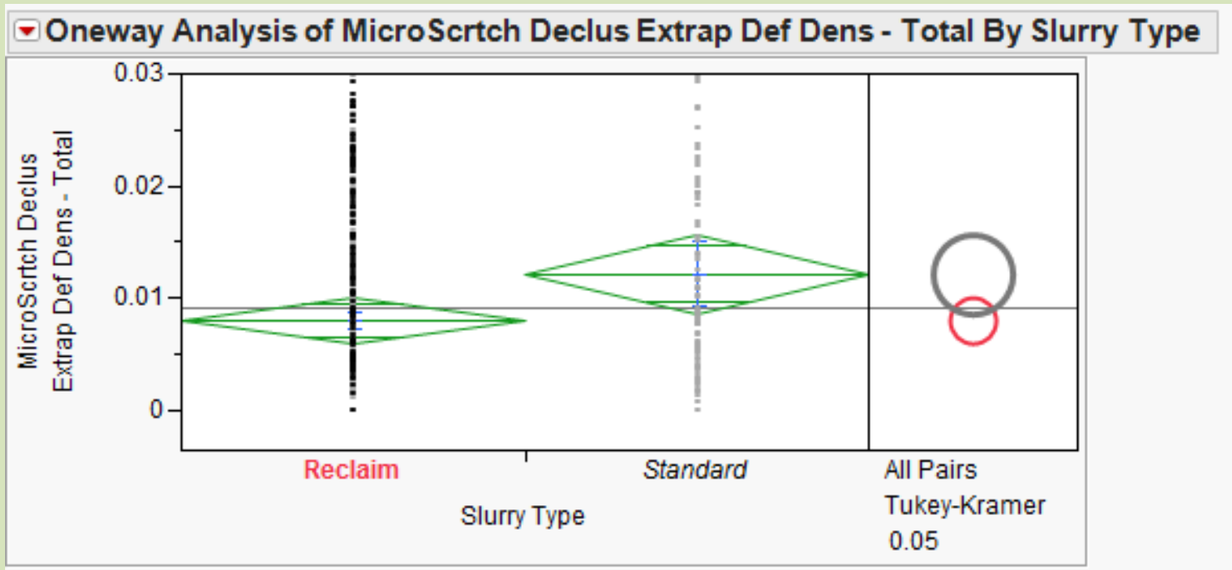
Ceria Slurry Recycling: Micro-scratching



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Reclaim	2719	0.007985	0.038094	0.00073	0.00655	0.00942
Standard	909	0.012112	0.086337	0.00286	0.00649	0.01773

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
1.96062	0.05

LSD Threshold Matrix

Abs(Dif)-HSD

	Standard	Reclaim
Standard	-0.00500	0.00004
Reclaim	0.00004	-0.00289

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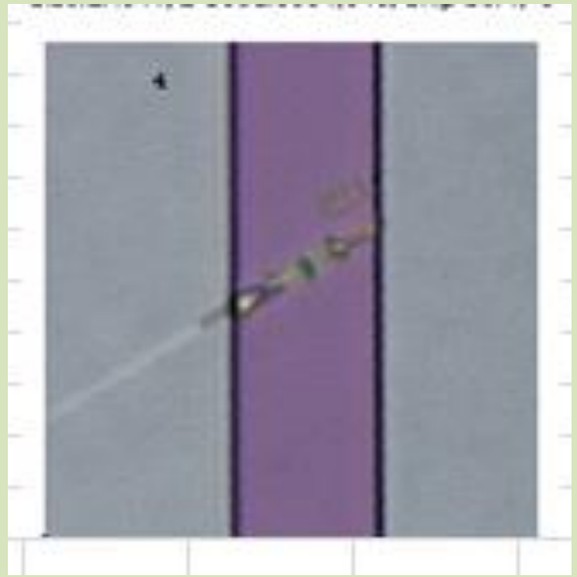
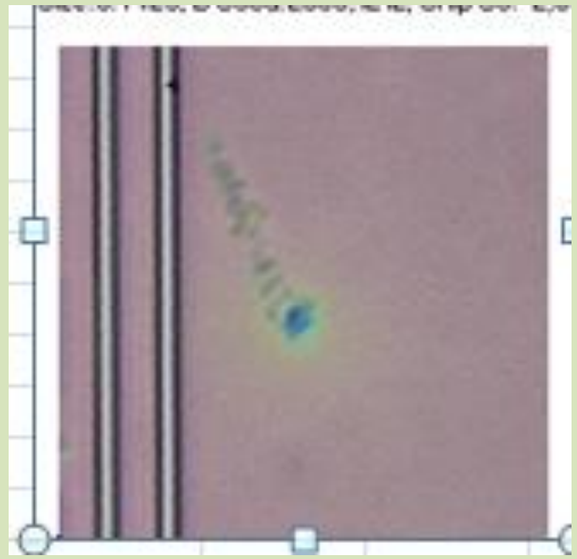
34% Improvement

Customer reported result: "Classified extrapolated micro-scratch defect density was 34% lower for reclaimed slurry on 65nm production wafers."



Deeper scratches with 2-step, 2-slurry polish process.



Scratches are more shallow with recycled Ceria slurry.

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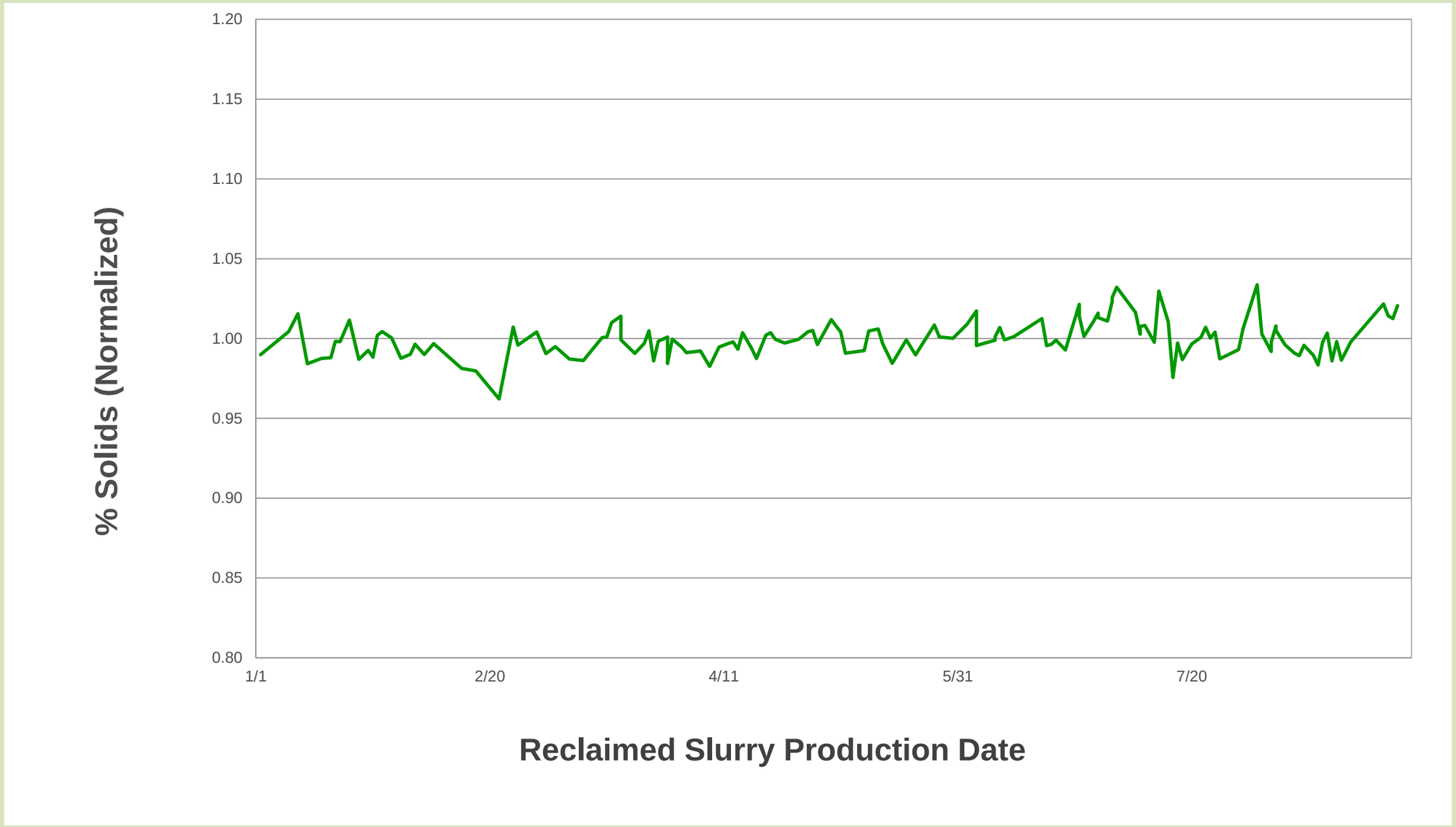
Ceria Slurry Recycling: Long Term Stability



Customer reported result: "Very stable and consistent %total solid results from High-Q: %1.01 +/- 0.01 (normalized data)"

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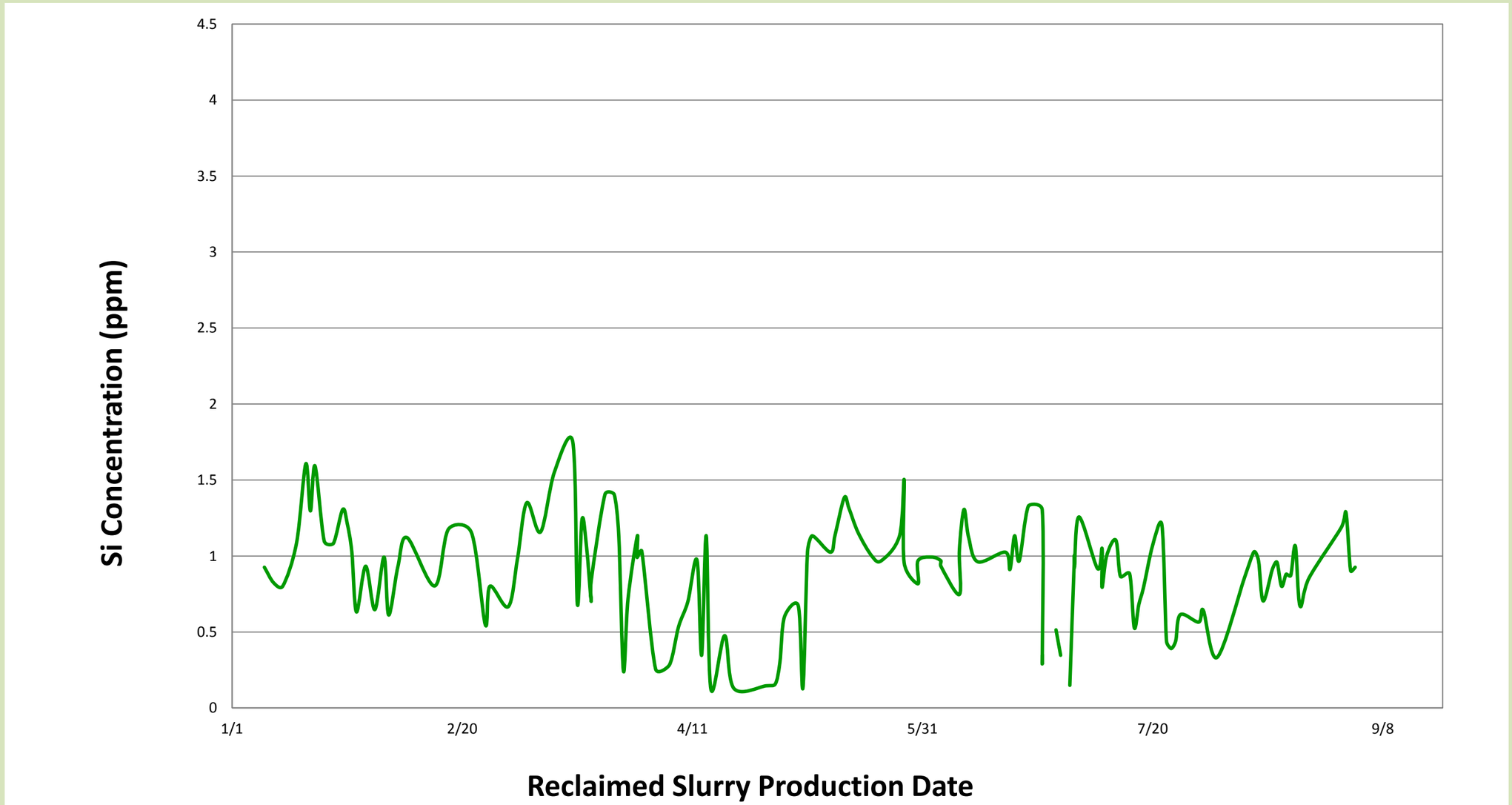
Ceria Slurry Recycling: Long Term Stability



Customer reported result: "No buildup of Silicon in the Ceria slurry reclaim system over time: Silicon concentration well below 5ppm "

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Ceria Slurry Recycling: Summary

- **Why?**
  - **Slurry Costs**
  - **Environmental Impact**
  - **Ceria Slurry Performance**

- **When?**
  - **2000 – 2013 Development**
  - **2013 – Present High Volume Manufacturing with Ceria Slurry**

- **Where?**
  - **Cypress Technologies, Austin, TX**
  - **Next - TBD**

- **How?**
  - **Robust Design**
  - **Self Cleaning**
  - **Closed Loop Quality Control**

- **How Well? (Performance)**
  - **Matched Removal**
  - **34 – 38% Defectivity Improvement**
  - **Stable/Sustainable Solids Concentration**
  - **No Accumulation of Impurities**

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Thank you for your attention!

ACKNOWLEDGMENTS:

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