



Building A More Sustainable CuCMP Process

Selective Copper Removal & Recovery

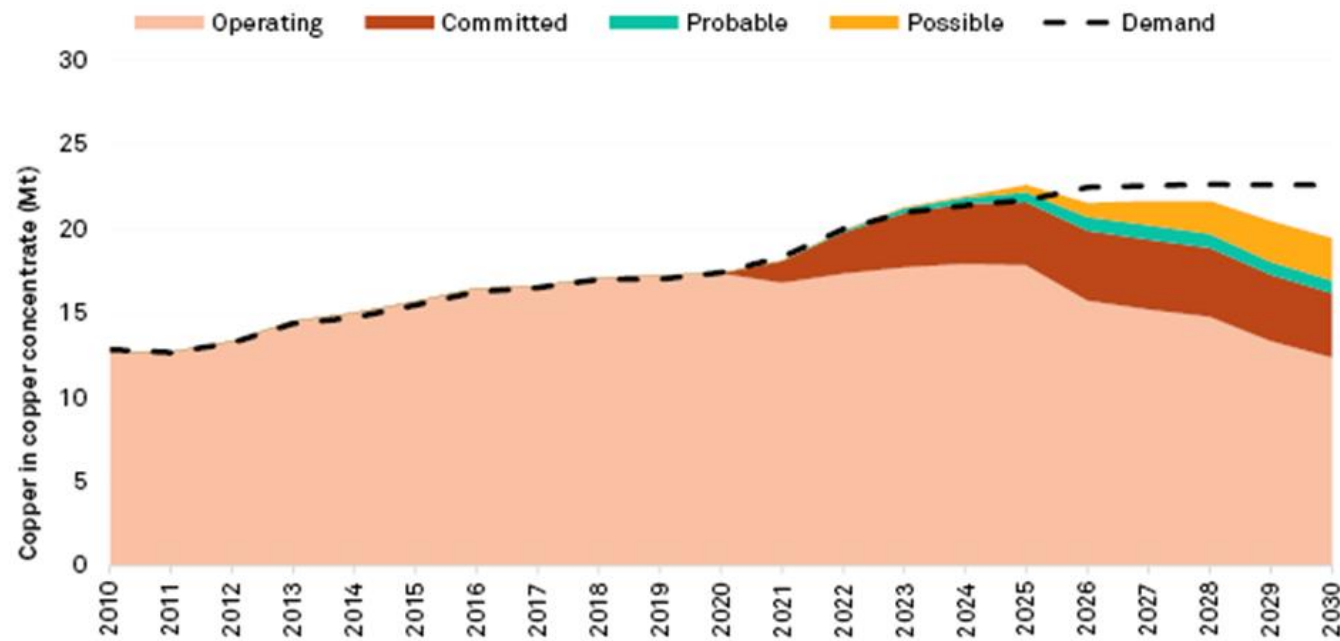


CAMERON LIPPERT, PHD | CO-FOUNDER + CHIEF INNOVATION OFFICER

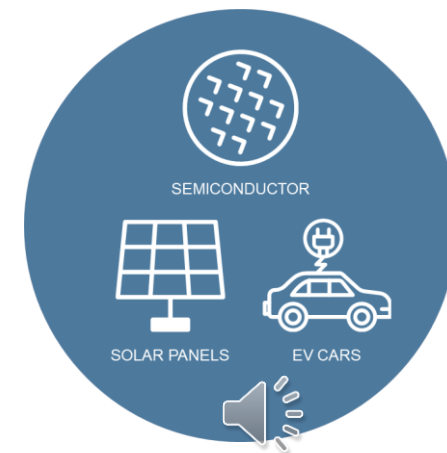


Looming Copper Supply Gap – Metals are Key for the Future

> 2,000,000 lbs of Copper Waste Every Year in US Fabs!



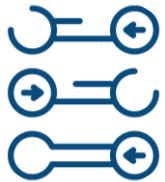
Copper is a **Critical Component** for Electrification



Incumbent Treatment Options to Meet Compliance

Outdated Tools for the Job

Incumbent Process



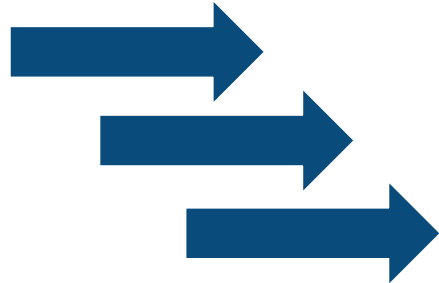
Ion Exchange



Chemicals



Trucking Off-Site



Resulting Challenges



Haz Waste
Generation



GHG
Emissions



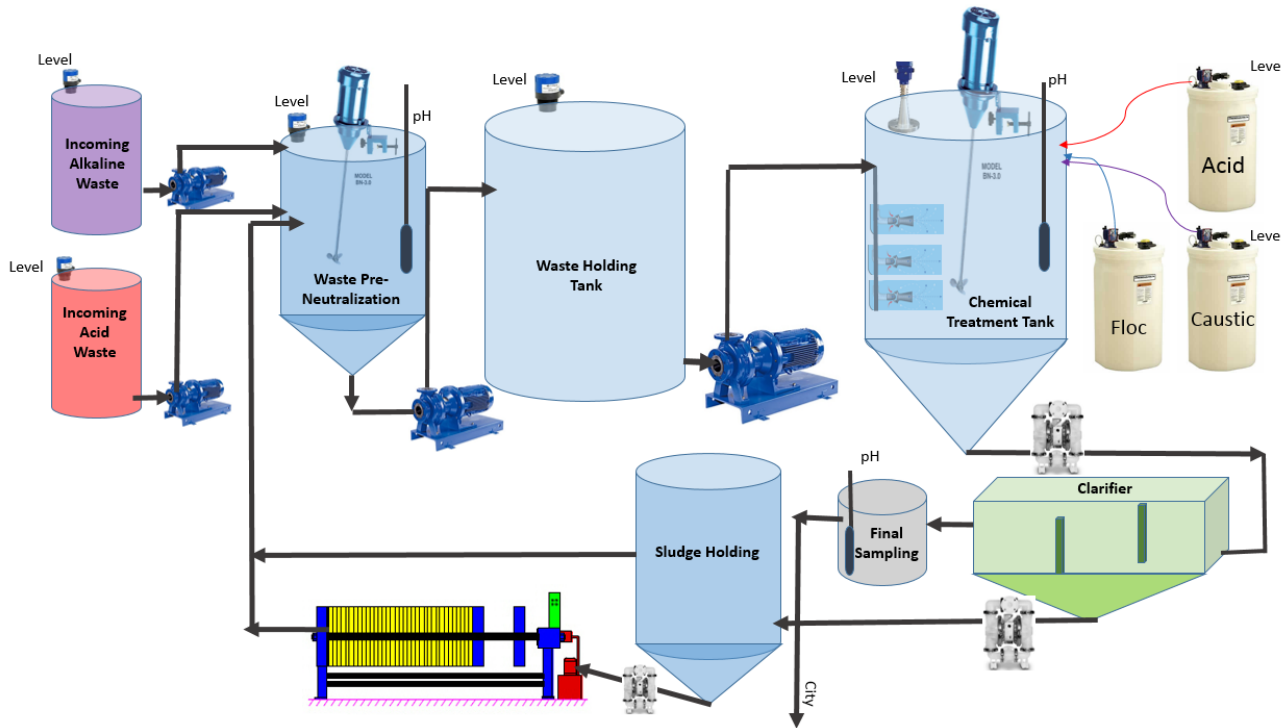
Supply Chain
Risk



Incumbent Treatment Options to Meet Compliance

Chemistry & Trucking

Chemical Coagulation



Challenges with Chemistry

- Poor performance with chelators
- Interferences with peroxide
- Highly susceptible to upstream changes

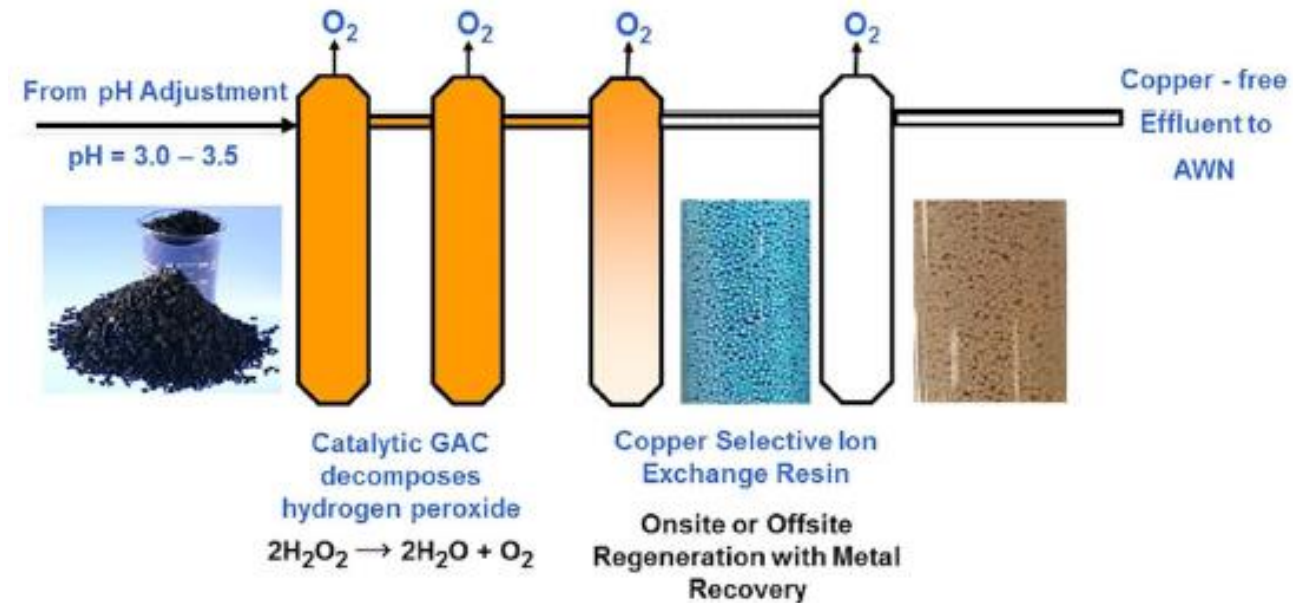


Incumbent Treatment Options to Meet Compliance

Ion-Exchange Process Solution

Typical Copper CMP Wastewater Composition

Component	Range
Copper	5 – 100 ppm
Hydrogen Peroxide	50 – 1,000 ppm
Total Solids	500 – 5,000 ppm
Organic Chelators	10 – 50 ppm
TOC	10 – 100 ppm
Triazole(s)	50 – 200 ppm
pH	2 - 6

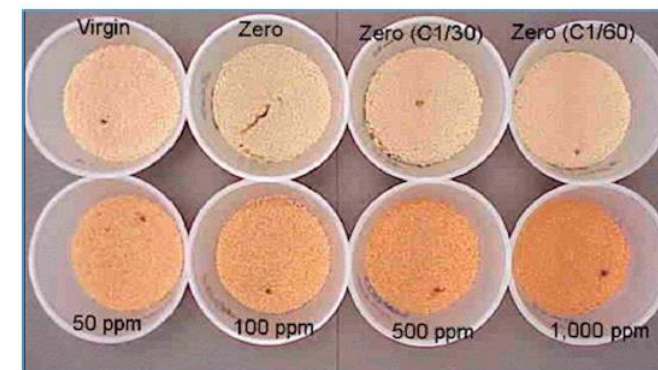
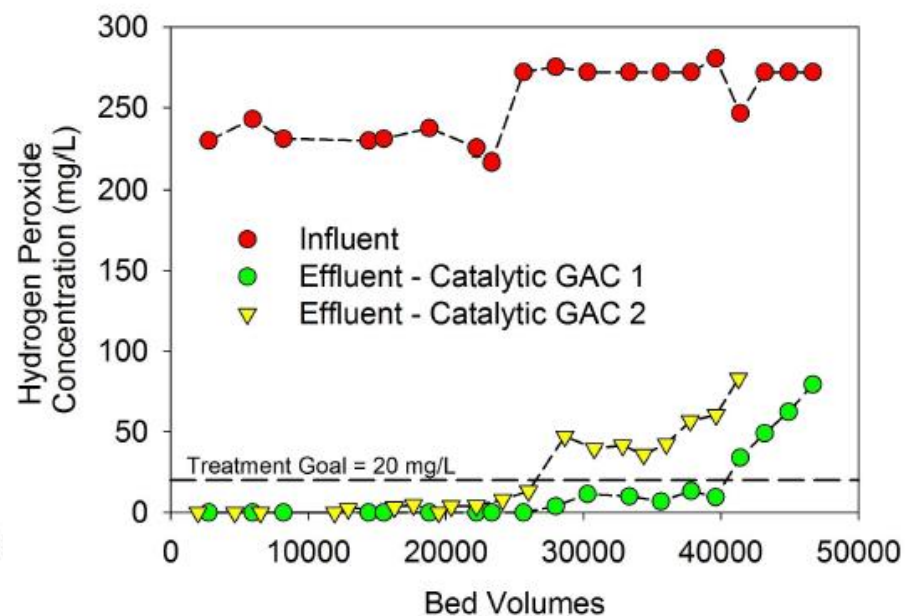
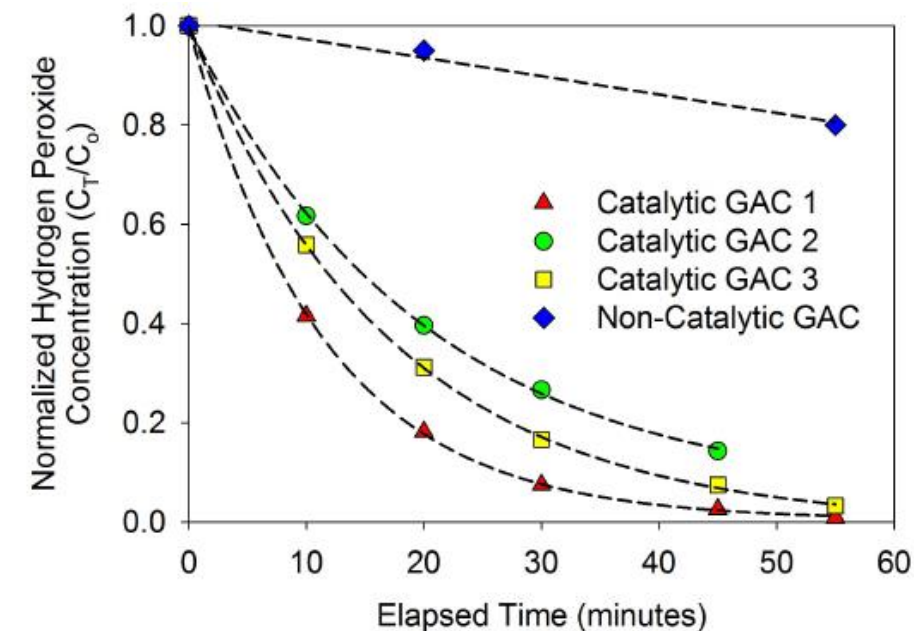


Wisner, M.; Woodling, R. “Copper CMP Treatment Using the Copper Select™ Process”, *Semiconductor Fabtech*, 25th ed., pp. 51-55, (2005).

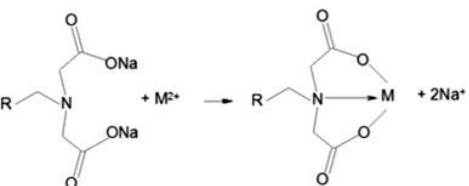
Wisner, M.; Riley, C.; Redding, A “An Approach for Copper and Hydrogen Peroxide Removal from Copper CMP and Solar Cell Wastewater”, *Ultrapure Water* (2016).

Ion-Exchange is NOT Peroxide Tolerant

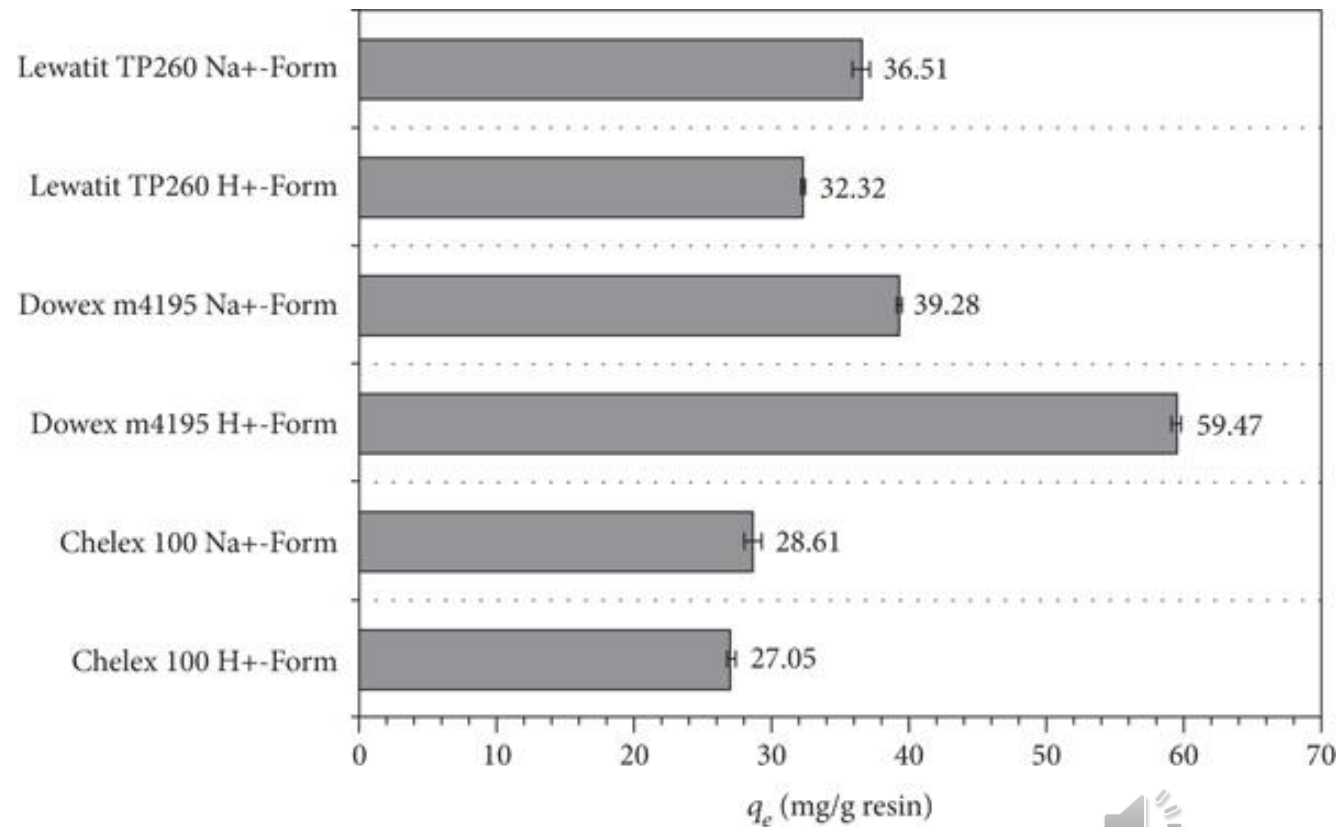
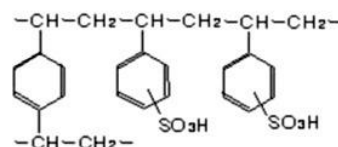
GAC - Peroxide Treatment



Copper Selective Resins Need Higher Capacity



vs.



Pros & Cons of Ion-Exchange for CMP Wastewater



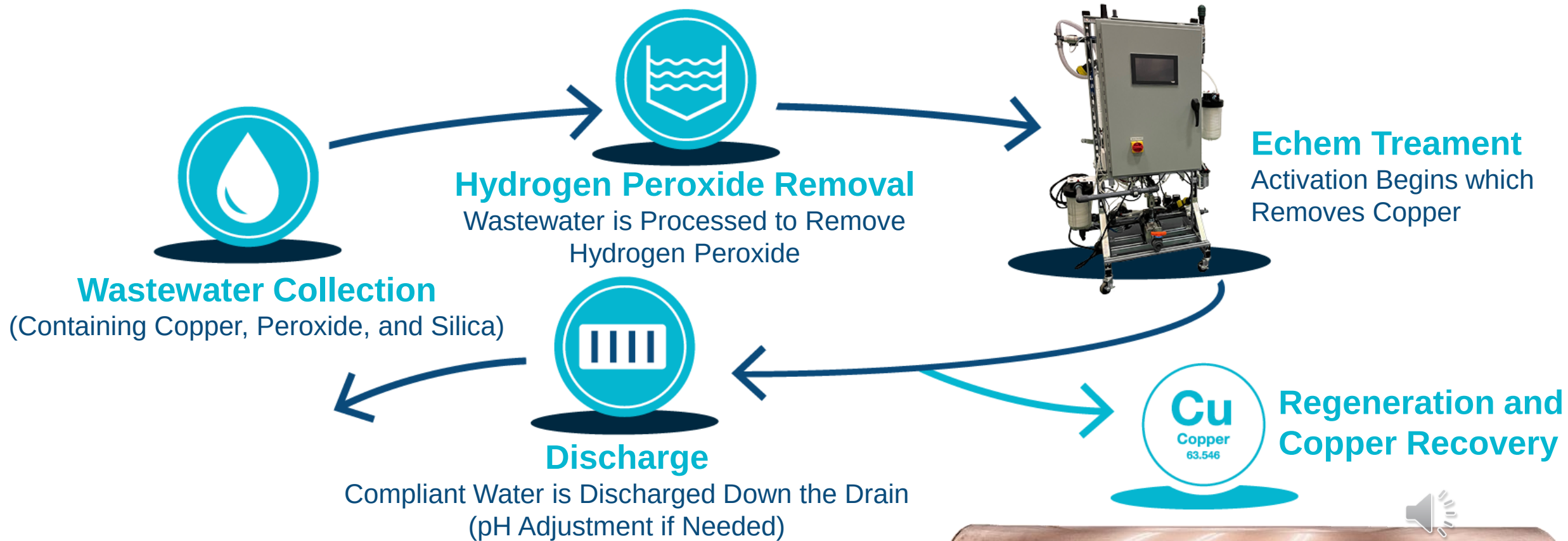
- Excellent copper removal capability (assuming appropriate resin choice and operating conditions)
- Common and familiar unit operation in a fab facilities



- Pre-treatment required to prevent resin fouling and degradation (eg, removal of oxidants and organics necessary)
- Expensive regeneration system
- Lower system flexibility for subsequent upstream process changes

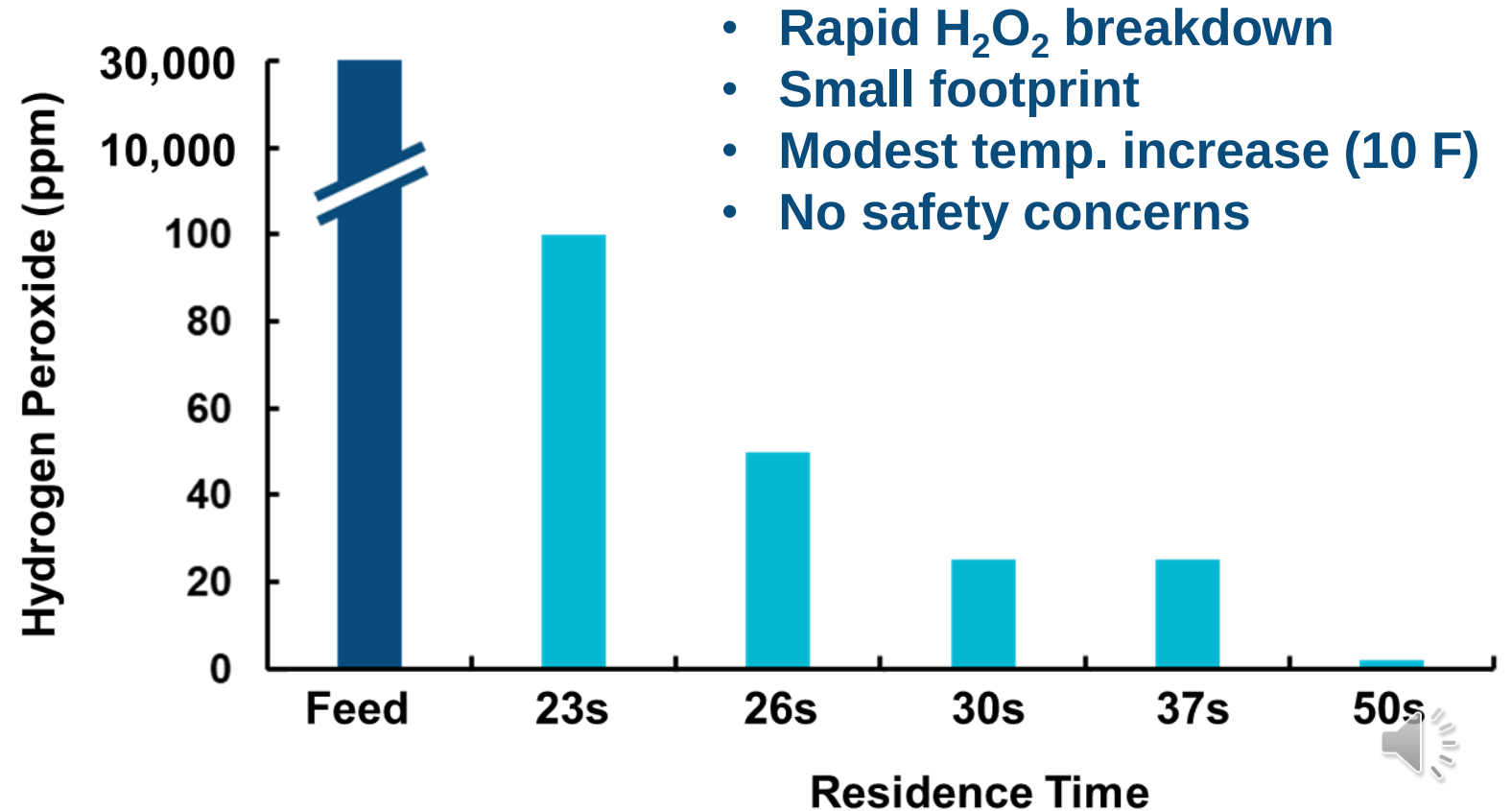
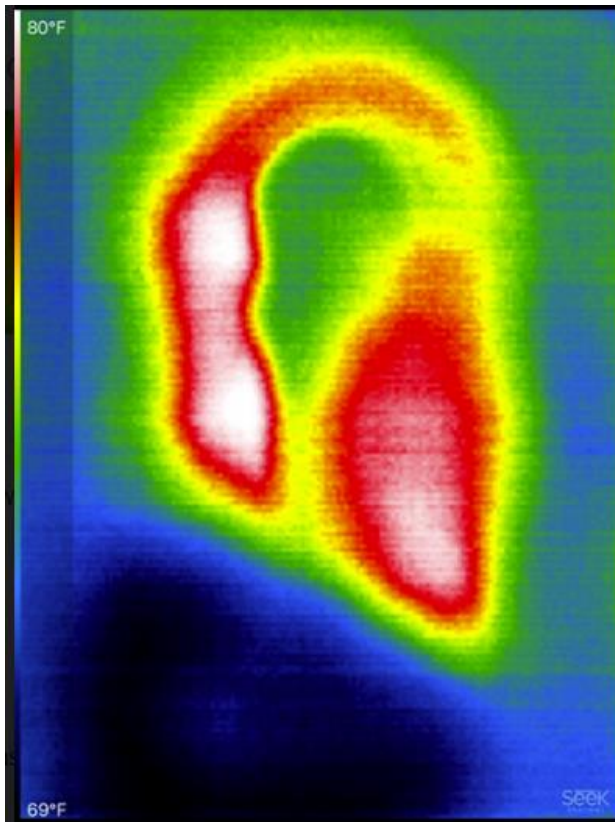


A New Tool – A New Flow Chart



Heterogenous Peroxide Destruction Media

Peroxide Destruction Column

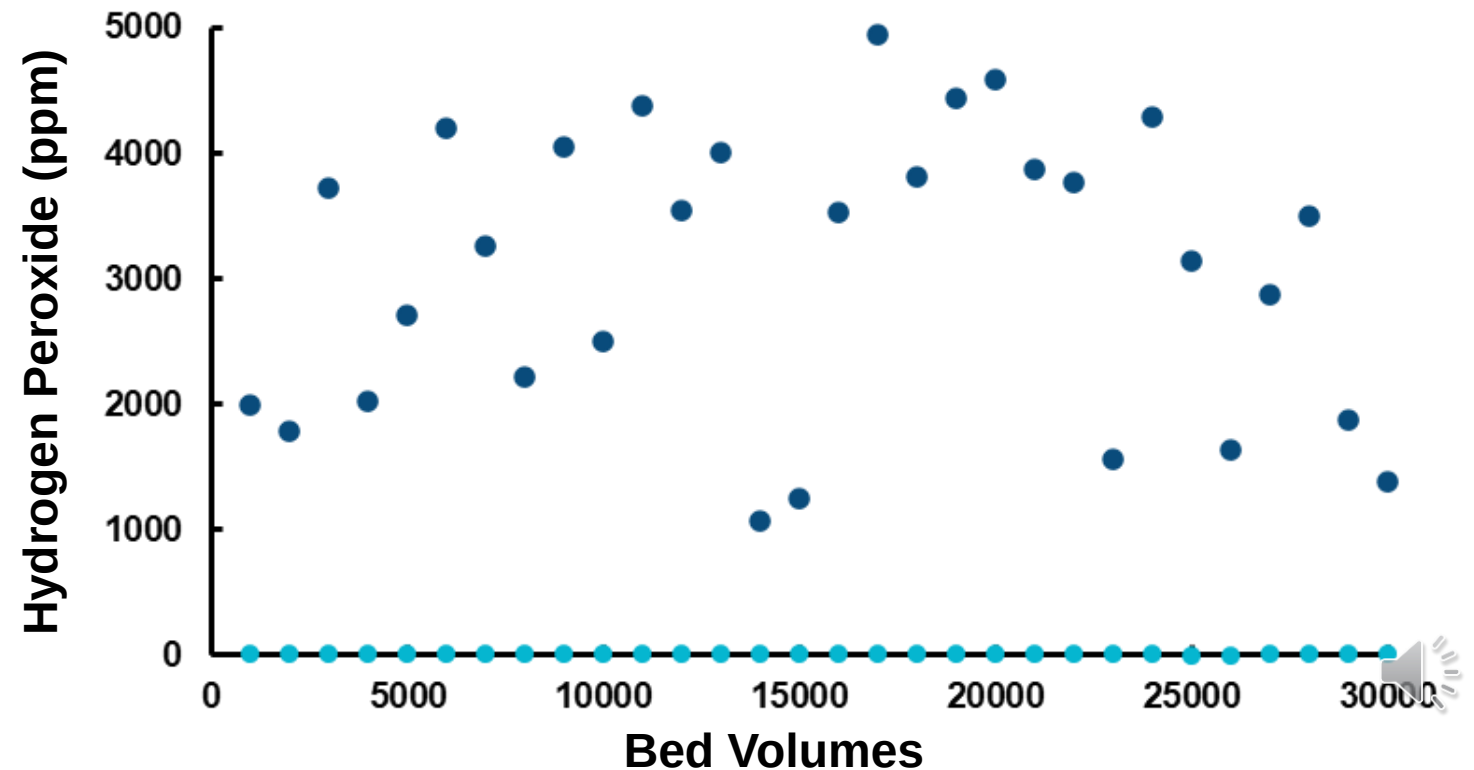


Commercial Peroxide Destruction Installation

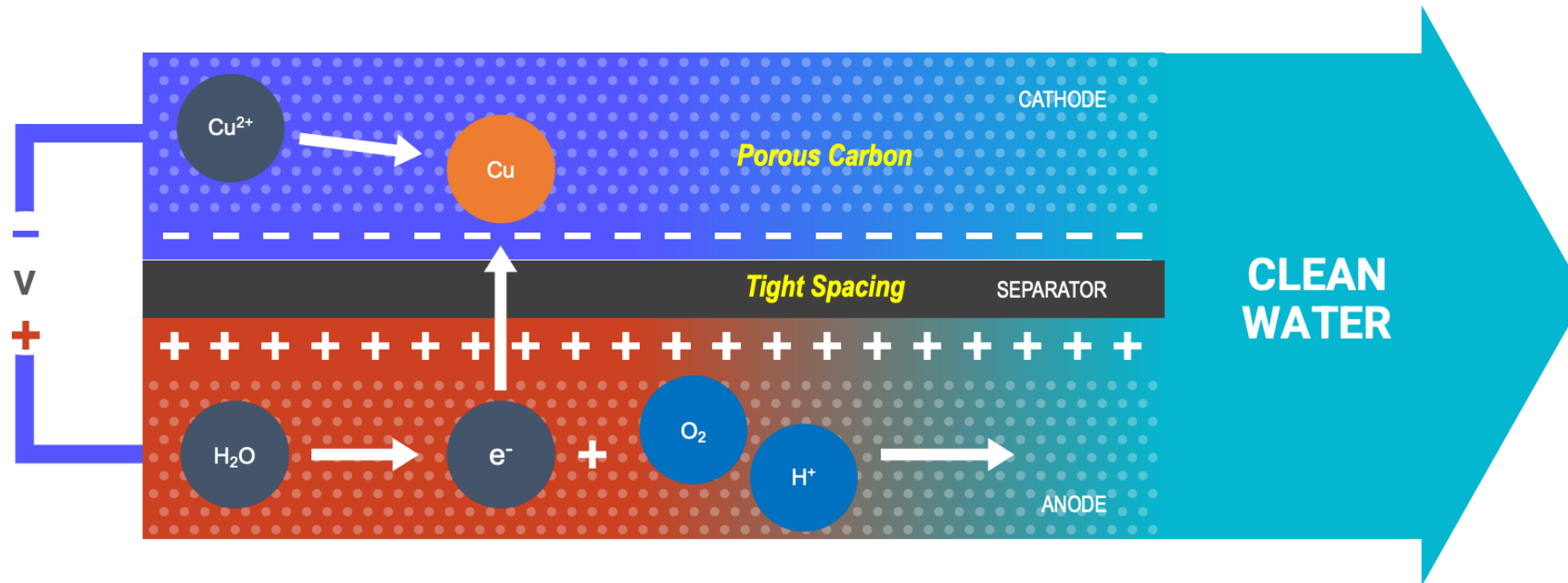
Peroxide Destruction Column



- 2 Years of Commercial Operation
- Highly Dynamic Feed [H_2O_2]



Electrochemical Reactor Design for Dilute Copper

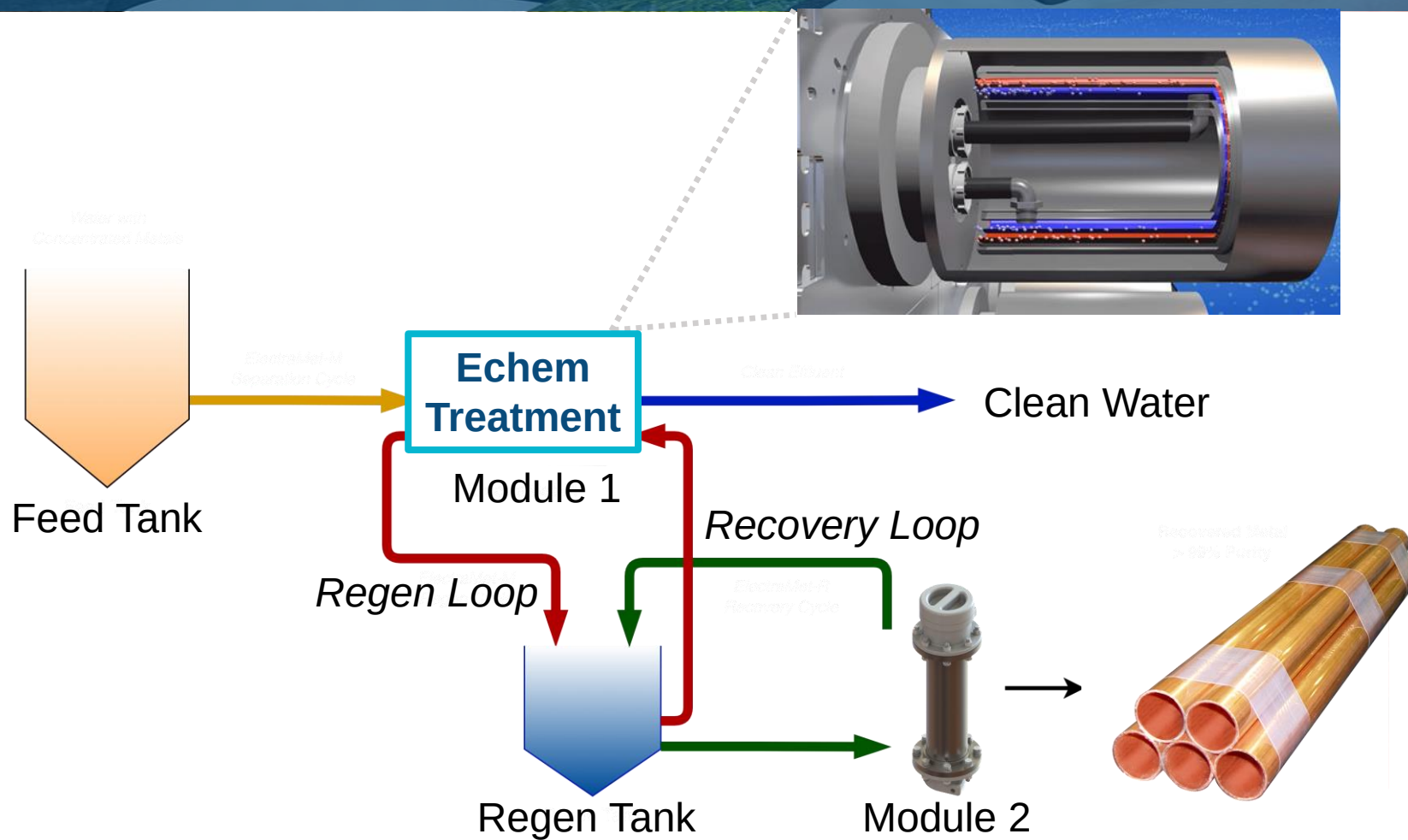


Water Quality Considerations

- Low TSS (< 10 ppm)
- TOC/COD/BOD (< 100 ppm)
- Biological/Microbes (N/A)



Copper Removal & Recovery



Delivering Proven Success – Traditional CuCMP Processes



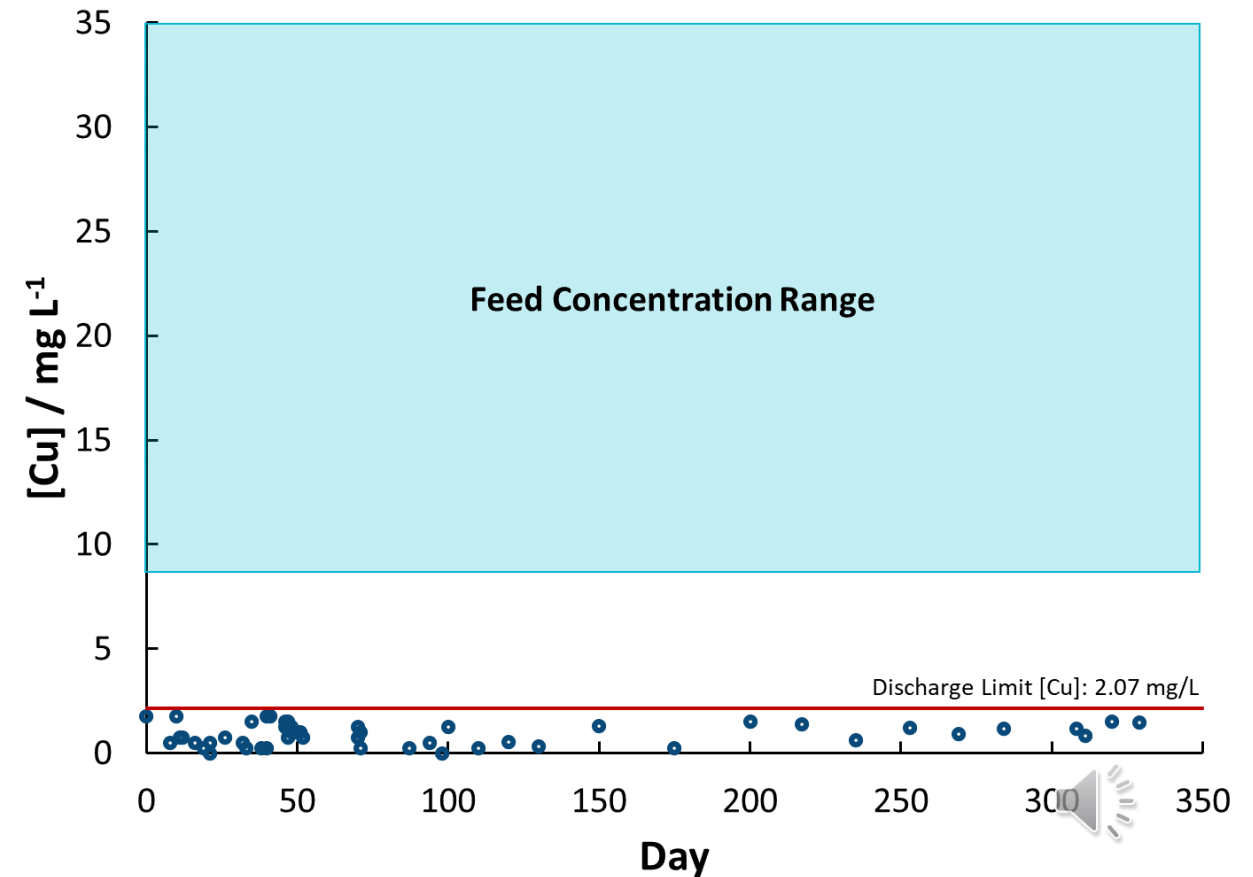
24 Months of Steady Operation

- 100% Planned Uptime
- Consistently and Reliably Met Permit Discharge Limit



Automated Process Adaptation

- Tolerable to Upstream Process Changes
- Adapts to Dynamic Upstream Process Changes Such as Large [Cu] Fluctuations & Peroxide Bleed Through

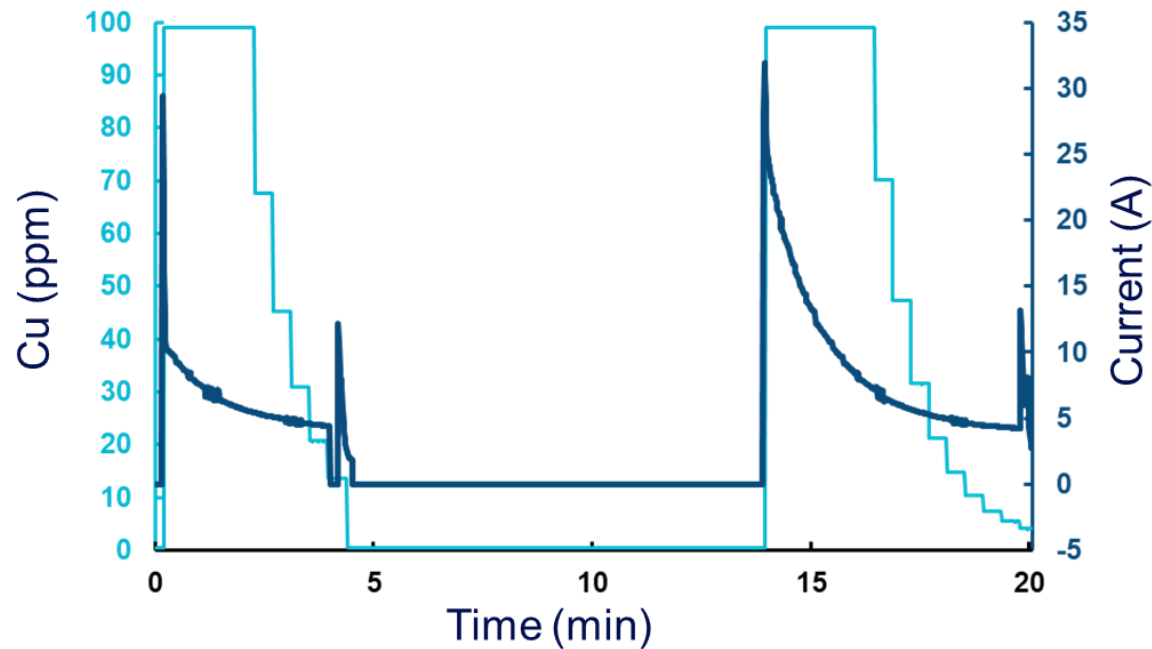


Delivering Proven Success – Traditional CuCMP Processes



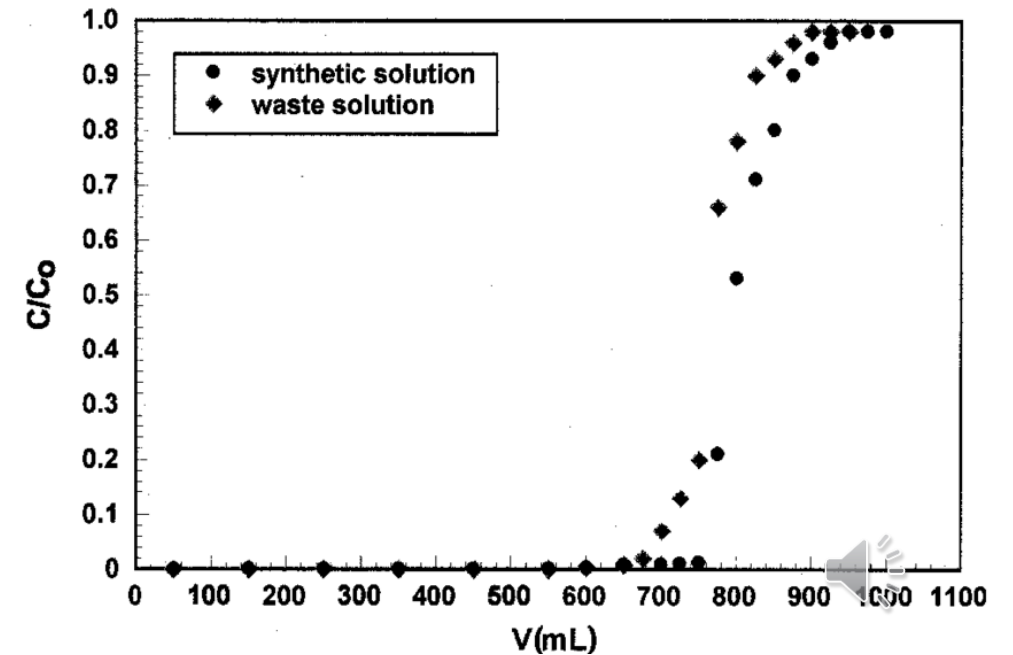
Echem: Inherent Feedback Signal

- Floating current (amps) matches [Cu] levels
- Automated dynamic operation



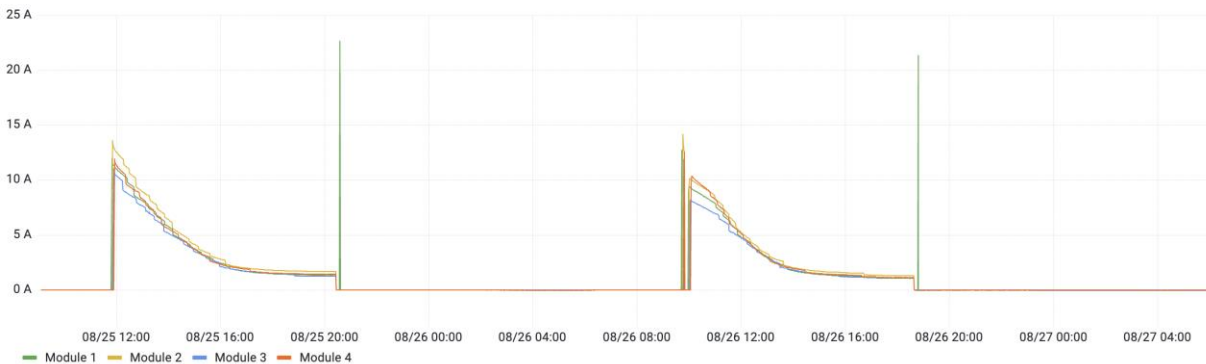
Phys. Chem: Blind → Breakthrough

- No real-time insights
- Need second system in case of breakthrough

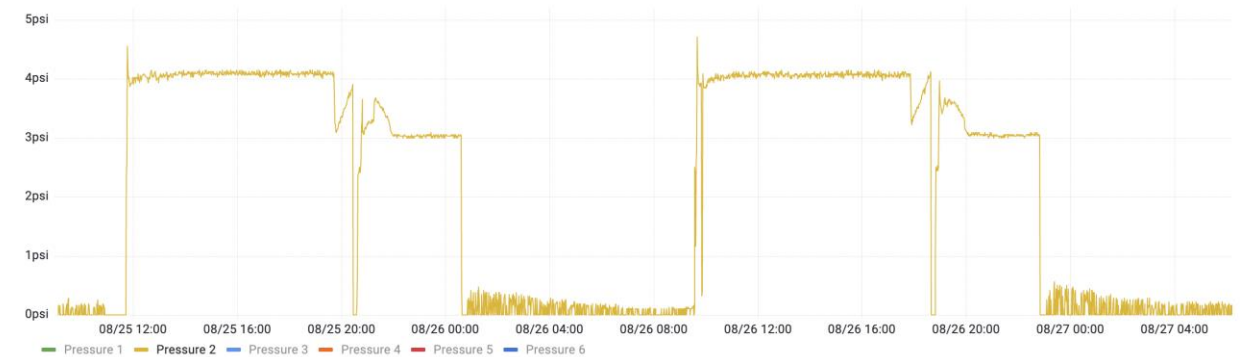


Delivering Proven Success – Traditional CuCMP Processes

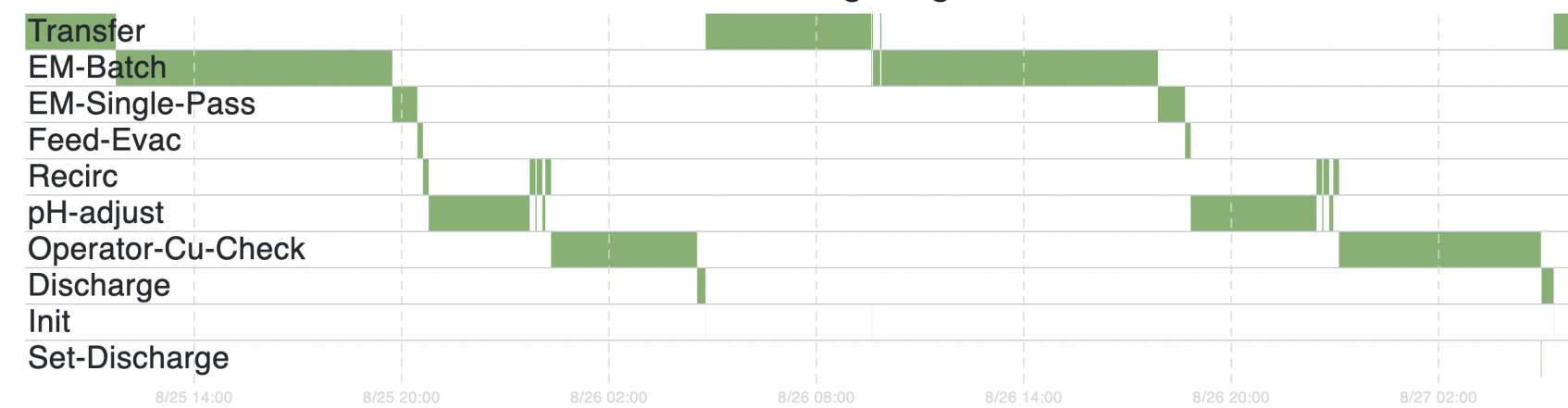
Current



Pressure



Process Timing Diagram



Trackable Parameters

- pH
- Temperature
- Flow
- TDS
- ORP
- Tank Levels



Delivering Proven Success – Emerging Slurry Technologies



Removes Copper from Stronger Chelates



Recover Cu as High Purity Sheets



Potential to Reuse Slurry



Delivering Proven Success – Commercial Installation



Electrochemical Systems Allow for a Smaller Footprint

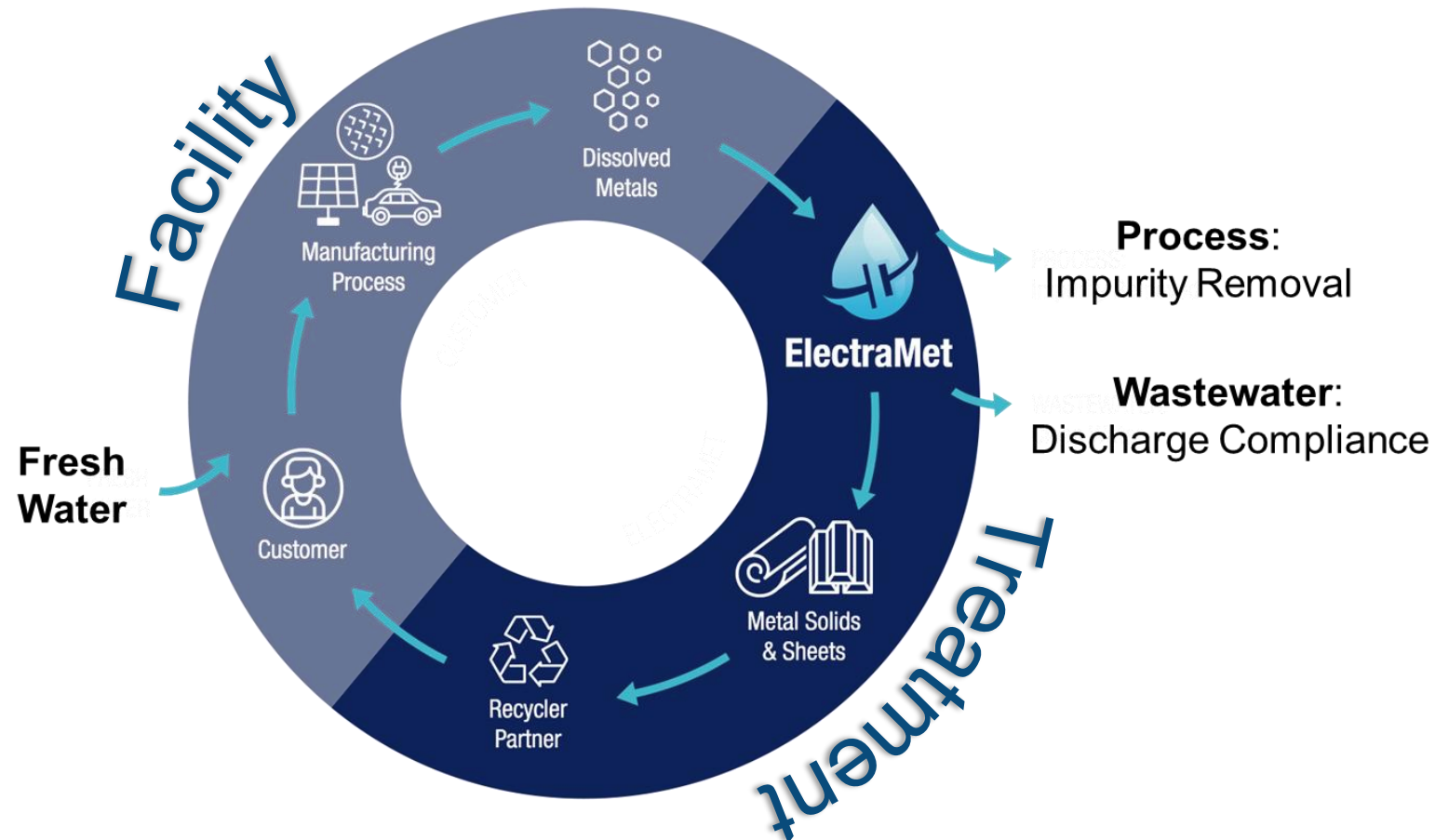
Power – 0.05 kWh/m³ Treated

Power – 0.6 kWh/m³ Treated



4.5ft D x 17ft L x 7ft H

Electrochemistry Enables a Circular Economy



Thank You | Q&A

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