ELECTRODEIONIZATION EVALUATION IN A SEMICONDUCTOR FAB RECYCLE SYSTEM

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Water Use Reduction--Goal or Aspiration?

•SIA *Roadmap* points to lowering use by 20-30 % every few years, perhaps by Rinse Optimization, Extreme Rinse Optimization, Recycle, Dry processes, ??.

But, the alternatives are-

* not clearly outstanding--require device level testing, equipment changes, correctly operating wet benches.

* only partial answers (percentages being a trade-off between facilities operations and recovery).

Water Use Reduction--Goal

- Meet the *Roadmap* milestones;
- Break even (or save money) in reduced water use;
- Lose no wafers (same rinse quality);
- No increased fab downtime (from poorly engineered UPW system);
- No adverse impact on UPW COO (excluding water costs);
- Meet community use/discharge needs (the actual driver to water conservation).

Water Use Reduction--Aspiration

- *Exceed* the *Roadmap* milestones by a nautical mile;
- *Management-visible* ROI in water use/discharge costs;
- Lose *no* wafers (better rinse quality with ***no*** water use constraints--increased margin);
- *Decreased* fab downtime (isolated from 'not my fault' feedwater problems);
- *Positive* impact on UPW COO (excluding water costs);
- *Far Exceed* community use/discharge needs (be a community leader).

Aspirations--Anything else while we're at it?

- *Lower* system maintenance by reducing equipment size (lower flows, pressures--fewer joints, PLC's);
- *Lower chemical use* by lessening RO, UF, media, carbon cleans; fewer filter changes; reduced regens;
- *Lower* energy costs;
- *Lower* downtime exposure with easier to manage hardware (smaller RO, UF, # of components, spares..);
- *Increase* water quality to the fab;
- *Far Exceed* community use/discharge needs (the actual driver to water conservation).

Is there more? *Yes!!*

- Support fab expansion with just pumps & pipes, *no* new generation equipment, *no* more acreage;
- *Increase AWN efficiency* by reducing the massive water load;
- *Recover* 'difficult' water (with some organic loading);
- *Even CMP water* (you do have to remove particles).

What Is EDI About?

ElectroDeionization

- **EDI is a separate- or mixed-bed resin in a strong electric field.**
- **EDI works like an ideal resin with real-time regeneration to *as-new* performance.**
- **EDI removes up to 99+% of the mineral load of (pretreated) water to deliver treated water of high purity, normally in the 10 to 18-megohm-cm range**
- **EDI units can be stacked to recover thousands of gpm.**

Why Hasn't EDI Worked Before? Cons & Pros.

Issue:	*Vendors Consensus:*	*Recycle view:*
Feed stream contents	**Conductivity too high/low**	**To Be Determined (TBD)**
	Conductivity too variable	**Variable, but 'too' is subjective. TBD**
	Unknown components	**Known components-unlike city water**
Concentrate stream conductivity	**Too high--will deposit scale**	**Won't scale--no cations except ammonium ion, unlike city water.**
	pH too low	**TBD**
Organics	**Too many**	**Virtually none, unlike city water.**
Iron contamination	**EDI very sensitive**	**No Iron in our fab water!**
Hydrogen Peroxide	**Sensitive--must avoid**	**Removed in Carbon Bed.**
COO	**Should be OK**	**Should be impressive!**

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Heard on the Street....

Glowing Testimonials

"Your goal to replace your cation/ anion train with an EDI unit is not recommended.."

"Is EDI to replace an existing DI unit, thereby reducing process design flexibility to near zero?"

"...at some elevated concentration, other deionization methods (RO?) will be more effective."

"….desire to recycle as much water as possible, but EDI is a polishing technology."

"...applied EDI on raw waters, softened waters, and waste waters with high conductivities. The results were not good..."

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Our Modest Needs...

Parameter	***Typical Feedwater Characteristics--Classic EDI***	***--Needs as Used in Recycle***
Conductivity	< 40 uS/cm	<300 uS/cm
Hardness	<0.25-1.0 ppm as CaCO3	N/A--No 'hardness' cations
TOC	<0.5 ppm	<100 ppb
Pressure	20-50 psi.	Dial-in
Temperature	10 to 35^{o} C	Keep it <30^{o} C
pH	4 to 10	Tolerate <2
Chlorine	<0.1 ppm	None
Fe, Mn, Sulfide	<0.01 ppm	None/CMP*
CO2	<10 ppm	Highly variable, generally low

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Our Best Candidate--General Specs

Equipment	Ionics EDI 50
Nominal Capacity	50 gpm
Feed Connection	2" PVC 52.5 gpm @ 35 psi
Product Connection	2" PVC 50 gpm @ 50 psi
Recovery	95+%
Size	6’ by 12’

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FAQ Page

How is High Efficiency Achieved?

A single-stage 316 s.s. centrifugal pump recirculates the brine stream in a feed-and bleed arrangement to achieve 95+% recovery.

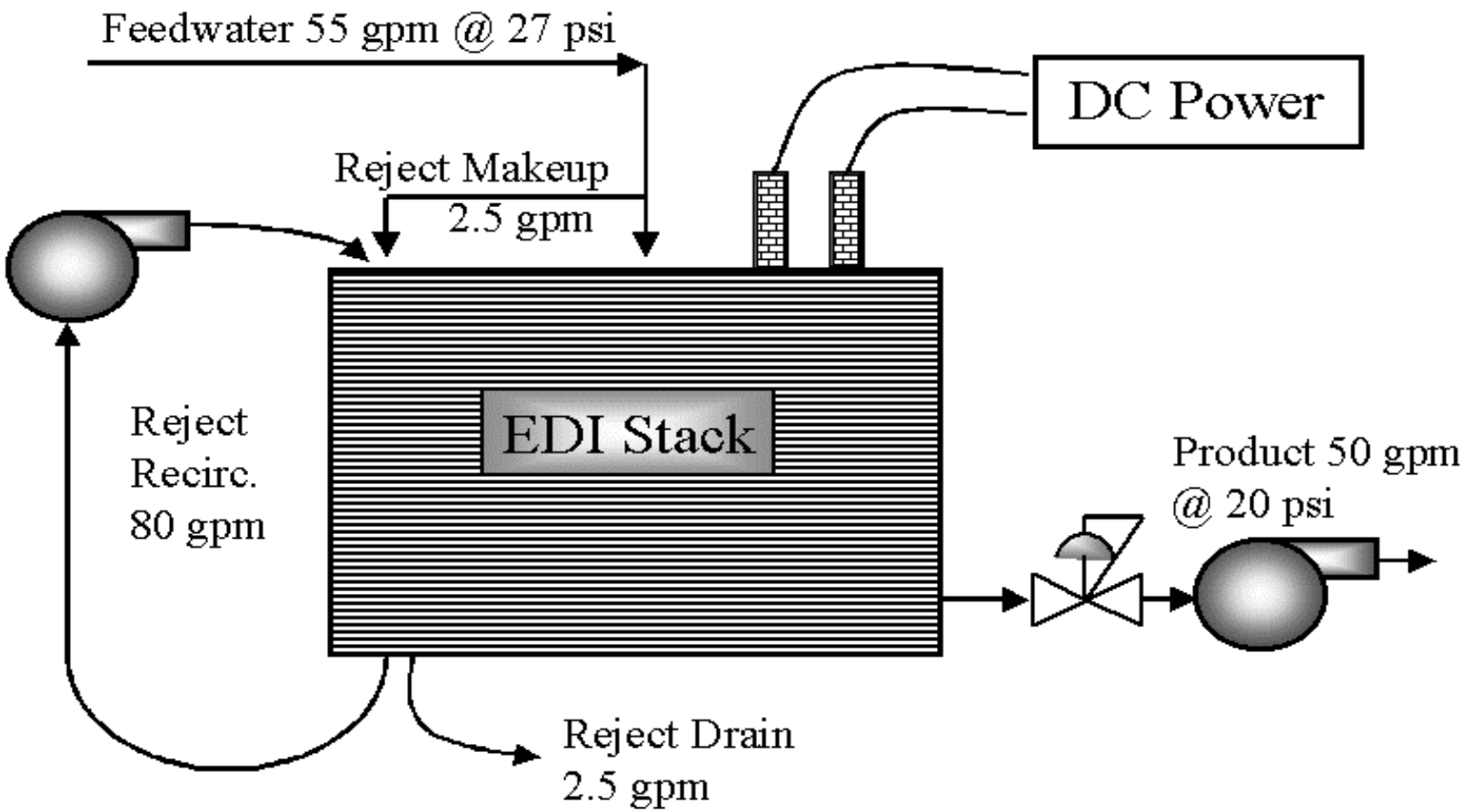
How Often is Maintenance Needed?

With proper pretreatment, EDI units operate 24 hours per day for months at a time with virtually no operator attention or maintenance. The pump skid supports a simple clean-in-place (CIP) subsystem.

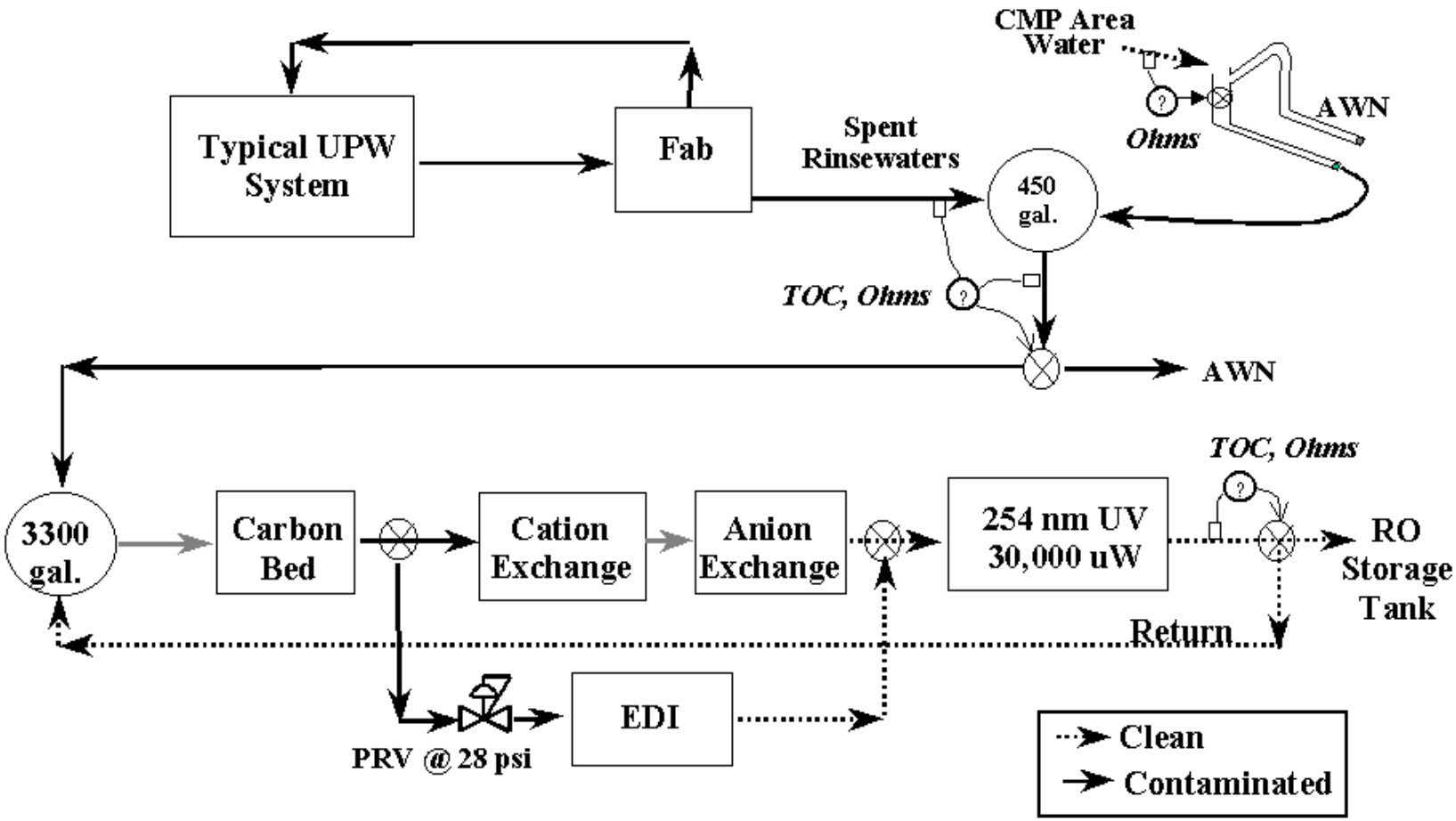
How is it Controlled?

A central PLC monitors and controls all pump, rectifier and instrumentation signals.

Schematic of the Stack



Installation



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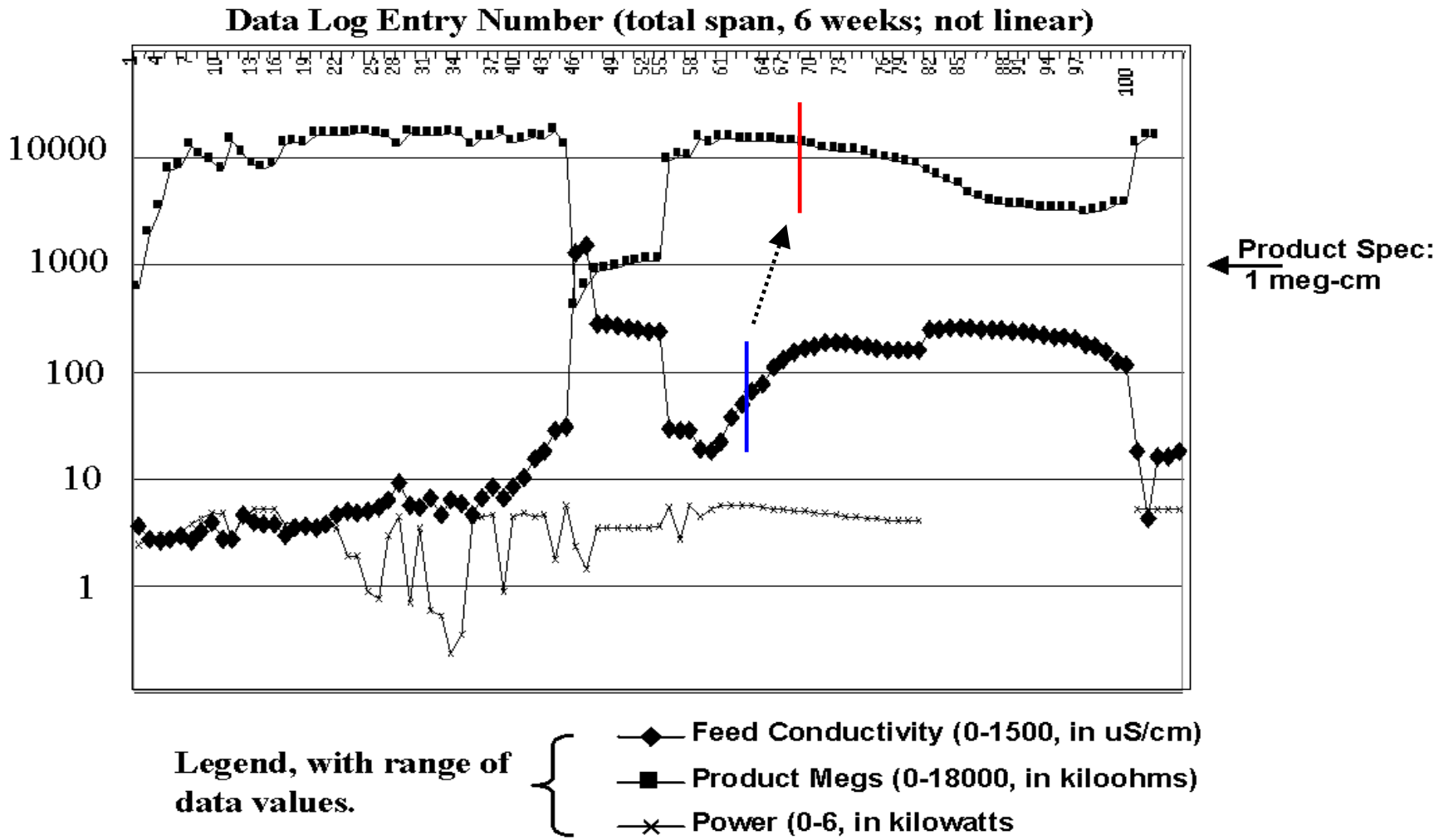
Testing

1. **Just let it run.**
2. **Connect *All* wetbenches. Disconnect diverters. Feed it some chemistry.**
3. **Time for action--we're getting impatient. Every 5 minutes--Rinse baths were treated to one of:**
   - *** 200 mls of SPM (85% Sulfuric Acid);**
   - *** 200 mls of Buffered Etch;**
   - *** 5% HF;**
   - *** 200 mls of 80% Phosphoric Acid;**
   - *** RCA chemistry.**
4. **'Corrosive' chemistry to look for dissolving EDI equipment.**
5. **Organics**

Our Early Marathon Tests



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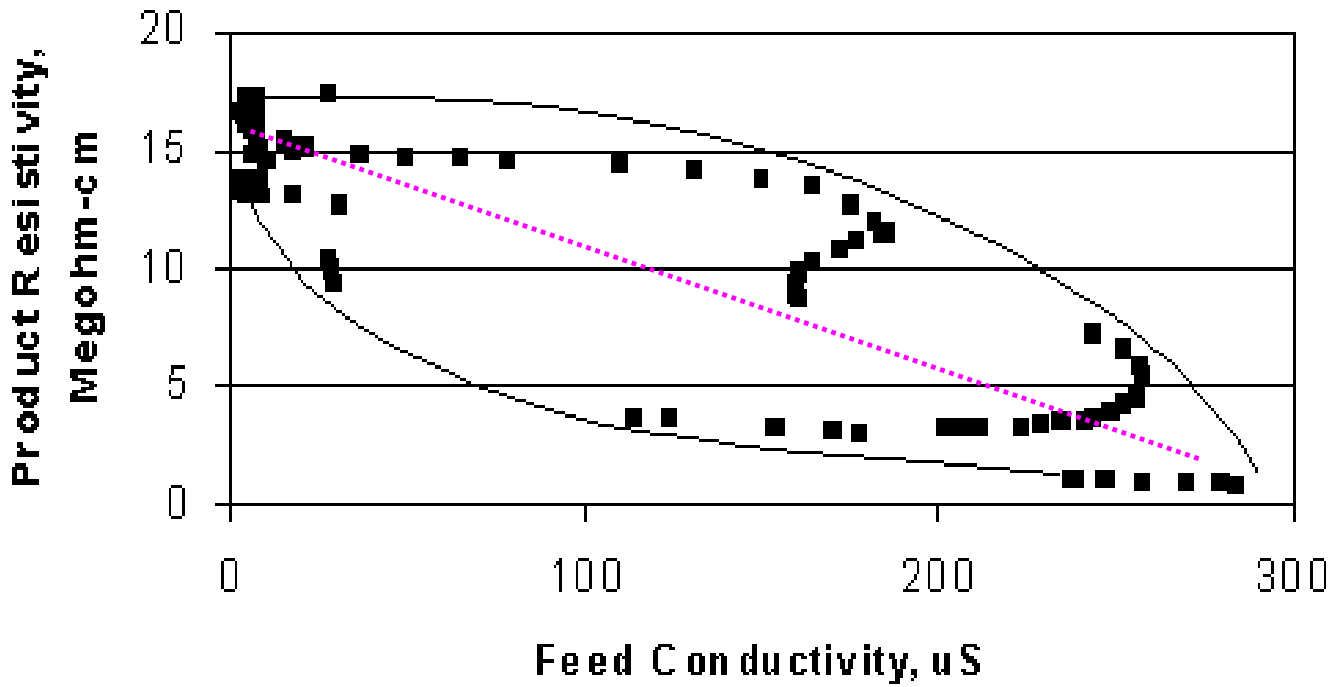
Success!! But, Interesting Patterns..

Product conductivity seems to lag feed conductivity. There is a delay between an event in the feed and the response of the product. There's also a lag in the brine conductivity. The response lag occurs with increasing or decreasing feed conductivity. Is there a relationship?



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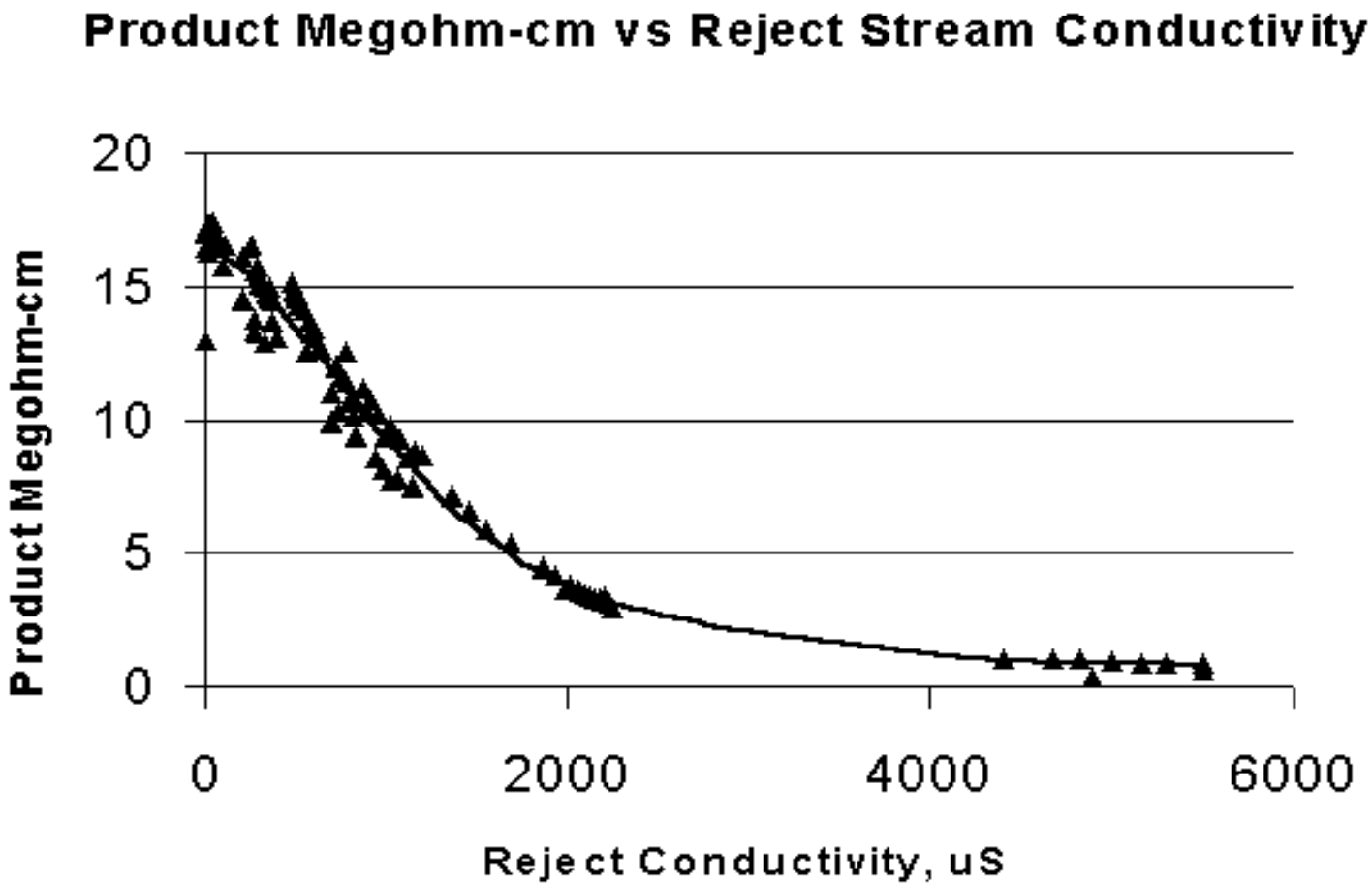
Dependence on Brine Concentration



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Dependence on Brine Concentration

- **Use the curve to predict product water resistivity.**
- **Dependence is due to flow paths and differential pressures between paths.**
- **The non-linear characteristics do not effect the desired result of obtaining high resistivity water for recycling.**
- **These results may offer some insight for vendors of EDI equipment to enhance the design for operation in a recycle application.**

Ion Survey in the Fluids

Element	*Detection Limit, ppb*	*Concentration in feed, ppb*	*in Brine, ppb*
Al	**0.5**	**6.4**	**7.8**
B	**2**	**2.9**	**480**
Cu	**0.5**	**nd**	**5.9**
Mg	**0.2**	**nd**	**0.7**
Si	**20**	**nd**	**850**
Si	**1 (in-house analyzer)**	**424 in feed, 2.76 in product**	**1134**
Na	**0.6**	**35**	**260**
Sn	**0.2**	**nd**	**0.9**
Zn	**0.5**	**1.0**	**0.8**

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Cost for HP--- 90 % Recycle

Item:	*Cost without EDI*	*Cost with EDI*	*UPW Operation Savings, first year*
Electric Power	$6,200 + $1,800	$800 + $2723	$4,377
Chemicals (regen, cleaning)	$8,000	$800	$6,200
Pre-RO Filters	$8,000	$800	$7,200
Cost of water/discharge	$156,666	$15,666	$141,000
Misc. items (maintenance)	$3,000	$3,000	0
M&L to install 50 GPM EDI		$100,000	-$100,000
Totals	$183,666	$123,789	**$59,877**
Totals with M&L upgrade to 100 gpm	$367,332 (twice 50 gpm costs)	$50,000 + $123,789	**$193,543**

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When Recycle? When Rinse Optimize?

- **Rinse Optimize to save time in a fully loaded fab.**
- **Rinse Optimize to save water any time.**
- **Rinse Optimize *difficult* chemistries.**
- **Recycle in a fully or partially loaded fab, before or after Optimization.**
- **Recycle to avoid wet bench leak maintenance.**

Conclusions & Future

- **Successfully removes fab rinse contamination (real and *simulated* chemistry) up to about 300 uS-cm;**
- **Removes silica and boron apparently without exhaustion;**
- **Removes (at least some) organics;**
- **Requires very little maintenance (one failure* so far).**
- **CMP/Copper plate water simulation (expect no problems);**
- **Time to look for more opportunities!! We've targeted scrubber water (aspiration--'zero' discharge) for the next round.**
- **Another volunteer? Two more HP sites have immediate needs, and will be assessed for use.**