REINHOLD ENVIRONMENTAL Ltd.

2018 APC & Wastewater Round Table & Expo Presentation

July 23 & 24, 2018 in Lexington, KY / Hosted by East Kentucky Power Coop

lessons learned in FGD wastewater treatment –

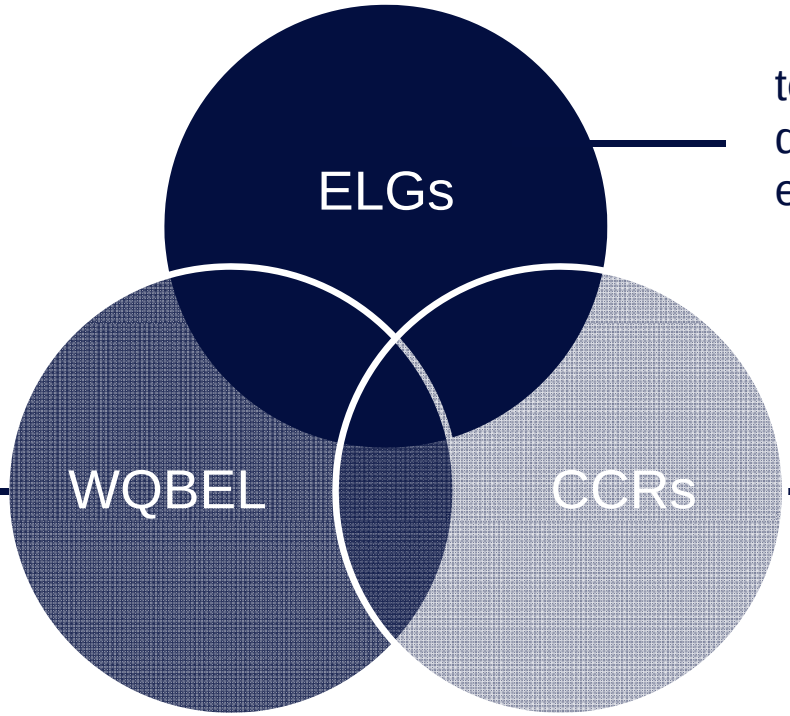
brine concentrators and physical-chemical treatment

July 2018

Lanny Weimer
Senior Product Manager

ready for the resource revolution

regulations impacting coal fired power plants

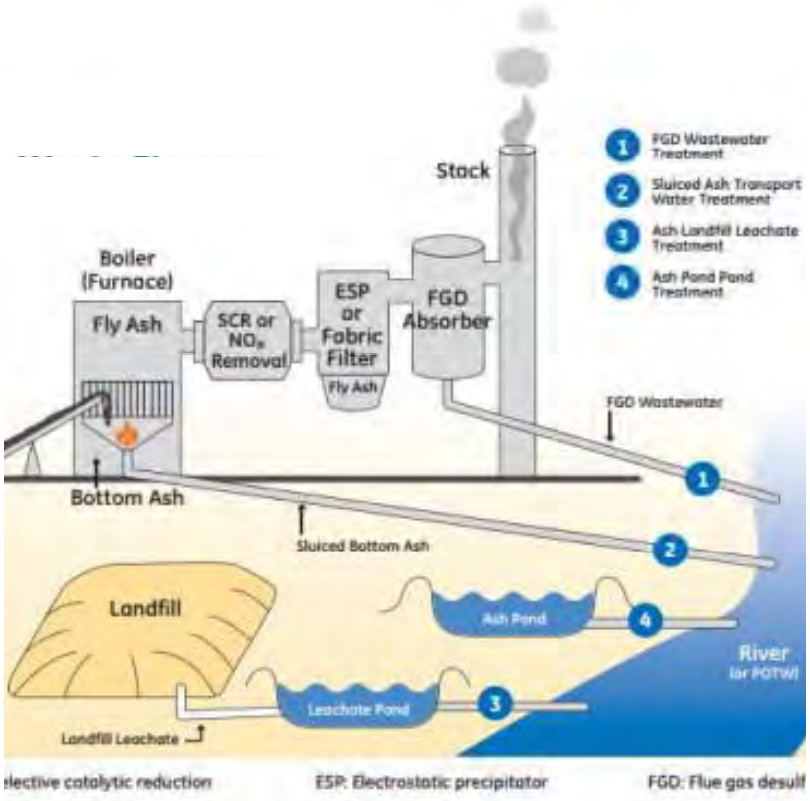


technology based water quality discharge limits for existing and new sources

water quality based effluent limits set by states

design and use of CCR impoundments

operations impacted by ELGs



- **FGD Blowdown**

  Treat & discharge or zero discharge required to meet ELG limits

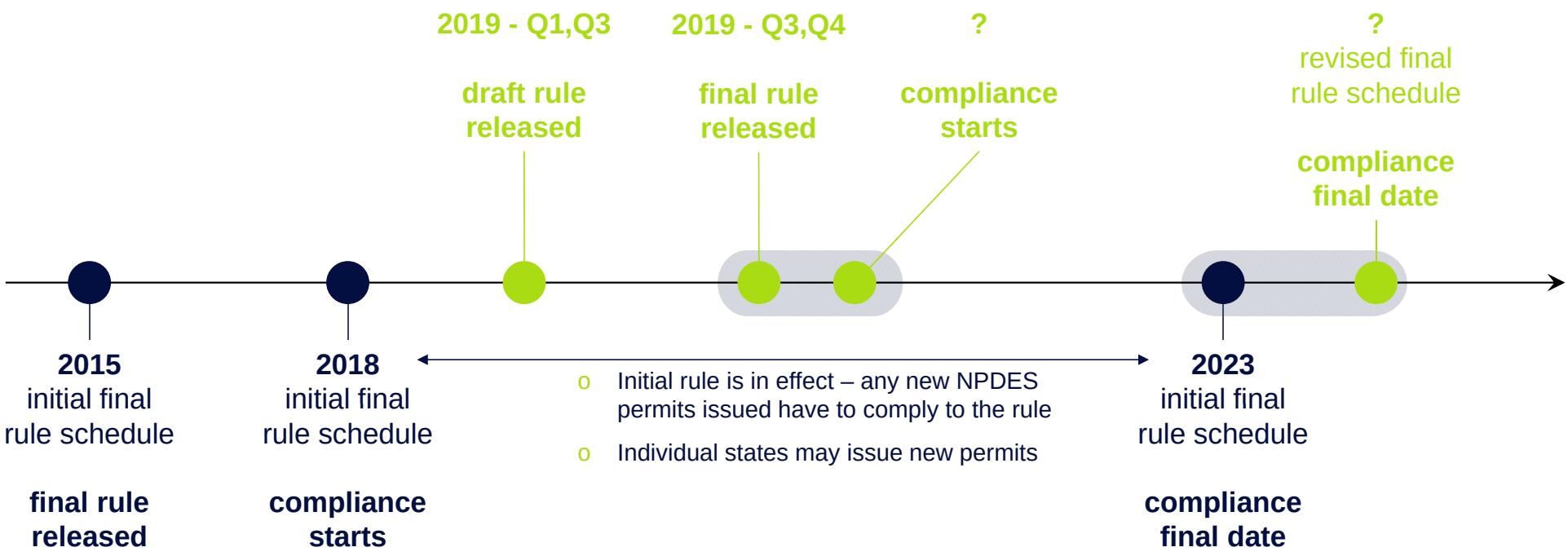
- **Ash Pond Remediation**

  requirements vary, but may require advanced treatment

- **Landfill Leachate**

  WQBELs regulations and local standards developed, enforced by State Regulators

revised rule expected 2019 - new discharge limits



treat & discharge options

- Physical/Chemical Treatment
- Advanced chemistries
- ABMet* biological treatment
- ZeeWeed* membrane utrafiltration

*Trademark of SUEZ; may be registered in one or more countries

zero discharge options

- Physical/Chemical Treatment
- Seeded Slurry Brine Concentration
- Mixed Salt Crystallization
- Pozzolanic Solidification

zero discharge project background

challenge

- Develop zero discharge system to treat 250 gpm FGD wastewater
- Recover >95% as high quality distillate for recycle
- Produce concentrated brine for fly ash wetting
- Provide redundancy for operational flexibility

solution

- Zero discharge system consisting of pretreatment + brine concentration
- Pretreatment - Lime softening/clarification to reduce magnesium, sulfate, TDS
- Brine concentration - falling film, MVR, seeded slurry evaporators
- Redundancy - 2 X 60% pretreatment + 2 X 60% brine concentrators

FGD wastewater design chemistry

Analyte	Units	FGD Wastewater Design Chemistry Range	
Calcium	ppm	500	600
Magnesium	**ppm**	**4,000**	**6,000**
Sulfate	**ppm**	**14,000**	**20,000**
Chloride	ppm	2,000	3,000
Sodium	ppm	200	300
pH	S.U.	5.0	7.0
Silica	ppm	100	150
Boron	ppm	500	750
Total Dissolved Solids (TDS)	**ppm**	**25,000**	**35,000**
Total Suspended Solids (TSS)	ppm	20,000	30,000

lime softening – non carbonate hardness removal

Magnesium Sulfate + Lime → Magnesium Hydroxide + Calcium Sulfate

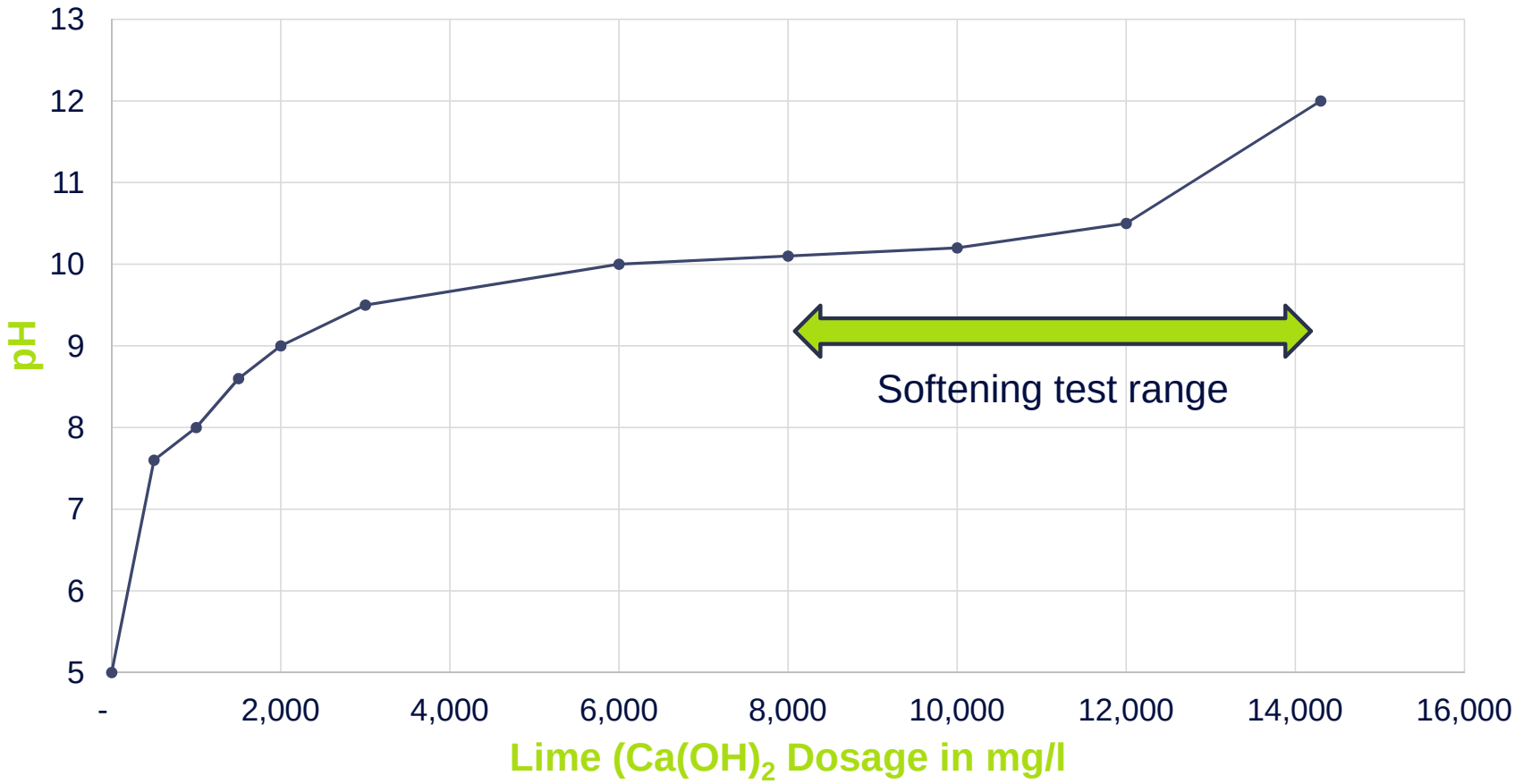
$$MgSO_4 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaSO_4$$

- FGD wastewater can contain high dissolved magnesium and sulfate concentrations
- Lime softening can precipitate magnesium hydroxide and calcium sulfate
- Lime softening reduces dissolved magnesium, sulfate, and total dissolved solids (TDS)
- Reducing TDS increases brine concentrator water recovery and reduces brine blowdown

FGD wastewater laboratory test chemistry

Analyte	Units	FGD Wastewater Design Chemistry Range		Laboratory Test Chemistry
Calcium	ppm	500	600	500
Magnesium	ppm	4,000	6,000	4,000
Sulfate	ppm	14,000	20,000	16,000
Chloride	ppm	2,000	3,000	2,000
Sodium	ppm	200	300	300
pH	S.U.	5.0	7.0	5.0
Silica	ppm	100	150	50
Boron	ppm	500	750	550
Total Dissolved Solids (TDS)	ppm	25,000	35,000	27,500
Total Suspended Solids (TSS)	ppm	20,000	30,000	NA

FGD wastewater – lime titration curve



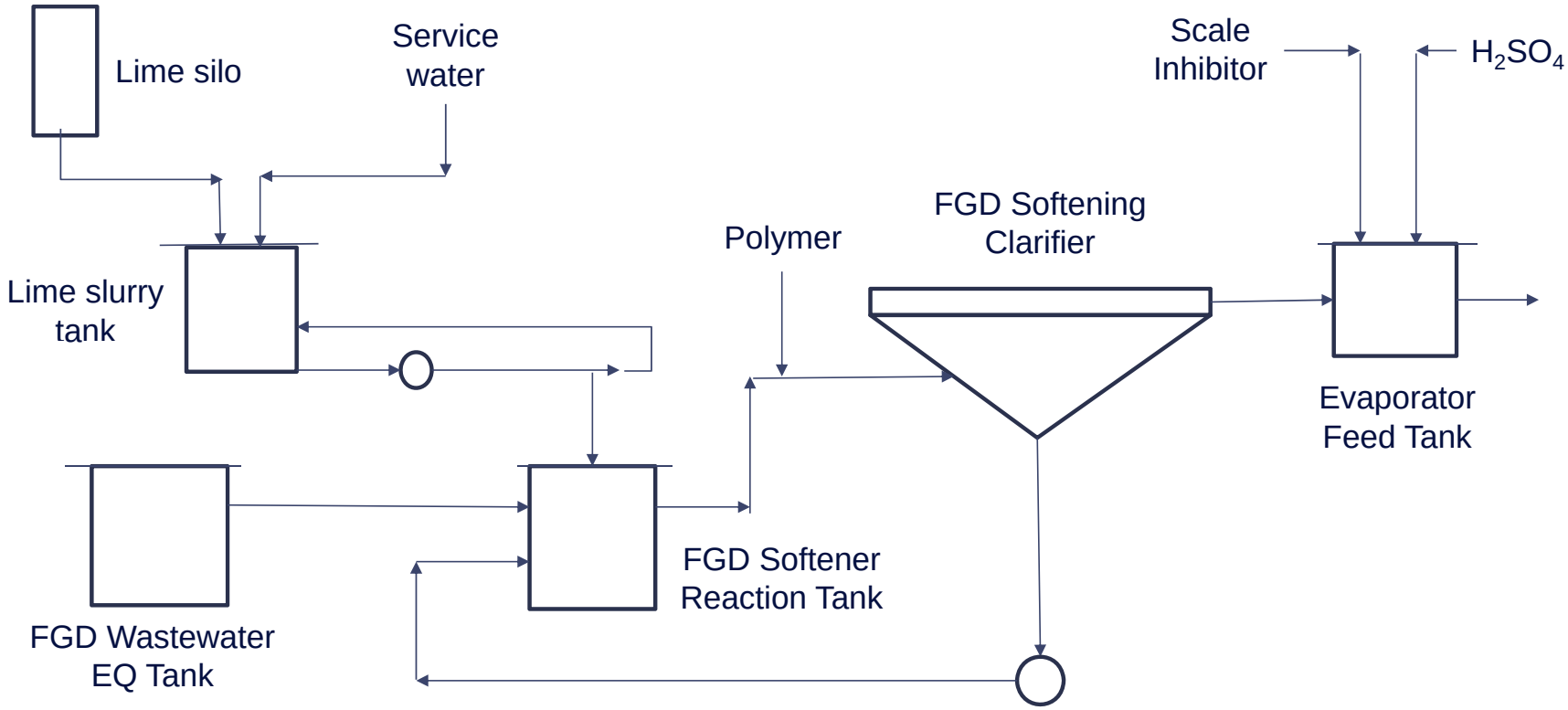
lime softening – laboratory test results

Lime Dosage	0	8,000 mg/l	10,100 mg/l	12,200 mg/l	14,300 mg/l
Calcium	500	1,190	1,270	1,580	2,200
Magnesium	4,000	1,510	806	269	<10
Silica	50	<12	<12	<12	<12
Sulfate	16,000	6,300	4,020	2,500	2,090
Fluoride	100	~3.0	~1.3	~1.2	5.3
Boron	500	237	189	214	360

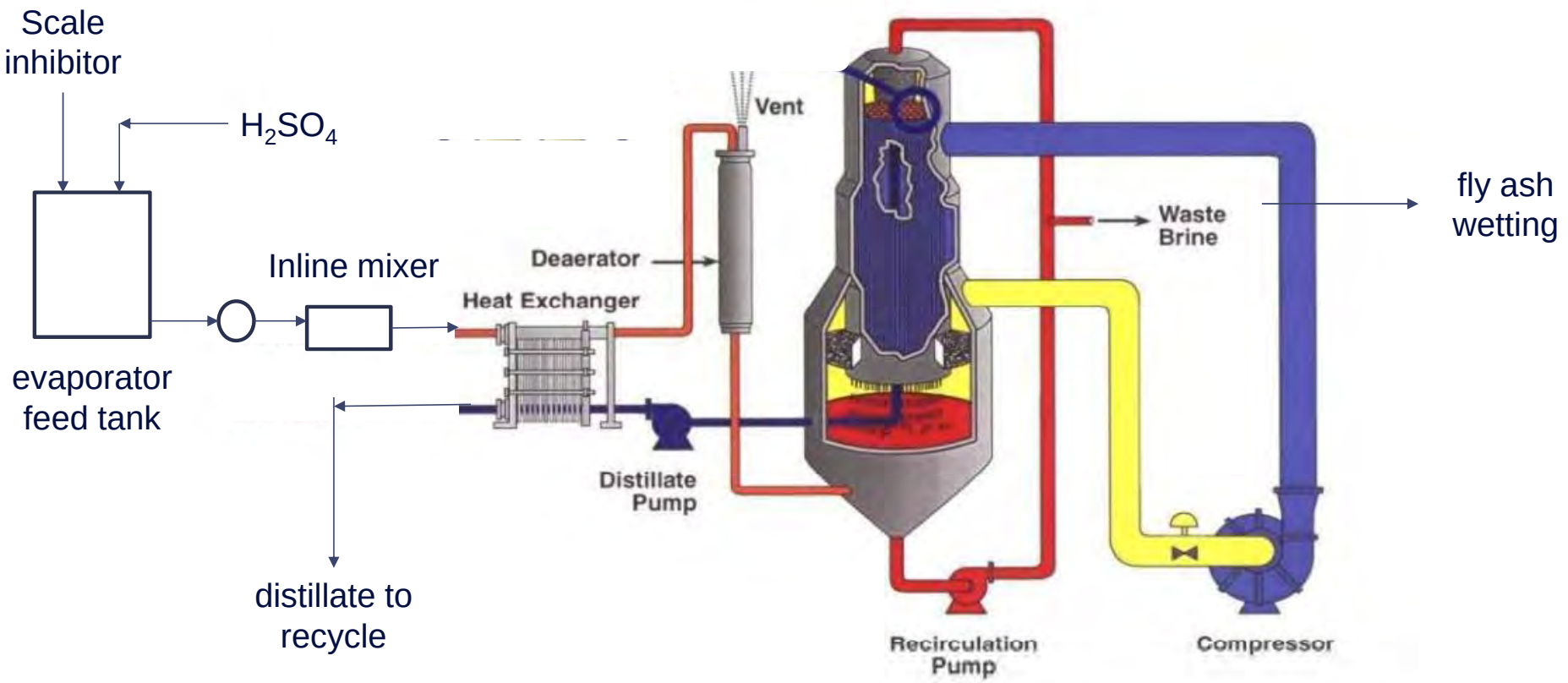
FGD wastewater softened laboratory test chemistry

Analyte	Units	FGD Wastewater Design Chemistry Range		Laboratory Test Chemistry	Softened Laboratory Test Chemistry
Calcium	ppm	500	600	500	1,000
Magnesium	**ppm**	**4,000**	**6,000**	**4,000**	**750**
Sulfate	**ppm**	**14,000**	**20,000**	**16,000**	**3,000**
Chloride	ppm	2,000	3,000	2,000	2,000
Sodium	ppm	200	300	300	300
pH	S.U.	5.0	7.0	5.0	10
Silica	ppm	108	136	51	<6
Boron	ppm	528	740	560	200
Total Dissolved Solids (TDS)	**ppm**	**25,000**	**35,000**	**27,500**	**10,000**
Total Suspended Solids (TSS)	ppm	20,000	30,000	ND	ND

FGD wastewater - lime softening system



seed slurry brine concentrator



heat transfer calculations

$$Q = U\ A\ \Delta T$$

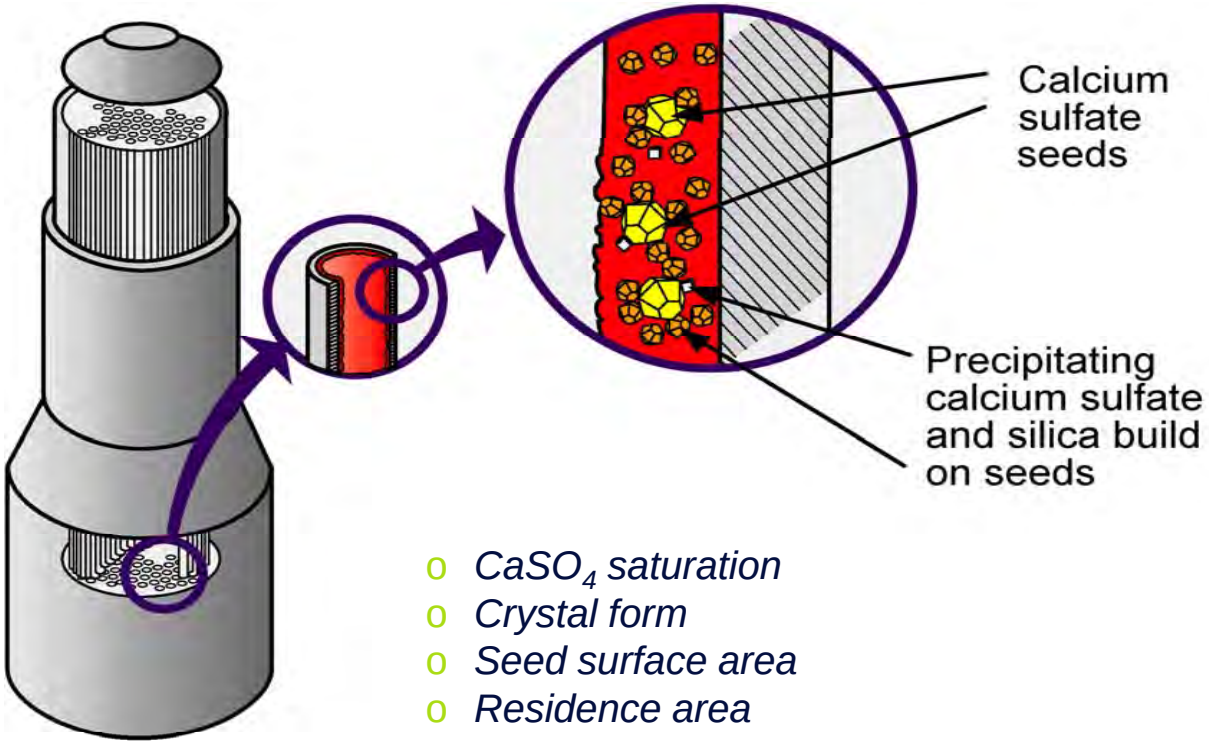
Q = Heat Transfer (Distillate Flow) [BTU/hr]

U = Overall Heat Transfer Coefficient [BTU/hr-ft^2-^{o}F]

A = Heat Transfer Area [ft^2]

ΔT = Heat Transfer Delta Temperature [^{o}F]

seeded slurry scale control



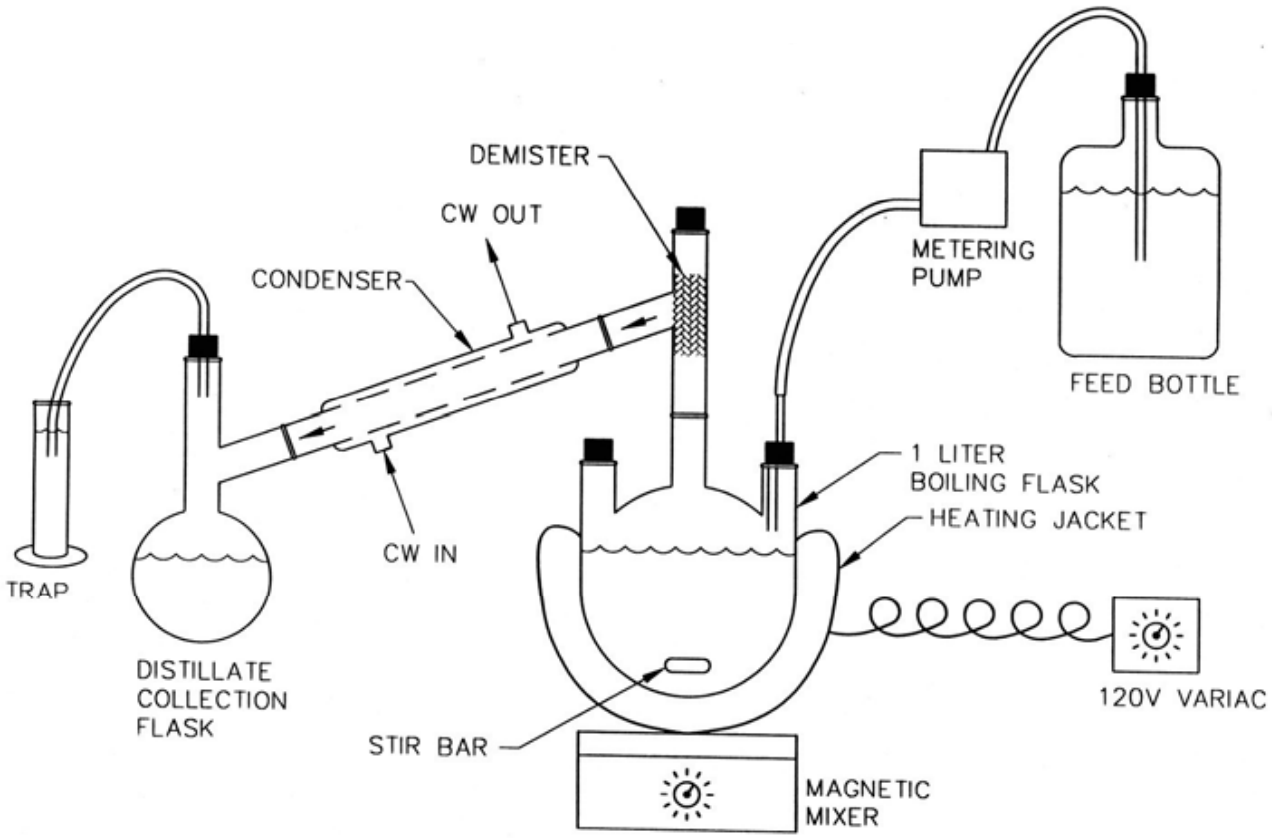
- *$CaSO_4$ saturation*
- *Crystal form*
- *Seed surface area*
- *Residence area*

heat transfer delta temperature

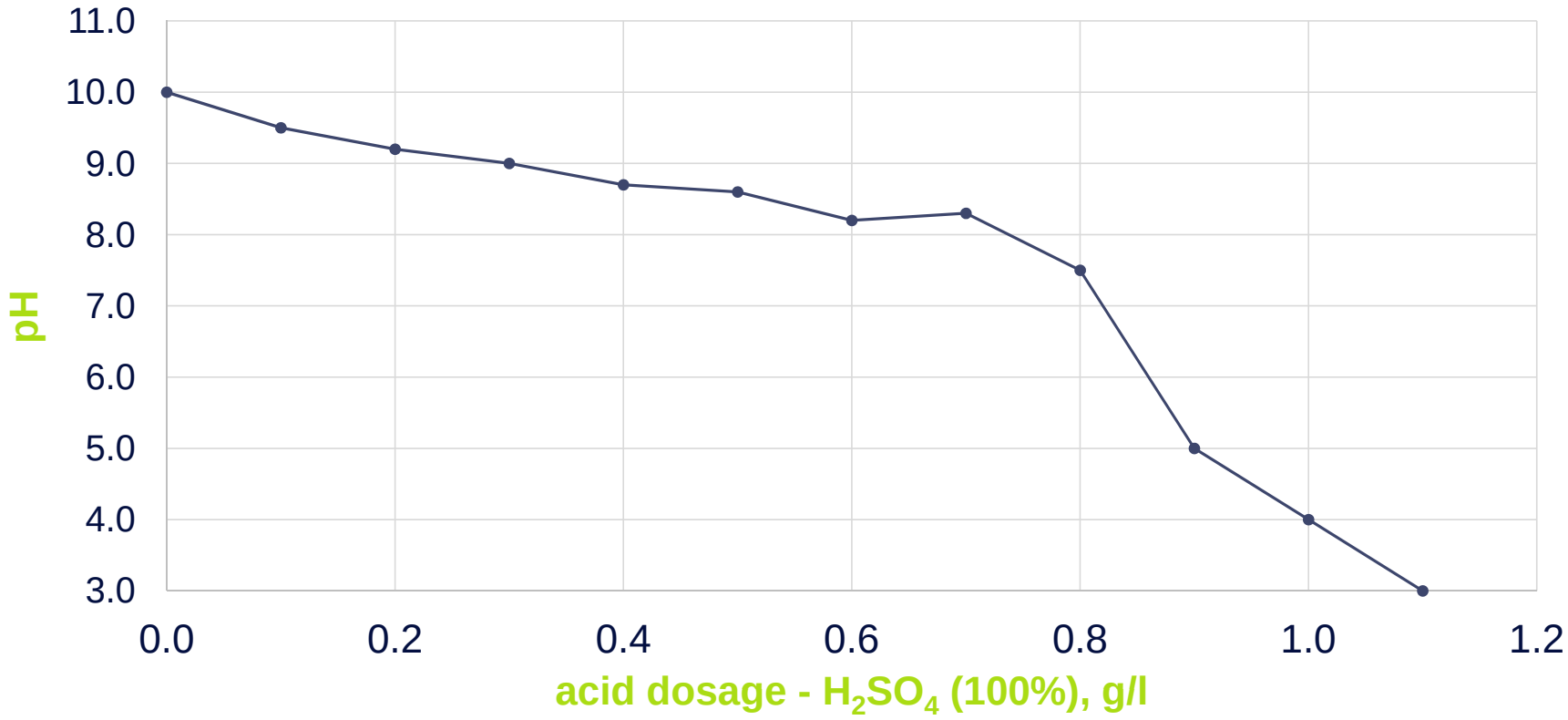
$$\Delta T = T_{\text{condensing steam}} - T_{\text{boiling brine}}$$

- The higher the ΔT the higher the distillate rate.
- $T_{\text{condensing}}$ = steam temperature @ condensing pressure. Function of vapor compressor discharge pressure
- T_{boiling} = temperature of boiling brine (boiling point rise - BPR)
- boiling point rise = brine boiling point elevation due to TDS in boiling solution

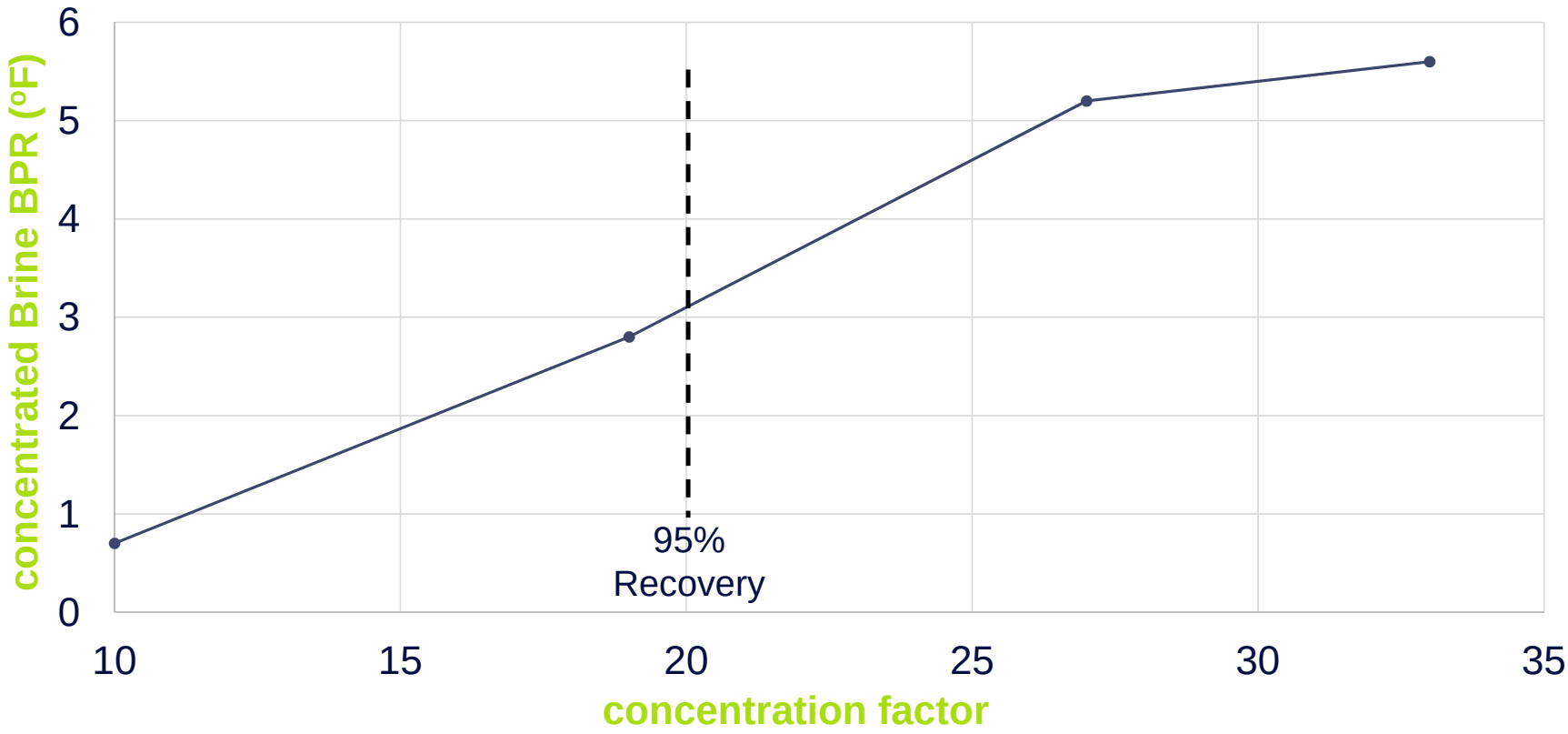
bench scale evaporator test apparatus



brine concentrator feed pH titration



concentrated brine boiling point rise



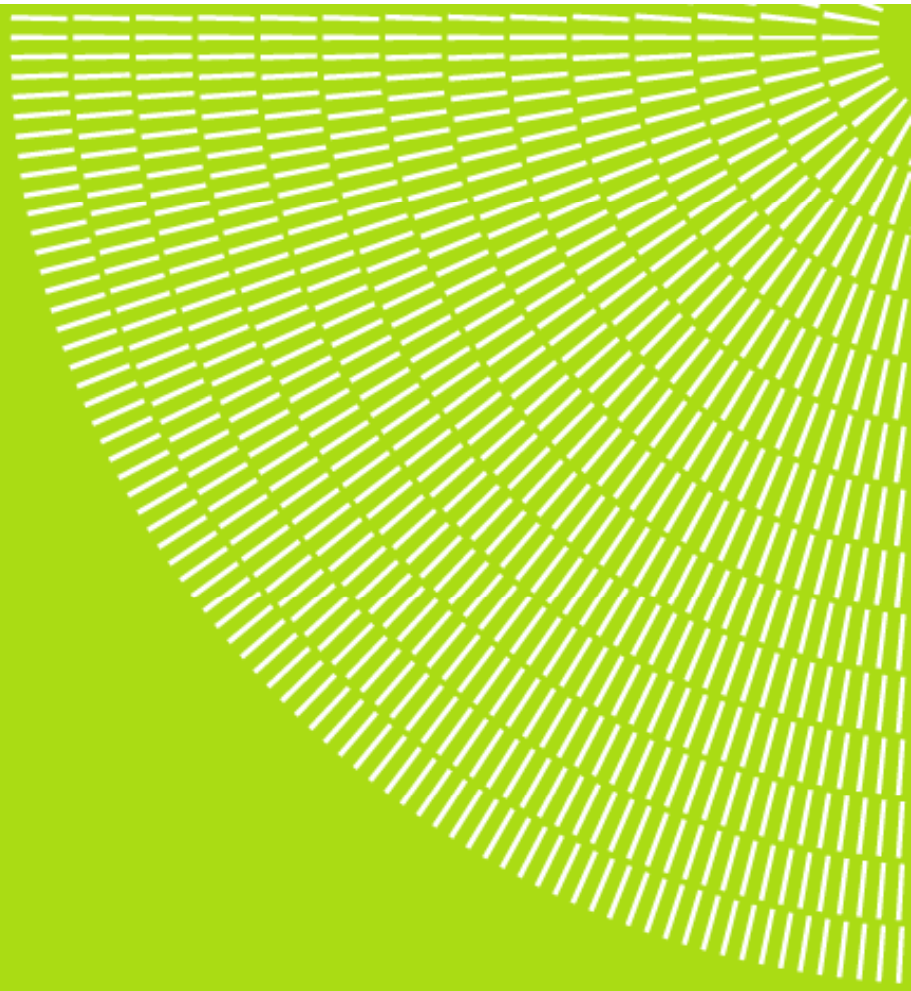
FGD wastewater full scale startup chemistry

Analyte	Units	FGD Wastewater Design Chemistry Range		Full Scale Startup Chemistry	Variation (%)
Calcium	ppm	500	600	550	--
Magnesium	ppm	4,000	6,000	2,200	<45%
Sulfate	ppm	14,000	20,000	7,250	<48%
Chloride	ppm	2,000	3,000	1,600	<20%
Sodium	ppm	200	300	300	--
pH	S.U.	5.0	7.0	7.0	--
Silica	ppm	100	150	35	<65%
Boron	ppm	500	750	350	<30%
Total Dissolved Solids (TDS)	ppm	25,000	35,000	16,000	<36%
Total Suspended Solids (TSS)	ppm	20,000	30,000	ND	

operational FGD wastewater zero discharge system

- System operational late 2017
- Meeting design criteria
- Demonstrates benefit of optimizing pretreatment + brine concentration systems

thank you



questions?

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