ONE SOURCE. MANY SOLUTIONS.

Vogt Power International
Babcock Power SERVICES
TEi
Riley Power
GSI
Boiler Tube Company of America
TEiC | CONSTRUCTION SERVICES
TEiC | HEAT EXCHANGER SERVICES
Struthers Wells
a TEi line of products

WFGD Concerns in Preparation for ELG & Alternative ELG Solutions

- Reclaiming water from ponds and water purge from closed loop ash systems
- Concerns with reclaim and cycling up water in WFGD absorber
  - Cl concentration
  - Fines concentration
  - Gypsum Quality
  - Limestone blinding
- WFGD Operation with Dual-Fuel Firing
- Designing water treatment for reclaimed waters and WFGD effluent
  - Nanofiltration
  - Brine Concentration
  - Alternative Evaporation

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GSI Fabricated GEOSTRUX™ Geotextile Tubes

- Used in a wide variety of projects where dewatering of sediments and industrial wastes is required
- Are cost effective and ecologically-friendly compared to other dewatering methods
- Applicable for dewatering of contaminated sediments, coal ash, mine tailings, WWTP sludge, organic and inorganic materials, silts and sands

GEOSTRUX™ Geotextile Tubes – Cont.

- Supports environmental and dredging contractors, as well as “superfund” contaminated sites
- Effluent is typically clean enough to be returned to the source
- Currently engaged in the largest coal ash project to date with 700,000+ cubic yards of coal ash being dredged and dewatered

Bottom Ash Water

Water reclaimed from pond or purge from closed loop ash system

- Water samples show low levels of Aluminum & Fluoride
- Cycling up Al & F in the WFGD can cause limestone blinding

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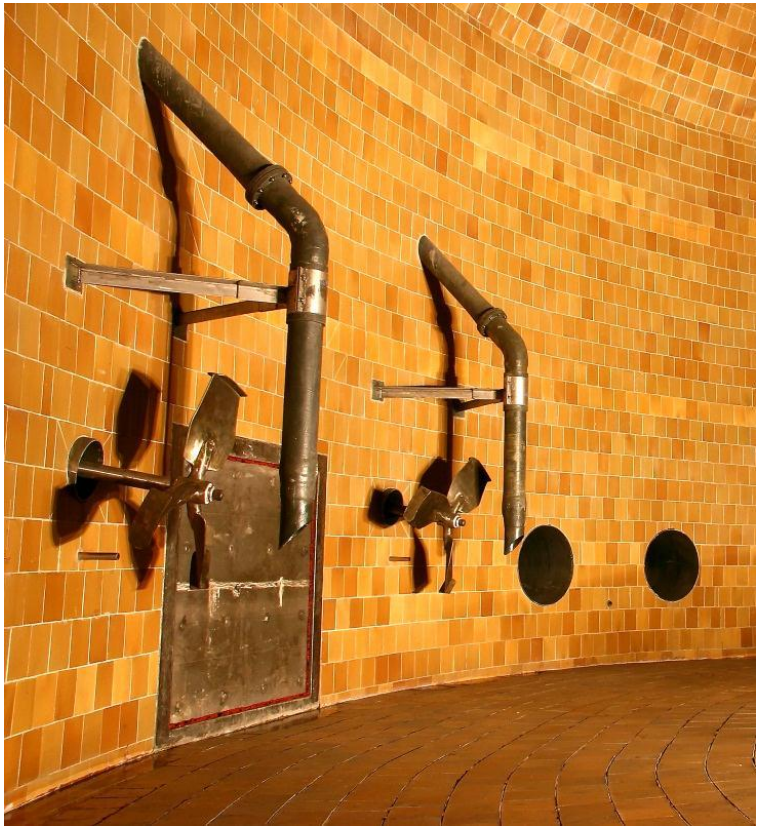
Materials of Construction Limits

Chloride concentration maintained in absorber slurry

- Additional chlorides through makeup water sources
- Existing materials of construction limit chloride concentration
- Chlorides leave the WFGD process with the water through effluent purge and gypsum byproduct
- Potential impact on mercury reemission

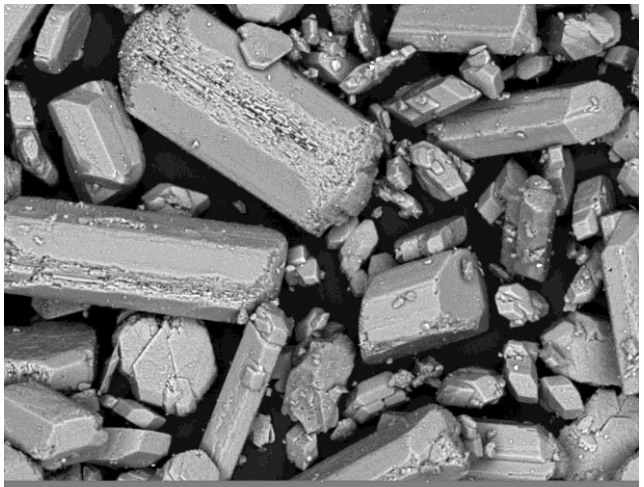


Cycling Up Chlorides Can Lead to Cycling Up Fines

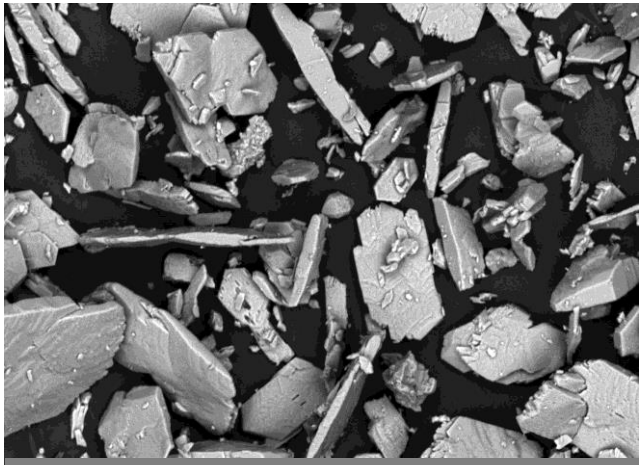
Consist of:

- Gypsum
- Fly ash
- Limestone inerts
- Mercury/selenium

- Cycle up with chlorides
- Impacts gypsum dewatering
- Accelerates erosion rate of rotating equipment and liners
- Re-emissions of mercury
- Foaming issues



Example of desirable crystal morphology



Crystal morphology with excessive fines present

Removing Fines from the Process and Addressing Foaming

Remove fines upstream of WFGD

- Maintain ESP/baghouse
- Filter makeup water
- Improve quality of limestone

Remove fines from WFGD reclaim

- Secondary Hydrocyclones
- Clarifier Tank and filter press

Add anti-foam to WFGD

- Solution tank with agitator for mixing and storing diluted (10:1) anti-foam chemical solution.
- Feed pump(s) and piping to the absorber
- Feed control valve(s) and a foam detector probe with transmitter

Gypsum Marketability

- Marketable gypsum requires cake washing to remove chlorides and salts
- Unmarketable gypsum
  - Remove chlorides from process
  - Spray fines on formed section of cake

Cycling Up Chlorides Can Increase Potential for Limestone Blinding

Understand cause

- Sulfite blinding
- Aluminum/Fluoride blinding

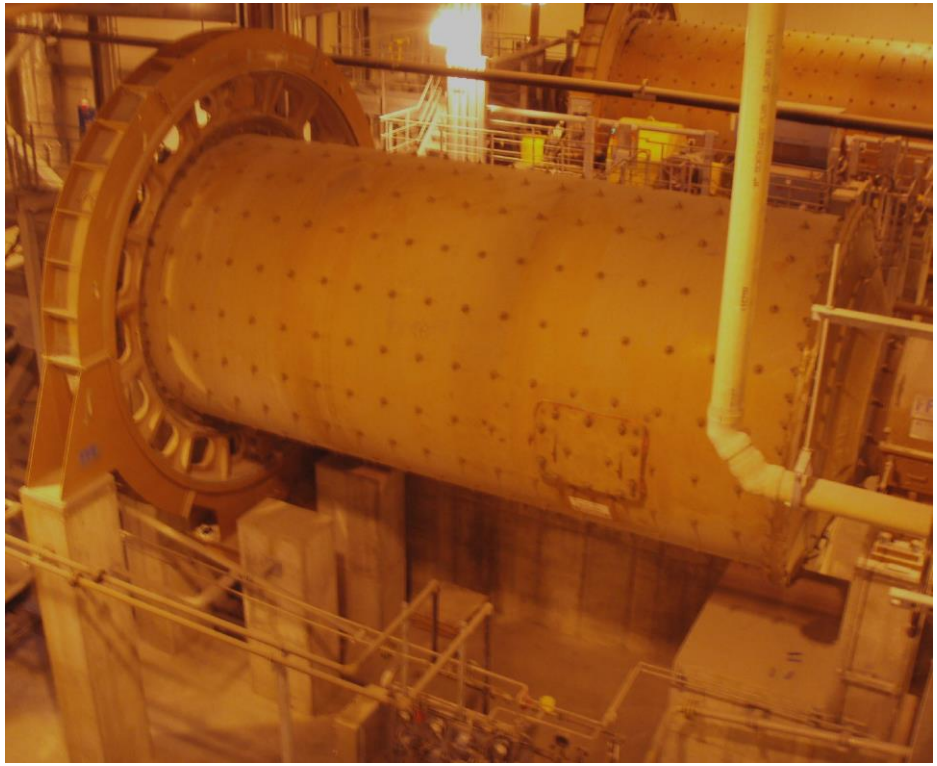
Reduce potential for a blinding event

- Address oxidation issues
  - Maintain spare blower available for service
  - Maintain air distribution in reaction tank
- Remove sources of Al and F
  - Improve particulate removal upstream of WFGD
  - Treat reclaim water
- Complete chemistry modeling of slurry to determine AlFx concentration in slurry

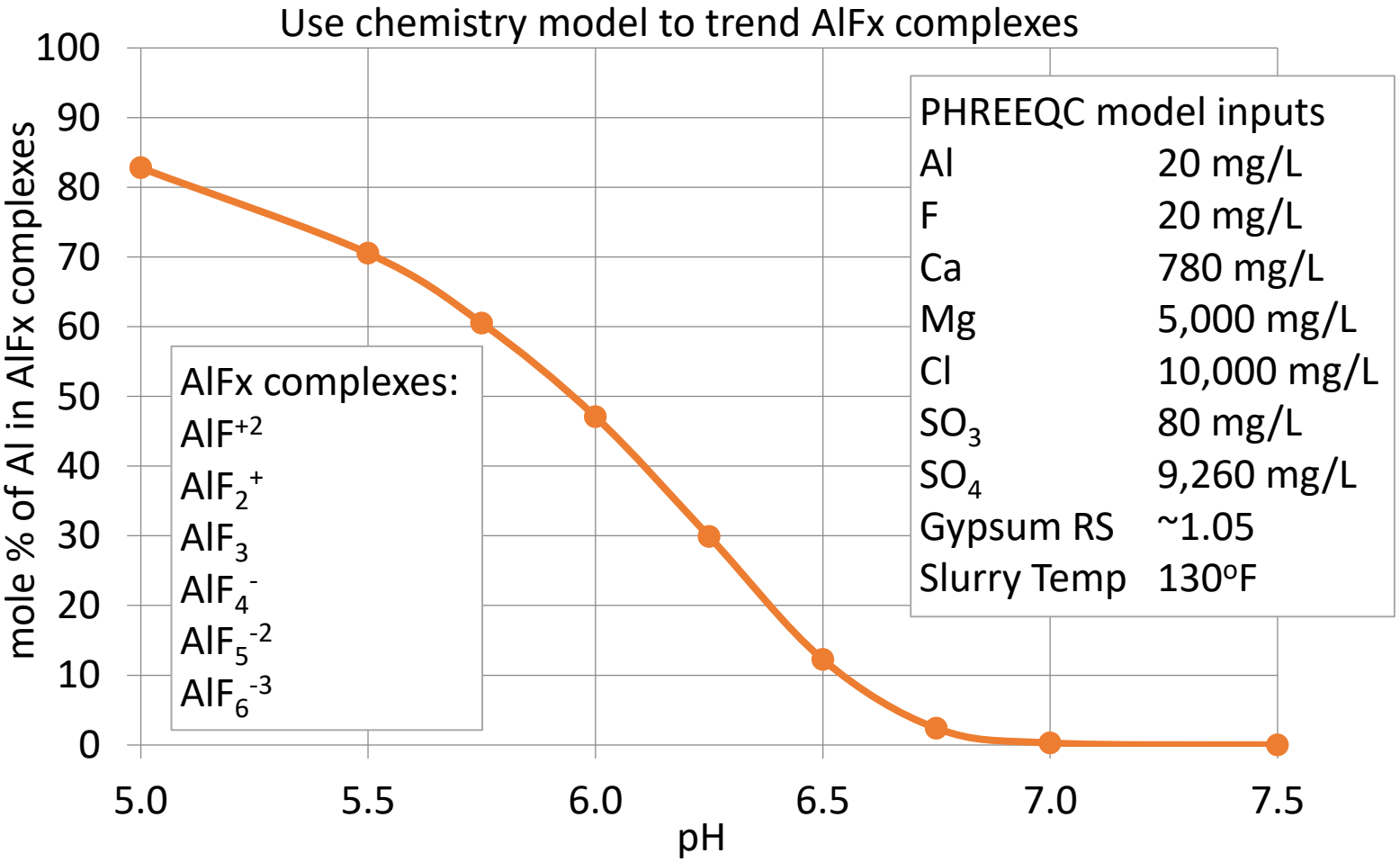
Addressing Limestone Blinding Events

Treating/preventing a limestone blinding event

- Re-establish oxidation air
- Add sorbent or buffer to boost slurry pH and precipitate Al and F
  - Hydrated lime
  - Soda ash
  - DBA/sodium formate
- Review limestone slurry feed logic
- Utilize finer grind limestone
- Use chemistry modeling to look at pH required to decrease AlFx concentration in slurry
- Periodic spiking of sorbent to precipitate Al/F components prior to a blinding event



Decrease in AlFx Complexes with Increased pH



Chemistry Modeling and Graphics Support:

Benson Environmental

Lewis B. Benson · 412-225-8816 · LewB@BensonEnvironmental.com

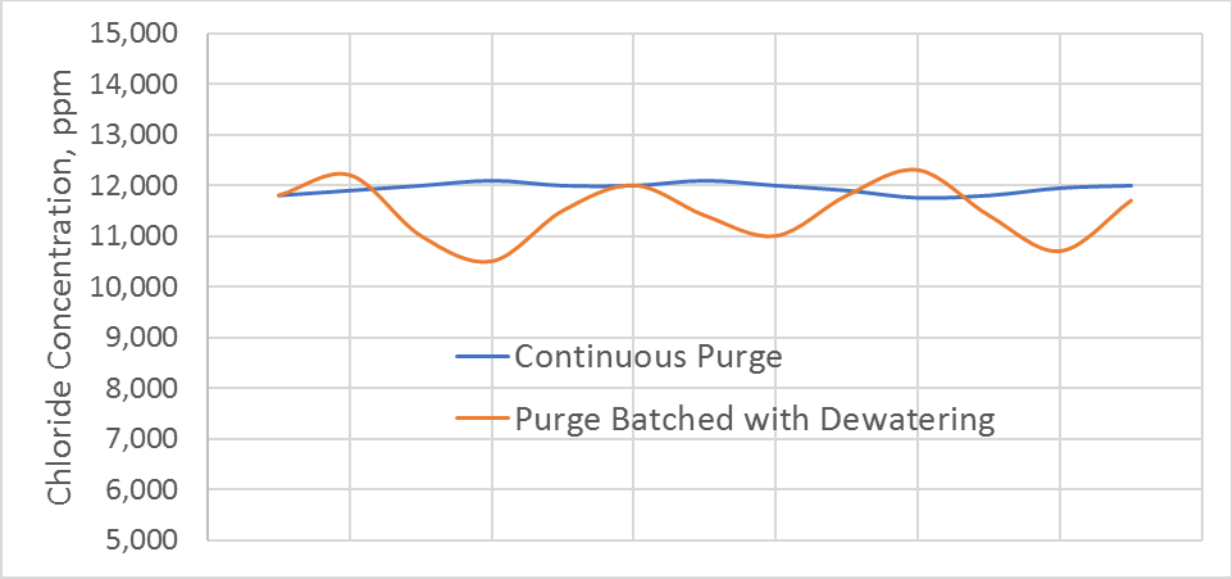
Continuous Purge

Traditional purge streams

- Often the effluent discharge is located at dewatering
- Creates a cyclic operation for chloride control
- Cannot purge at reduced load operation when there is less dewatering

Continuous purge streams

- Allows for continuous purge to downstream treatment
- Easier to maintain chloride concentration



Excess Water

Absorber Level

- Reduce operating level with load to provide more allowance for mist eliminator wash and reclaiming from dewatering at reduced load when system not evaporating water since these items are on/off operation

ME Wash

- ME wash logic to be revised to not initiate a wash sequence at low absorber level
- Individual ME wash header flows should be reviewed
- Leaking ME wash header valves to be repaired/replaced

Absorber Slurry Density

- Increase slurry operating density range from 14.5-15.5% to 14-17% to minimize number of flushes

Flushing

- Optimize flushing durations and cycles
- Use reclaim water as flush water

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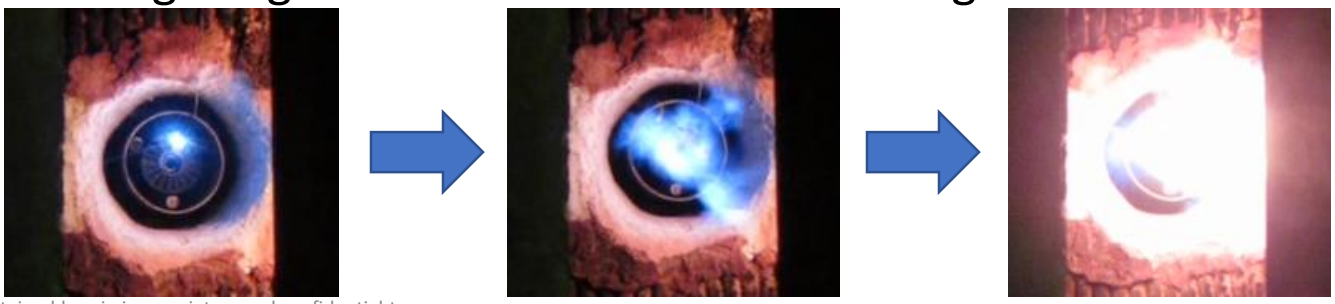
Changes to Flue Gas Profile

Change in emissions leaving the boiler when firing gas only

- 1/3 the NO_x emissions of coal
- Lower CO (typically <50 ppm)
- Lower VOCs (typically <0.001 lb/MMBtu on a methane basis)
- Virtually no SO_x emissions (small amount of Sulphur added as odorant)
- Virtually no PM
- 50-80% less CO_2 than coal

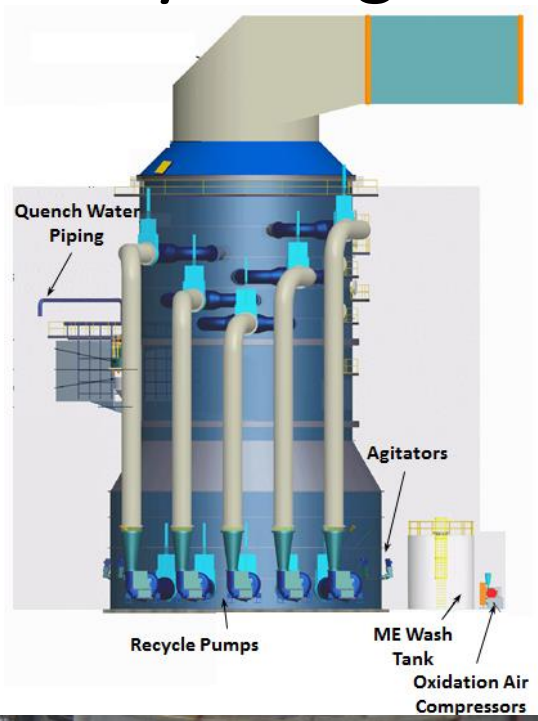
Change in flue gas when firing gas only

- Flue gas flow will typically decrease with natural gas by approximately 5-10% due to reduction in excess air requirements
- Flue gas temperature leaving the boiler bank will typically decrease slightly with natural gas firing due to increased heat absorption in the SH/RH sections from having a higher effectiveness due to no slag



WFGD O&M Considerations for Gas Only Firing

- Utilize flue gas bypass if available - remove oxidation air and recycle pumps from service to reduce power consumption
- Maintain absorber(s) in service to evaporate water
  - Utilize a minimum number of recycle pumps to quench flue gas
  - Remove oxidation air from service to reduce power consumption
  - Monitor slurry pH
- Quench flue gas with at absorber inlet
  - Add quench system to absorber inlet and control water rate based on flue gas temperature
  - Remove oxidation air and recycle pumps from service to reduce power consumption




Quench System at Absorber Inlet

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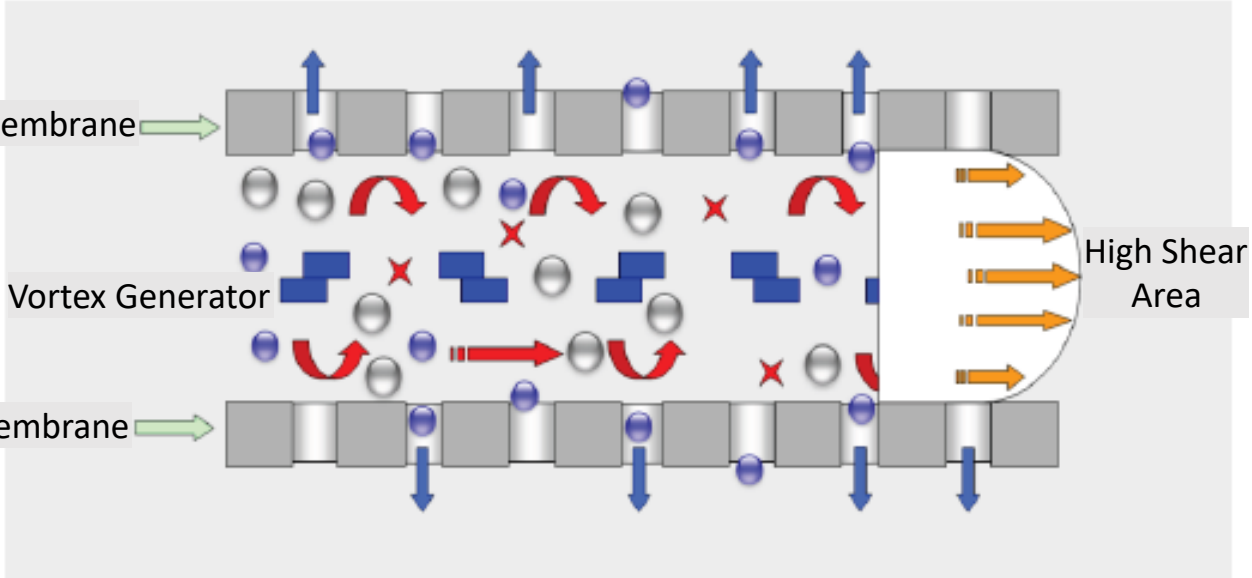
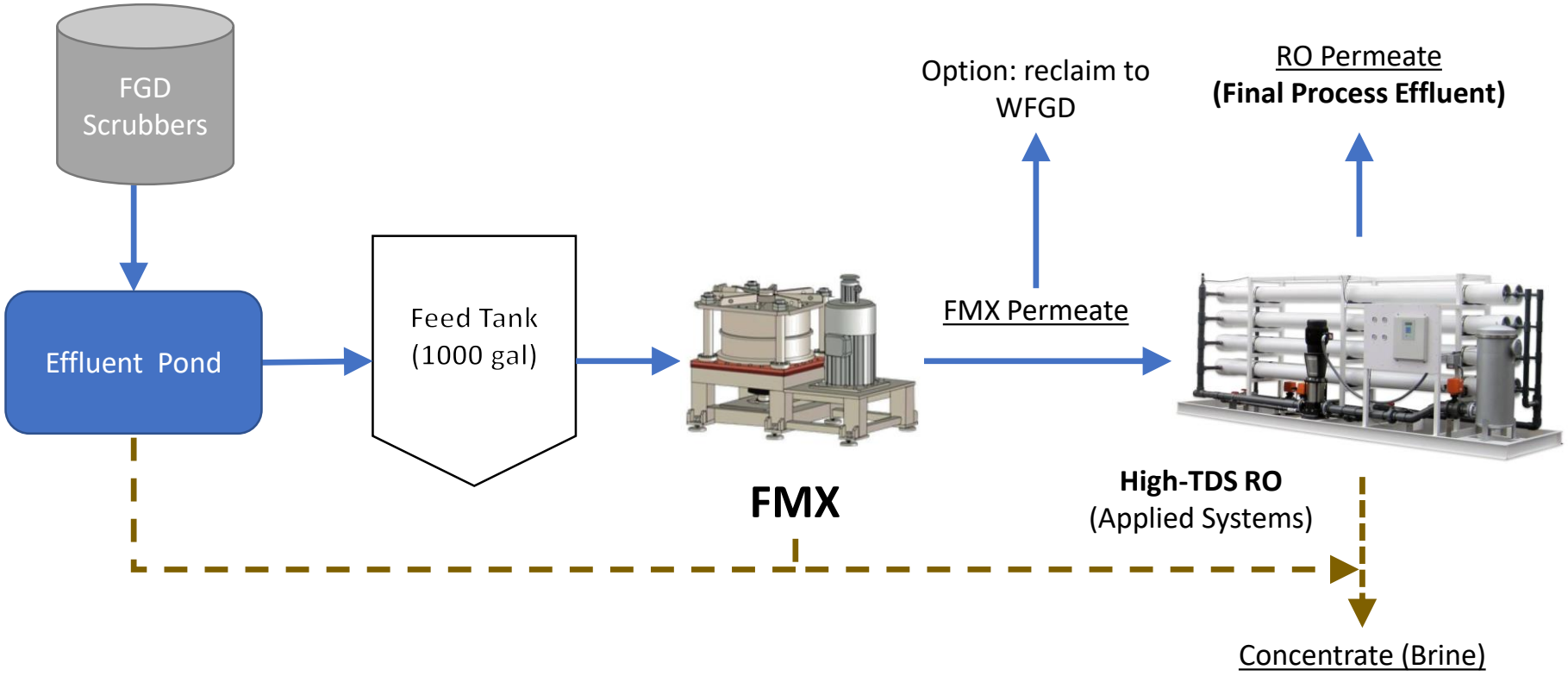
Nanofiltration – FMX System

Intermediate Step to Reduce Further Effluent Discharge after Optimization or Treat Pond Water

- FGD effluent high in TDS and TSS leads to fouling in traditional RO systems
- Nanofiltration membrane system utilizes vortices to eliminate fouling
- The membrane is dependent on the type of water recovery and chloride levels



Case Study (2018):
Single Pass Mode with RO polish



Case Study:

3-month RESULTS

Raw FGD

Steam Electric Power Plant
Southeast US

FEED: **FGD Holding Pond**

PRETREATMENT: **None**

AVERAGE FLUX: 128 LMH

RECOVERY: 80-85%

TOTAL VOLUME TREATED: **525,042 gal** (w/anti-scalant)

Validated using RO Pilot (Applied Systems High-TDS RO):

ANALYTICAL RESULTS: RECOVERY AVERAGES (N=7)

	UNITS	FEED	**FMX** EFFLUENT	FMX % REMOVAL	**FMX+RO** EFFLUENT	FMX+RO % REMOVAL	2015 ELG BAT Daily Max	All samples met BAT?
TDS	ppm	3887	1857	52%	192	95%	NA	NA
Sulfate[1]	**ppm**	**2379**	**929**	**61%**	**20**	**99%**	NA	NA
Arsenic	ppb	11.14	8.46	>24%[2]	6.09	>28%[2]	11	✓
Mercury	pptr	240	16.6	>93%[2]	< 5	> 98%[2]	788	✓
Selenium	ppb	1,927	726	62%	6.84	99%	23	✓
NO_x-$N_{(aq)}$	ppm	5.6	5.6	NA	1.25	78%	17	✓

[1] *Main contributor in scale formation*

[2] Sample results below LDL levels mean removals are underestimated

Meeting ELG

FMX+RO Effluent was able to meet and **exceed** 2015 EPA BAT targets.

FGD Wastewater Discharge Limits		
	BAT	
	DAILY MAX	30 DAY AVERAGE
Arsenic	✓	✓
Mercury	✓	✓
Selenium	✓	✓
NO_x-N $_{(aq)}$	✓	✓

BOTTOM LINE

Add FMX *for the most* ***reliable, cost-effective*** *FGD wastewater solution*

→ Volume Reduction

→ Permit Compliance

→ Discharge-Quality

→ Smaller Evaporator

→ Protects RO systems

Making ZLD Economical

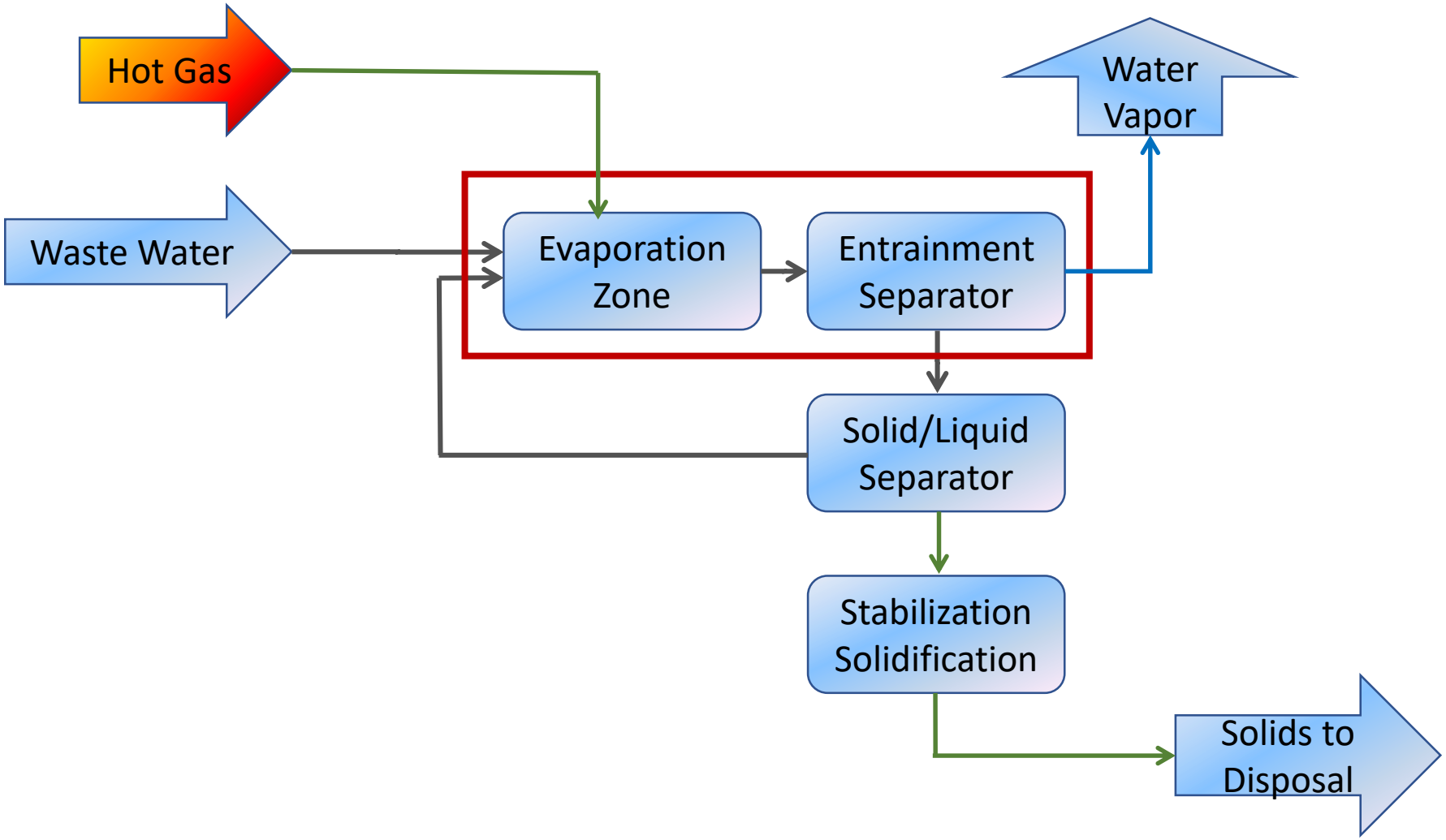
- Volume reduction + brine concentration optimizes the cost of ZLD treatment and provides flexibility in operation
- Meets compliance with all discharge regulations and provides ELG compliant water for reuse
- Test units available

Alternative Evaporation - Direct Contact Evaporation

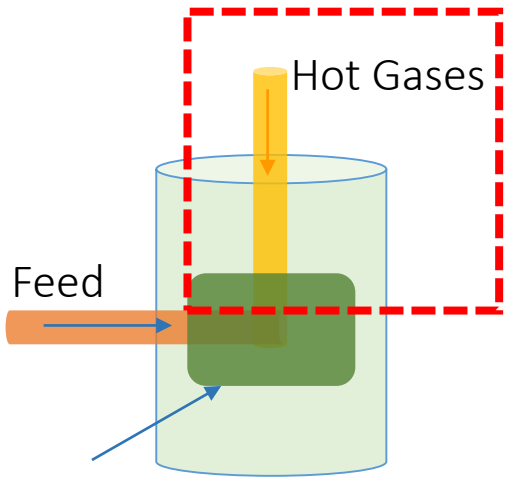
1. Heat Source
2. Concentrator Section
3. Feed and Recirculation
4. Droplet Separator
5. Sump
6. Exhaust

Mobile Test Units Available

Direct Contact Evaporator Process Flow Diagram



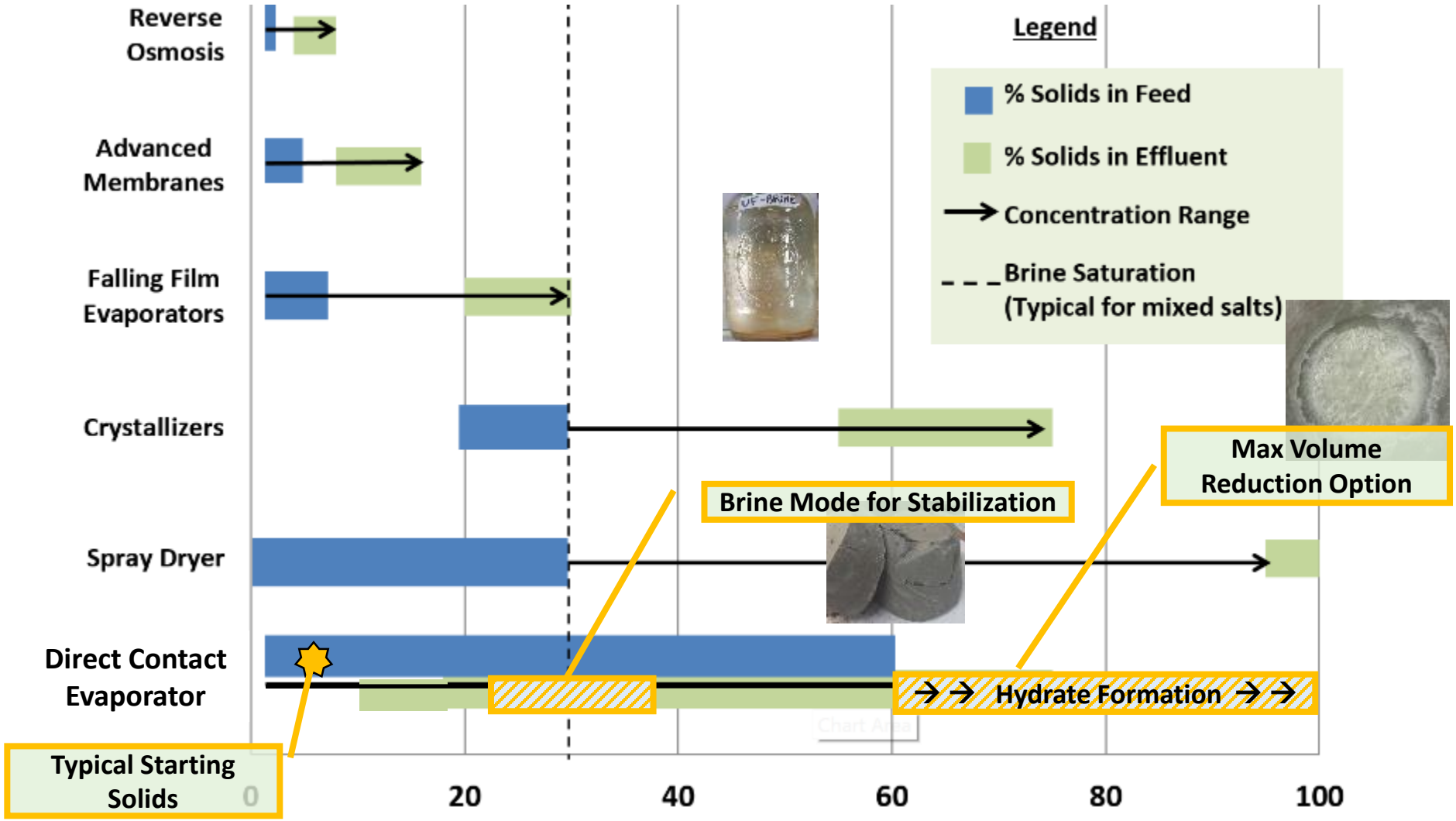
Direct Contact Evaporation vs. Falling Film



Direct Contact
"Concentrator"

- Compact
- No heat exchange surfaces or membranes to foul; low-cost materials
- Direct use of waste heat (exhaust gases) and/or natural gas
- Patented Gas-Liquid Section creates large surface area for rapid evaporation
- Require no pre-treatment
- Simple to operate and maintain

Direct Contact Evaporator Process Flexibility



Power Industry Experience

EPRI Project at Plant Bowen

- FGD wastewater treatment/concentration using flue gas as a waste heat source
- 24/7 study realized 93% availability.
- Integration on operating 900 MW unit successful.
- Fly-ash improved mixing and better solids production
- 97% volume reduction producing solids for disposal passing TCLP

Brine Dewatering

- Multiple options for dewatering including:
  - Dewatering tubes
  - Centrifuges
  - Filter presses
- Enhanced stabilization of metals such as selenium
- Producing a solid with improved properties over crystallized salt
- Elimination of a crystallization step

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