REINHOLD ENVIRONMENTAL Ltd.

2016 APC-Wastewater Round Table & Expo Presentation

July 18 & 19, 2016 in Dearborn, MI / Hosted by DTE Energy

Evaporative Drying of Wet FGD Wastewater via Salt Drying – A ZLD Technology

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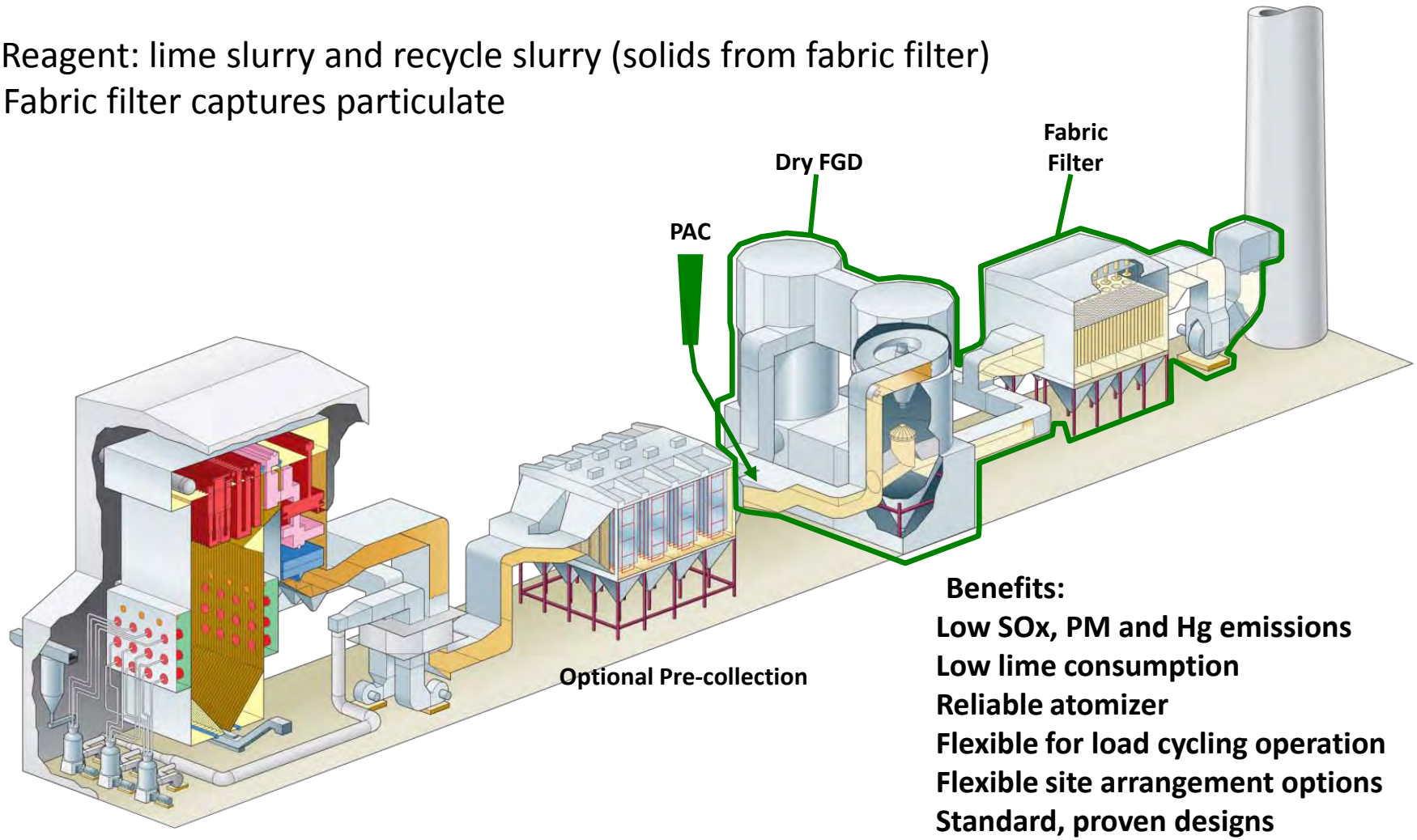
July 18, 2016

Presentation Outline

- Spray Drying FGD Overview
- Salt Dryer Overview
- Technology Comparison
- Waste-to-Energy Salt Drying Operating Experience
- Process Validation
- Recent Utility Salt Dryer Project Evaluations and Offerings

Typical Retrofit SDA Arrangement

- Reagent: lime slurry and recycle slurry (solids from fabric filter)
- Fabric filter captures particulate



Benefits:

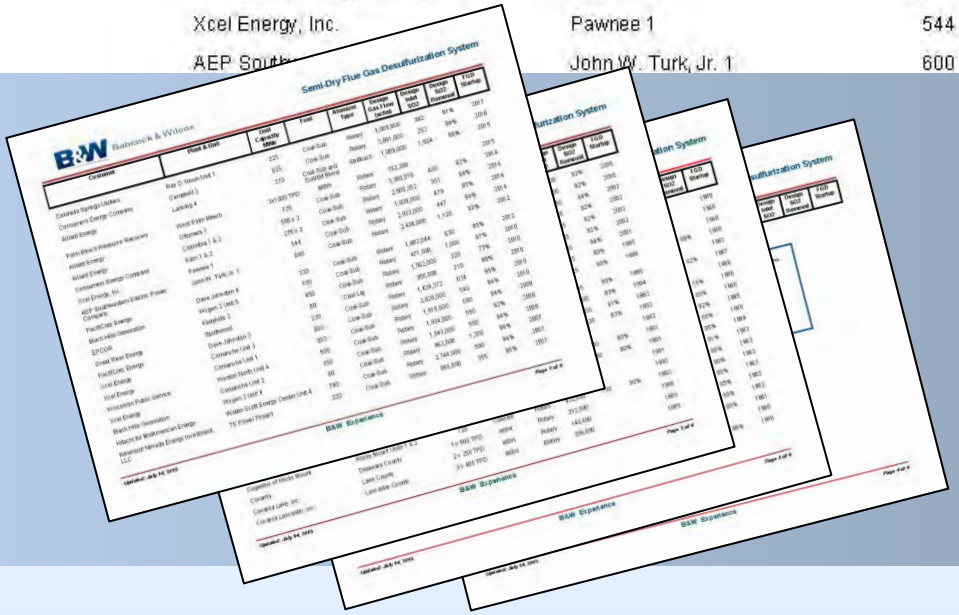
Low SOx, PM and Hg emissions
Low lime consumption
Reliable atomizer
Flexible for load cycling operation
Flexible site arrangement options
Standard, proven designs
Long bag life
Easy maintenance

B&W/GEA Spray Drying FGD Experience

Babcock & Wilcox

Semi-Dry Flue Gas Desulfurization System

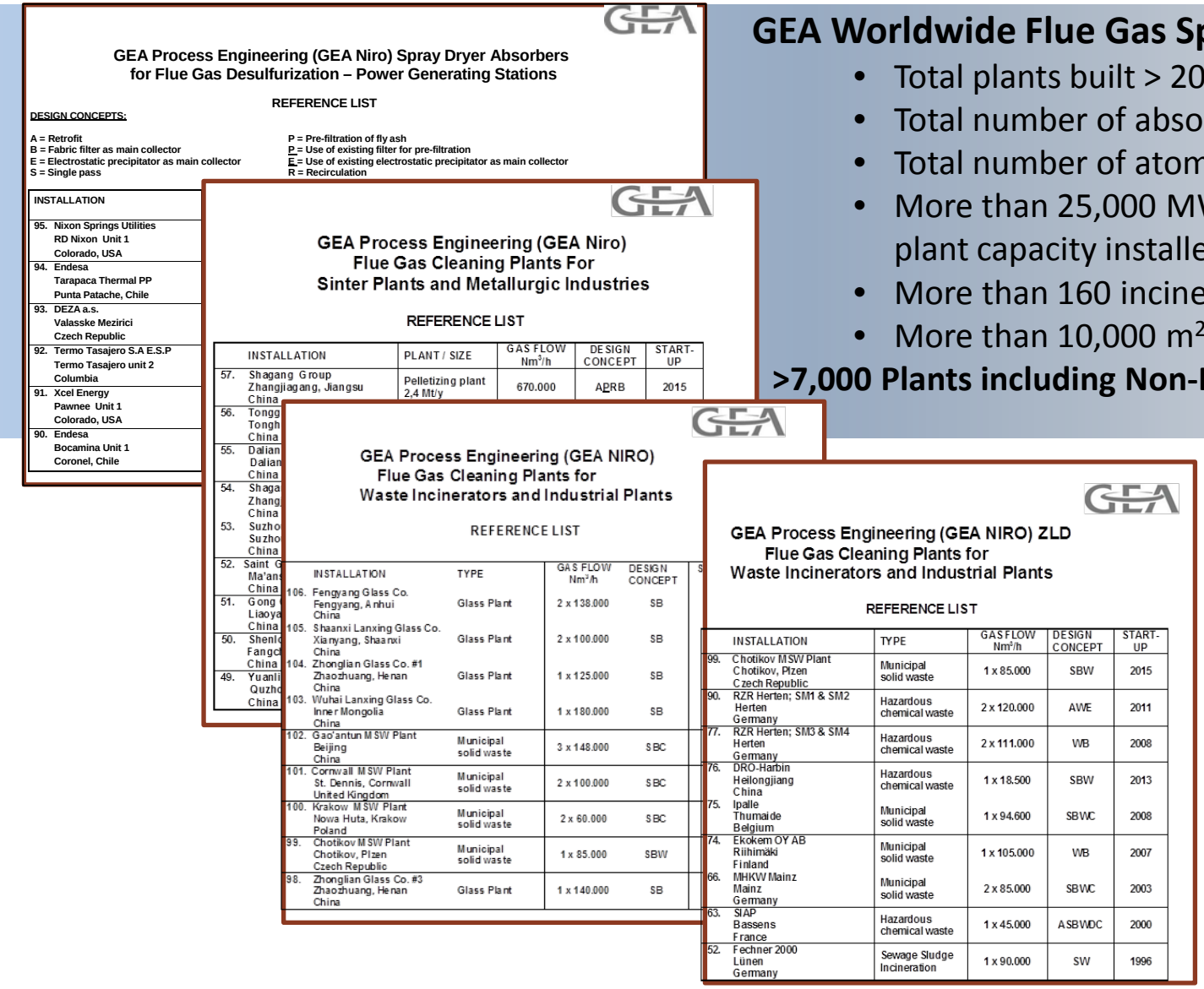
Customer	Plant & Unit	Unit Capacity MWe	Fuel	Atomizer Type	Design Gas Flow (acfm)	Design Inlet SO2	Design SO2 Removal	FGD Startup
Colorado Springs Utilities	Ray D. Nixon Unit 1	225	Coal-Sub	Rotary	1,009,000	382	91%	2017
Consumers Energy Company	Campbell 3	835	Coal-Sub	Rotary	3,691,000	252	94%	2016
Alliant Energy	Lansing 4	270	Coal-Sub and Sub/Bit Blend	Spillback	1,059,000	1,504	98%	2015
Palm Beach Resource Recovery	West Palm Beach	3x1000 TPD	MSW	Rotary	192,280			2015
Alliant Energy	Ottumwa 1	726	Coal-Sub	Rotary	3,390,518	400	92%	2014
Alliant Energy	Columbia 1 & 2	580 x 2	Coal-Sub	Rotary	2,500,352	351	94%	2014
Consumers Energy Company	Karn 1 & 2	275 x 2	Coal-Sub	Rotary	1,026,000	479	95%	2014
Xcel Energy, Inc.	Pawnee 1	544	Coal-Sub	Rotary	2,833,000	447	94%	2014
AEP South	John W. Turk, Jr. 1	600	Coal-Sub	Rotary	2,436,000	1,120	92%	2012



Key Facts about B&W DRY FGD

- ~17,000 MW total
- Fuels: coal: sub-bituminous, sub-bituminous / bituminous blend, bituminous, lignite waste; MSW, RDF
- Reagents: lime, hydrated lime and Na_2CO_3
- Installed single module designs up to 20 m (400 MW) and multiple modules up to 900 MW

GEA/Niro Spray Drying Experience



GEA Process Engineering (GEA Niro) Spray Dryer Absorbers
for Flue Gas Desulfurization – Power Generating Stations

REFERENCE LIST

DESIGN CONCEPTS:

A = Retrofit
B = Fabric filter as main collector
E = Electrostatic precipitator as main collector
S = Single pass

P = Pre-filtration of fly ash
P = Use of existing filter for pre-filtration
E = Use of existing electrostatic precipitator as main collector
R = Recirculation

INSTALLATION
95. Nixon Springs Utilities RD Nixon Unit 1 Colorado, USA
94. Endesa Tarapaca Thermal PP Punta Patache, Chile
93. DEZA a.s. Valasske Mezirici Czech Republic
92. Termo Tasajero S.A E.S.P Termo Tasajero unit 2 Columbia
91. Xcel Energy Pawnee Unit 1 Colorado, USA
90. Endesa Bocamina Unit 1 Coronel, Chile

GEA Process Engineering (GEA Niro)
Flue Gas Cleaning Plants For
Sinter Plants and Metallurgic Industries

REFERENCE LIST

INSTALLATION	PLANT / SIZE	GAS FLOW Nm³/h	DESIGN CONCEPT	START-UP
57. Shagang Group Zhangjiagang, Jiangsu China	Pelletizing plant 2,4 Mt/y	670.000	ARB	2015
56. Tongg Tongh China				
55. Dalian Dalian China				
54. Shaga Zhang China				
53. Suzho Suzho China				
52. Saint G Ma'an China				
51. Gong Liaoya China				
50. Shenl Fangc China				
49. Yuanli Quzho China				

GEA Process Engineering (GEA NIRO)
Flue Gas Cleaning Plants for
Waste Incinerators and Industrial Plants

REFERENCE LIST

INSTALLATION	TYPE	GAS FLOW Nm³/h	DESIGN CONCEPT
106. Fengyang Glass Co. Fengyang, Anhui China	Glass Plant	2 x 138.000	SB
105. Shaanxi Lanxing Glass Co. Xianyang, Shaanxi China	Glass Plant	2 x 100.000	SB
104. Zhonglian Glass Co. #1 Zhaozhuang, Henan China	Glass Plant	1 x 125.000	SB
103. Wuhai Lanxing Glass Co. Inner Mongolia China	Glass Plant	1 x 180.000	SB
102. Gao'antun MSW Plant Beijing China	Municipal solid waste	3 x 148.000	SBC
101. Cornwall MSW Plant St. Dennis, Cornwall United Kingdom	Municipal solid waste	2 x 100.000	SBC
100. Krakow MSW Plant Nowa Huta, Krakow Poland	Municipal solid waste	2 x 60.000	SBC
99. Chotikov MSW Plant Chotikov, Plzen Czech Republic	Municipal solid waste	1 x 85.000	SBW
98. Zhonglian Glass Co. #3 Zhaozhuang, Henan China	Glass Plant	1 x 140.000	SB

GEA Process Engineering (GEA NIRO) ZLD
Flue Gas Cleaning Plants for
Waste Incinerators and Industrial Plants

REFERENCE LIST

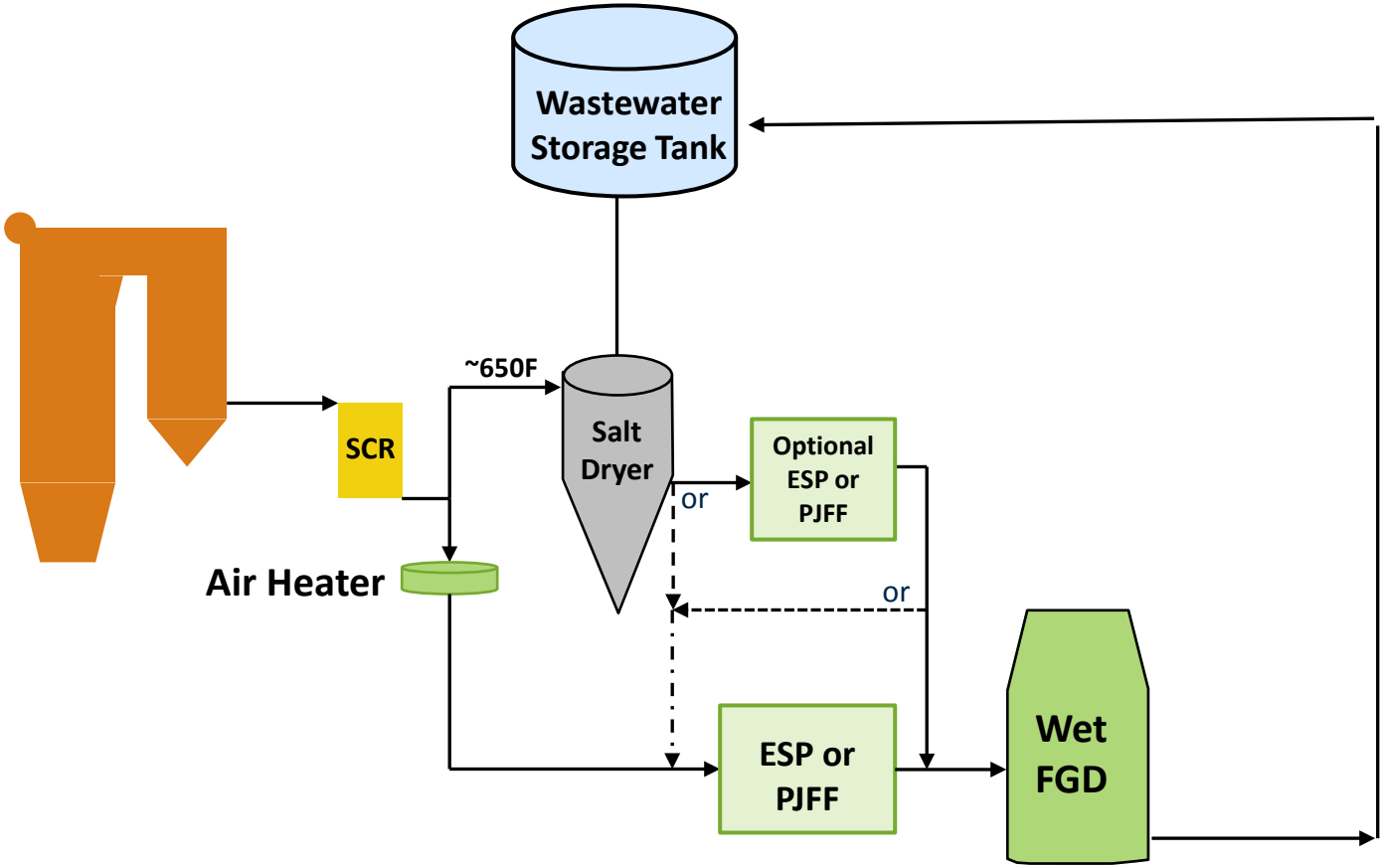
INSTALLATION	TYPE	GAS FLOW Nm³/h	DESIGN CONCEPT	START-UP
99. Chotikov MSW Plant Chotikov, Plzen Czech Republic	Municipal solid waste	1 x 85.000	SBW	2015
90. RZR Herten; SM1 & SM2 Herten Germany	Hazardous chemical waste	2 x 120.000	AWE	2011
77. RZR Herten; SM3 & SM4 Herten Germany	Hazardous chemical waste	2 x 111.000	WB	2008
76. DRO-Harbin Heilongjiang China	Hazardous chemical waste	1 x 18.500	SBW	2013
75. Ipalle Thumaide Belgium	Municipal solid waste	1 x 94.600	SBWC	2008
74. Ekokem OY AB Riihimäki Finland	Municipal solid waste	1 x 105.000	WB	2007
66. MHKW Mainz Mainz Germany	Municipal solid waste	2 x 85.000	SBWC	2003
63. SIAP Bassens France	Hazardous chemical waste	1 x 45.000	ASBWDC	2000
52. Fechner 2000 Lünen Germany	Sewage Sludge Incineration	1 x 90.000	SW	1996

GEA Worldwide Flue Gas Spray Drying Experience

- Total plants built > 200
- Total number of absorbers > 350
- Total number of atomizers > 450
- More than 25,000 MWe and 4,300 MWt power plant capacity installed
- More than 160 incineration lines
- More than 10,000 m^2 sinter band capacity

>7,000 Plants including Non-Flue Gas Applications

Salt Dryer Process Flow Diagram



Salt Dryer Overview

- **Achieves ZLD with high reliability**
- **Similar equipment and operation with SDA**
  - Atomizer
  - Gas disperser
  - Spray chamber
  - Does not require PJFF recirculation or lime slaking equipment

Comparison with Utility SDA

- **Slipstream**
- **Operating temperatures**
- **Chlorides (can be similar to WTE SDA)**
- **Spray chamber sizes can be comparable**

	SDA	Salt Dryer
Feed Suspended Solids (%)	3-40	1-20
Inlet Temperature (^{o}F)	270-350	600-750
Outlet Temperature (^{o}F)	160-180	280-330
Byproduct Chlorides (%)	0.5-1.5	10-25

GEA Salt Dryer Installations in Waste Applications

Installation	Fuel	Start-Up
Chotikov MSW Plant Chotikov, Plzen Czech Republic	Municipal Solid Waste	2015
RZR Herten; SM1 & SM2 Herten Germany	Hazardous Chemical Waste	2011
RZR Herten; SM3 & SM4 Herten Germany	Hazardous Chemical Waste	2008
DRO-Harbin Heilongjiang China	Hazardous Chemical Waste	2007
Ipalle Thumaide Belgium	Municipal Solid Waste	2008
Ekokem OY AB Riihimaki Finland	Municipal Solid Waste	2007
MHKW Mainz Mainz Germany	Municipal Solid Waste	2003
SIAP Bassens France	Hazardous Chemical Waste	2000
Fechner 2000 Lunen Germany	Sewage Sludge Incineration	1996

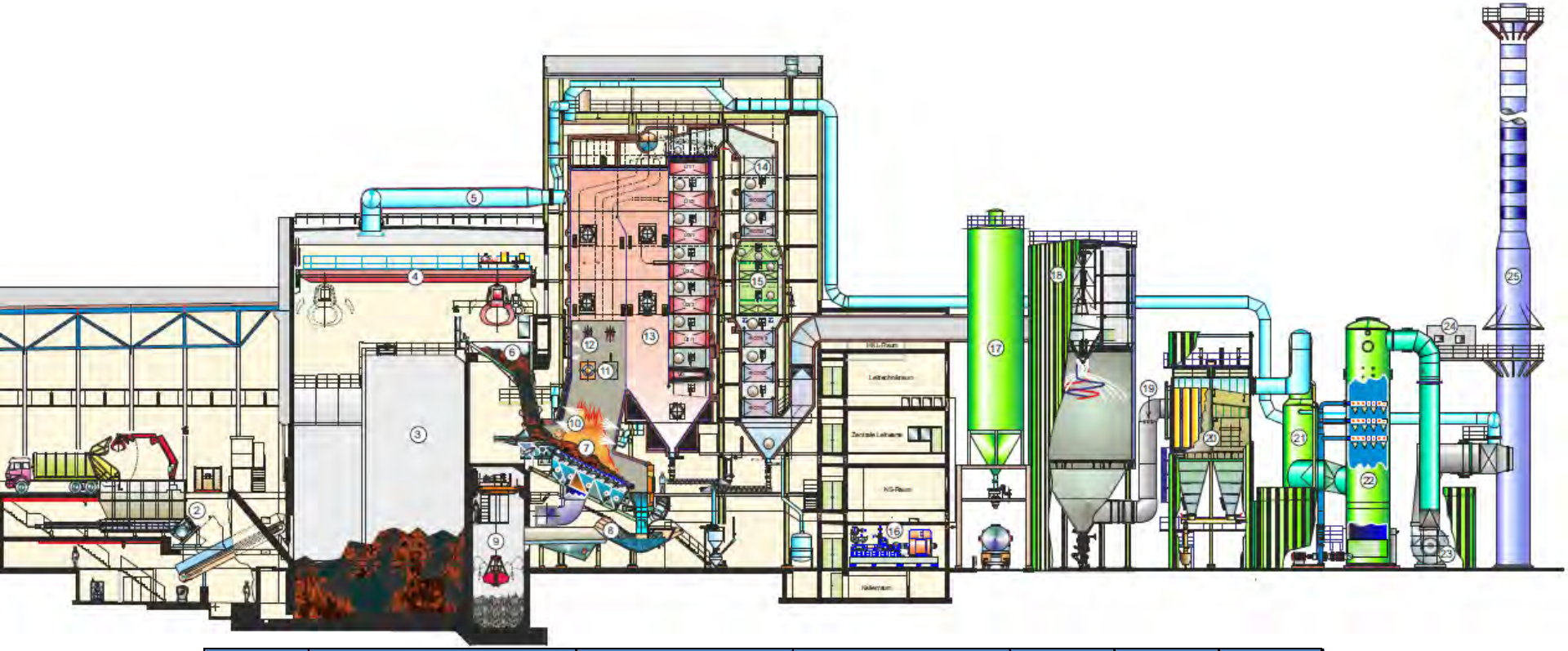
GEA Salt Dryer Installations in Waste Applications (continued)

Installation	Fuel	Start-Up
AVI-Twente I-II Hengelo Netherlands	Municipal Solid Waste	1997
AEZ Kreis Wesel Kamp-Lintfort Germany	Municipal Solid Waste	1996
ZAR Furth I-II Furth Germany	Municipal Solid Waste	1996
Werk Weiherhammer Flachglass AG Weiherhammer Germany	Glass Factory	1995
ARN-NV Nijmegen, Netherlands	Municipal Solid Waste	1994
IWIP Dorog Hungary	Hazardous Chemical Waste	1991
MHKW Schweinfurt Germany	Municipal Solid Waste	1994
Ekokem OY AB Riihimaki Finland	Hazardous Chemical Waste	1984
Hessische Industriemull GmbH Biebesheim Germany	Hazardous Chemical Waste	**1982**

Comparison with Waste Effluent Salt Drying

- **Similar evaporation temperatures**
- **Similar effluent chloride content**
- **Not base loaded**
- **Flue gas composition**
  - Swings
  - Moisture
- **Slipstream**
- **Higher magnesium**

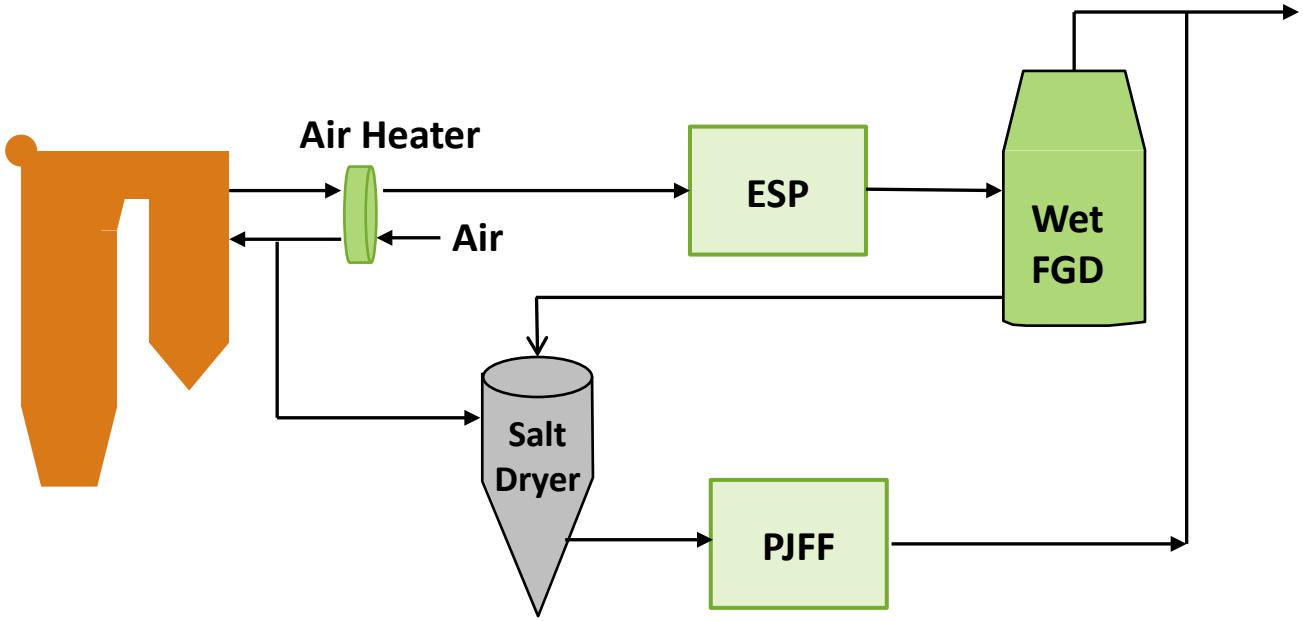
Plant Operating Data



Plant	Spray Chamber Diameter	Outlet Temperature	WFGD Effluent Flow	Chlorides	pH	TSS
	ft	F	gpm	ppm		wt%
Plant A	28	345	11.5	70000	6.2	3.5
Plant B	33	350	18.5	70000	6.2	6
Plant C	33	325	22	52000	7	4.5
NJV3	26	285	26.5	30000	?	?

Plant Schematic from MARTIN GmbH

NJV3 Process Flow Diagram



- Coal-fired boiler
- Wet FGD uses SDA byproduct as reagent
- Replacement of GGH
- Salt dryer byproduct is landfilled

Adapted from Knudsen, N.O., VGB PowerTech 5/2006-Production of a Liquid De-icer by evaporation of FGD Waste Water at Nordjyllandsvaerket, Unit 3

Operating Information

- **Installations exist with both ESP and PJFF**
  - Bag life reportedly ranges from 5 to 14 years
- **Hydrated lime use**
  - Plant A can add lime to the wastewater storage tank and also has the ability to add lime to the feed slurry during acid gas spikes
  - Plant B does not add lime to their wastewater after leaving the scrubber
  - Plant C adds lime as part of the dual alkali process before spray drying the wastewater
- **Material handling systems included pneumatic, screw, and conveyor type systems**

Operating Precautions

- **Issues during operation are reported to be rare**
- **Standard atomizer maintenance**
- **Precautions taken during shutdowns**
  - Baghouse blinding
  - Heat tracing
- **Spray chamber deposits**
  - Plant B Upgrade
- **Material handling**
  - Most common source of issues, typically during shutdown
  - Bulk density fluctuations

Process Validation

- Pilot testing
- Corrosion
- Volatilization
- Material handling

Salt Dryer Pilot Testing

Variables Tested

- Spray dryer inlet/outlet temperature
- Gas residence time
- Atomizer wheel speed – droplet size
- Gas composition
- Wastewater composition
- Suspended solids
- Dissolved solids

Testing Conditions/Results

Test Conditions

Fluid – Full-scale wet FGD wastewater

Composition variations included:

- gypsum, limestone, calcium bromide, calcium chloride, magnesium sulfate, recycled dried salts in varying modes/quantities

Atomizer wheel speed

- 11,000 rpm – 20,000 rpm

Spray dryer inlet temperature

- 538F – 612F

Spray dryer outlet temperature

- 283F – 340F

Test Results

High TSS vs. Low TSS – much improved drying

Good drying results from higher atomizer speeds

Nearly all solutions exhibited drying issues with atomizer speeds below ~12,500 rpm and with T_{out} ~300F. Droplet size at these conditions are well above what is anticipated in a commercial application.

All fabric filter solids were dry

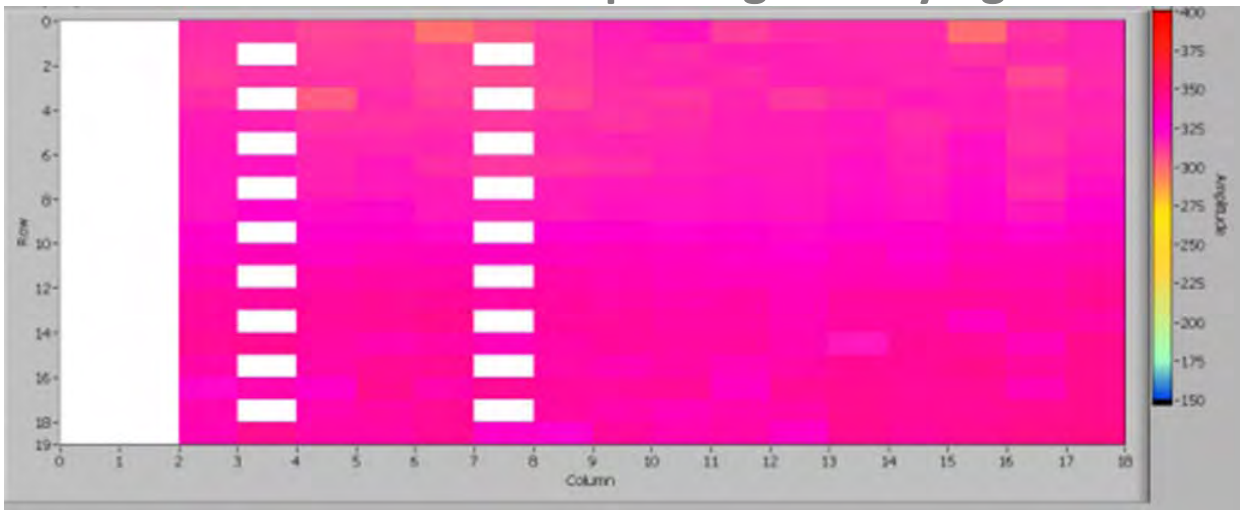
At 20,000 rpm atomizer speed, several wastewaters were dried to temperatures below 285F

Flue gas outlet composition monitored

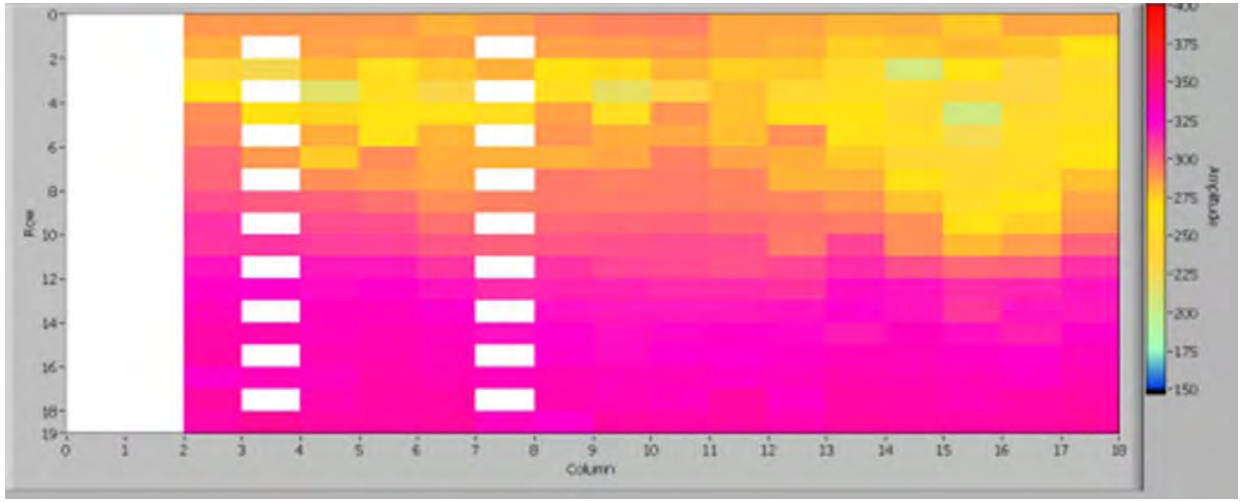
Dried product bulk densities ~65 lb/ft^3

Pilot Data Collection

Process Condition 1 – example of good drying



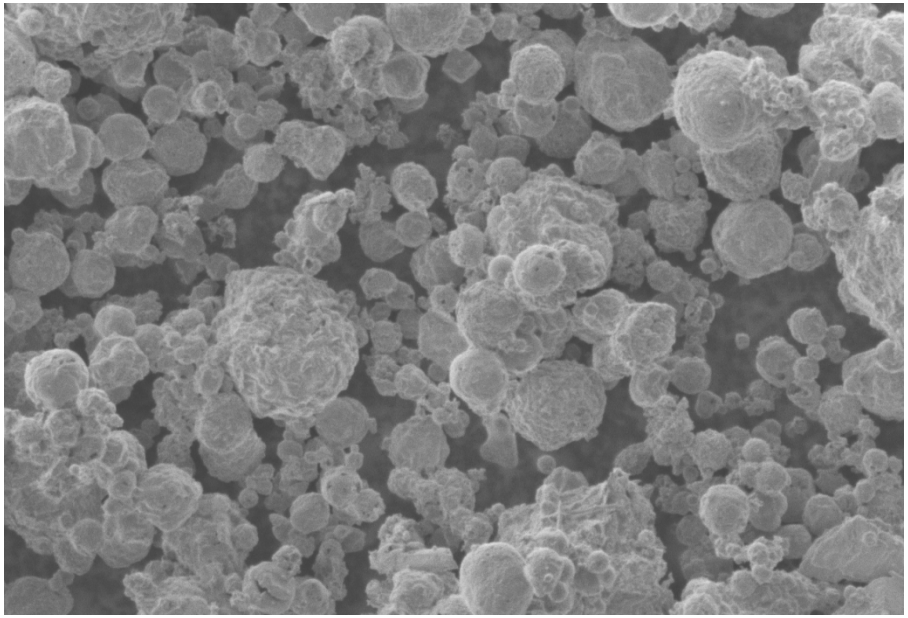
Process Condition 2 – example of poor drying



- **342 TCs**
- **10s scan rate**
- **Data used to compare drying rates**

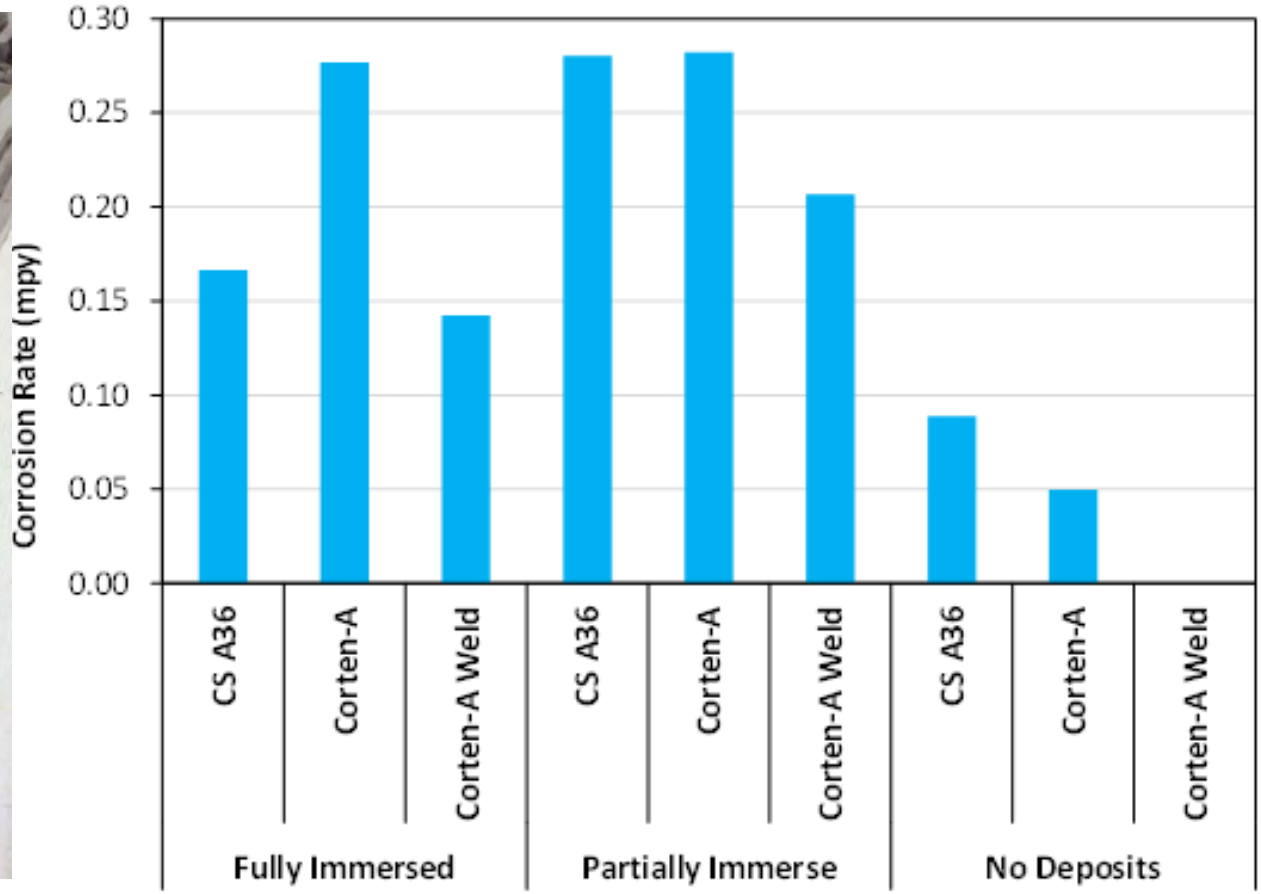
Salt Dryer Byproduct Material Testing

- Dried by-product bulk densities ~ 65 lb/ft^3
- Other material handling properties required for system design measured as well for various moisture levels and for various process conditions.



SEM Photograph of Dried By-Product

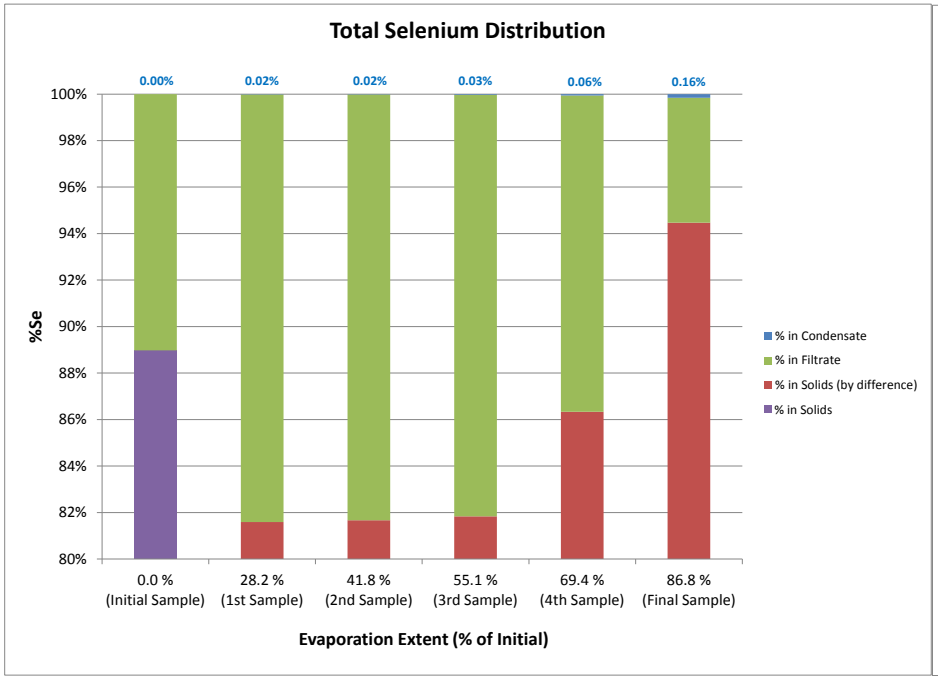
Corrosion Testing

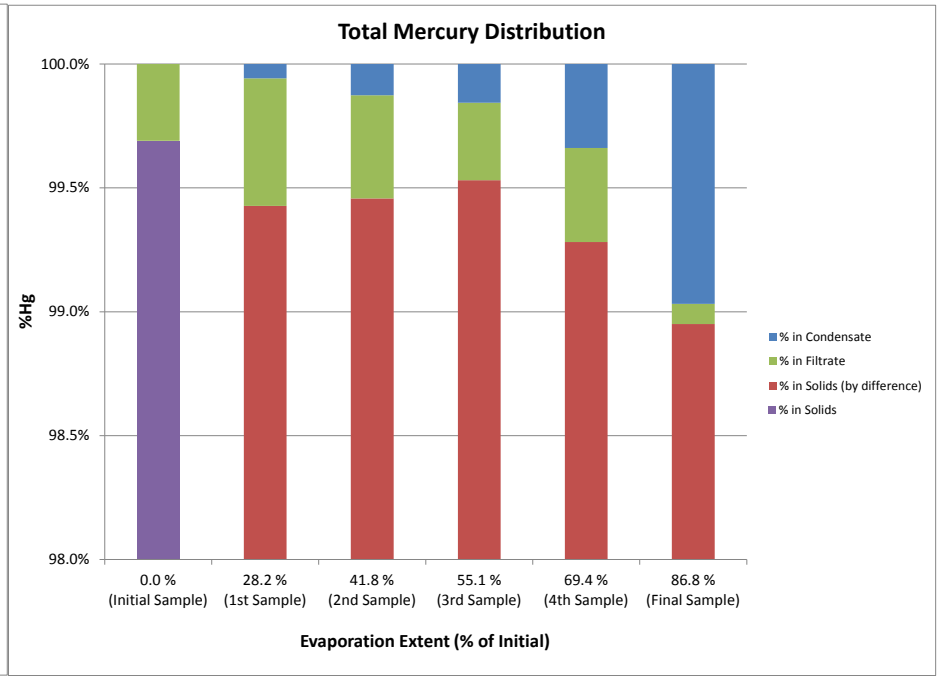


Volatilization Testing

- **Wet FGD wastewater evaporated while tracking pollutants of concern**
- **Testing has included experiments on filtrates, slurry, speciation studies, additives, and wastewaters from various sources.**

Example Charts





Recent Utility Salt Dryer Project Evaluations and Offerings

Unit Size	Coal Cl	Wastewater Properties		Flue Gas Properties			Spray Chamber	Plant Impacts	
		Flow Rate	Chlorides	Inlet Temperature	Outlet Temperature	Flow Rate	Diameter	Parasitic Load	Boiler Efficiency Loss
Gross MW	% by Weight AR	gpm	ppm	°F	°F	% of Total	ft	%	%
~1400	0.11%	150	40,000	650	330	NA	49	0.08%	Not Calculated
~725	0.12%	110	20,000	650	330	11.5%	46	0.19%	0.21%
~900	Not Provided	200	21,000	650	330	12.5%	52.5	0.12%	0.30%
~550	Not Provided	80	50,000	710	330	8.5%	37	0.05%	Not Calculated

Questions?

Thank you!

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