REINHOLD ENVIRONMENTAL Ltd.

2018 APC & Wastewater Round Table & Expo Presentation

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

Duct Wastewater Injection:

Low-Cost ZLD Strategy for ELG Compliance

Reinhold Environmental 2018 APC-Wastewater Conference

Lexington, Kentucky

Sterling Gray, AECOM

July 24, 2018

AECOM

Outline

- Effluent Limitation Guidelines Rule
- Compliance Alternatives
- Duct Wastewater Injection
- Experience / Issues
- Summary
- Questions

Effluent Limitation Guidelines (ELG) Rule

Background

– Applies to Steam Electric Power Generating Point Sources (> 50 MW)

– Regulates numerous plant water streams:
  - FGD Wastewater
  - Combustion Residuals (Landfill/Pond) Leachate
  - Fly Ash and Bottom Ash Transport Water
  - Flue Gas Mercury Control Water
  - Gasification Wastewater

– Compliance “window” was Nov 2018 – Dec 2023, but…

– Rule “stayed” April 2017 – draft rule Dec 2018 - final rule Dec 2019

ELG Rule Requirements

Compliance Approach and Technologies

Wastewater Stream	Best Available Technology Economically Achievable (BAT) for Existing Direct Dischargers
FGD Wastewater	Physical/Chemical precipitation with biological treatment * *No size threshold*
Fly Ash Transport Water	Zero discharge of fly ash transport water pollutants - vacuum systems to pneumatically convey ash to silos
Bottom Ash Transport Water	Zero discharge of bottom ash transport water pollutants – drag chain or remote drag chain * *No size threshold*
Leachate from ponds and landfills containing CCRs / gypsum dewatering	No change from current limits for TSS and Oil and Grease, separated from low volume wastewater definition
Flue Gas Mercury Controls Wastewater	Zero discharge – dry handling with vacuum system to convey directly to silos

ELG Rule Requirements

Current vs. Historical Limits for FGD Wastewater

	Daily Max	Monthly Average	Long Term Average Target*	1982 – Daily Max	1982 – Monthly Average
Arsenic, total	11 ug/l	8 ug/l	6.0 ug/l	Previously only limited to BPT as Low Volume Wastes	
Mercury, total	788 ng/l	356 ng/l	160 ng/l		
Selenium, total	23 ug/l	12 ug/l	7.5 ug/l		
Nitrate/Nitrite as N	17 mg/l	4.4 mg/l	1.3 mg/l		
Total Suspended Solids	100.0 mg/l	30.0 mg/l		100.0 mg/l	30.0 mg/l
Oil and Grease	20.0 mg/l	15.0 mg/l		20.0 mg/l	15.0 mg/l

*LTA Target for Design and Operations to Meet Limits

Wet FGD Systems

Utility & Independent Power Producers

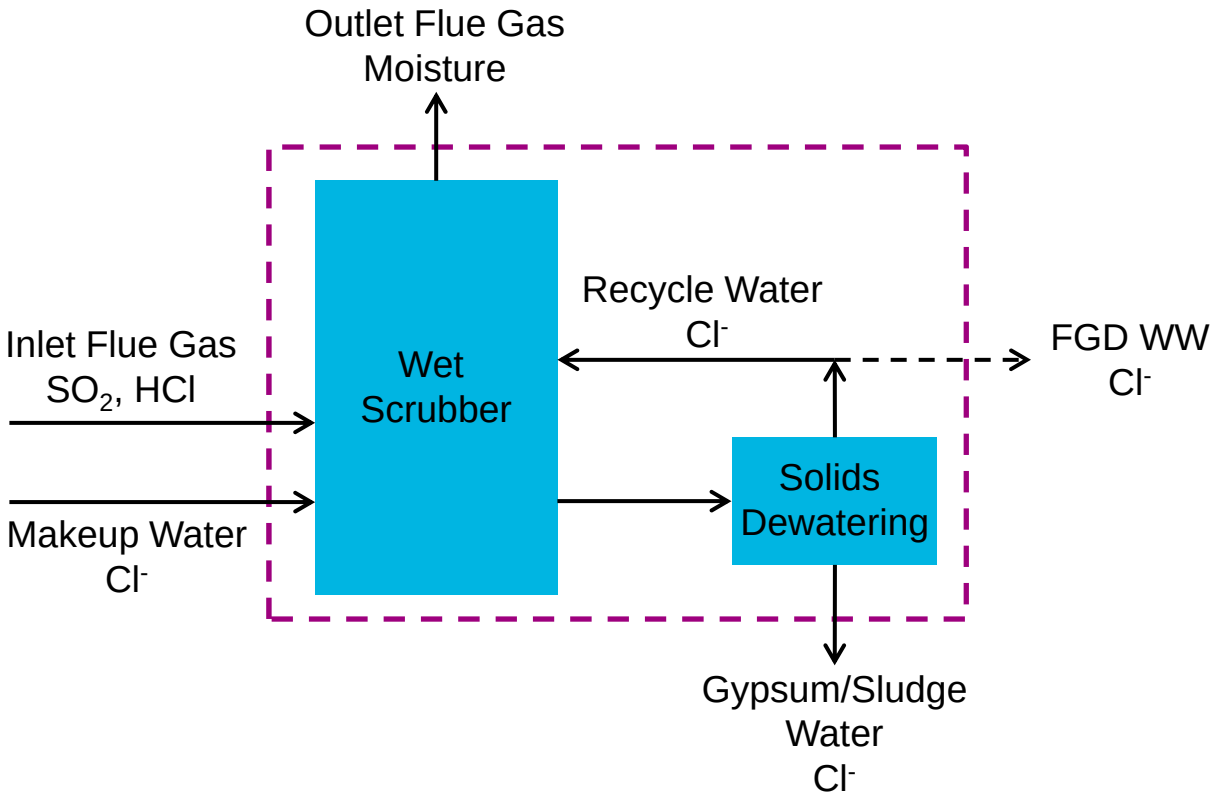
FGD Process	Units	Total MW
Dual Alkali	3	1,100
Wet soda ash FGD scrubber	6	2,900
Wellman-Lord process for FGD, sodium-sulfite based	2	740
Wet lime FGD scrubber	42	22,800
Wet lime-alkaline fly ash FGD scrubber	7	3,700
Wet limestone FGD scrubber	285	146,500
Wet FGD (unspecified)	3	1,700
Grand Total	**348**	**179,400**

** Data from Platts UDI, July 2015*

Approximately 180 GW Wet FGD Subject to the Rule

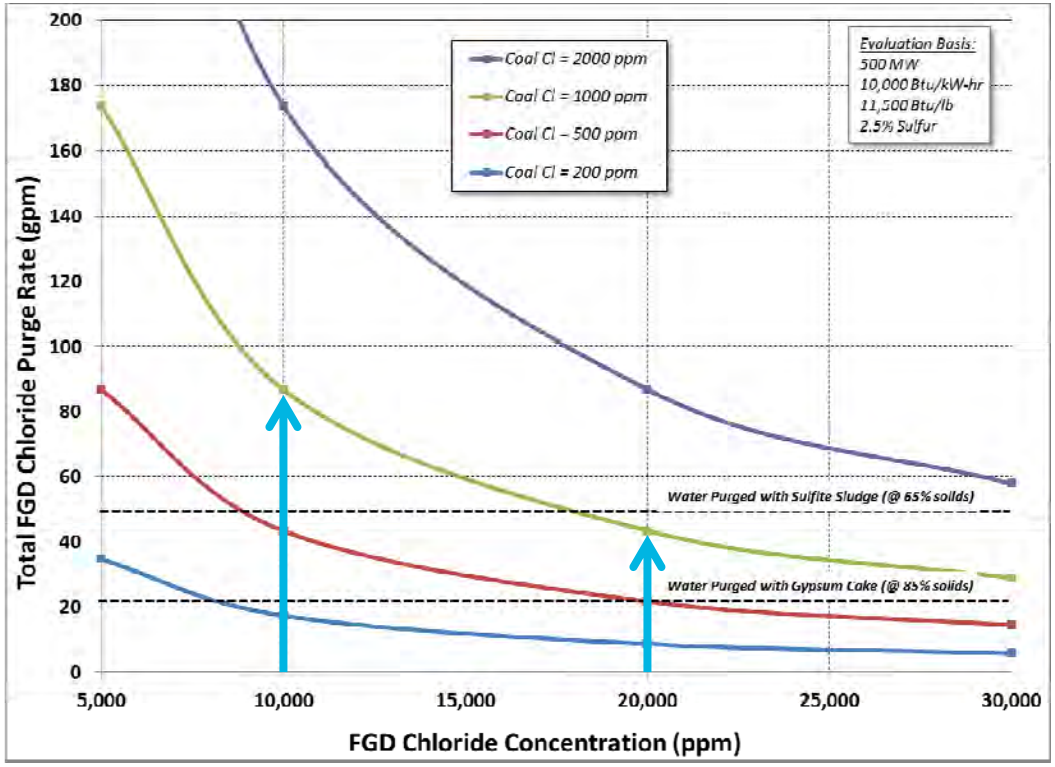
Wet FGD Systems

Chloride Material Balance



Wet FGD Chloride Purge Rate

Effect of Coal Cl Content and FGD Cl Concentration



Example:
Coal Cl ~ 1,000 ppm
FGD Cl ~ 20,000 ppm

FGD Waste Basis	Required Chloride Purge (gpm)	Waste Solids Chloride Purge (gpm)	Net FGD WW Cl Purge Rate (gpm)
Landfill Sulfite Sludge	43	49	< 0
Landfill Gypsum	43	21	22
Sell Gypsum	43	0	43

ELG Rule Requirements

FGD WW Treatment Alternatives

Treat ‘n’ Discharge

Zero Liquid Discharge (ZLD) – Evaporative Technologies

Wastewater Treatment	Brine Concentrator – Crystallizer	Spray Dryer	Duct Wastewater Injection

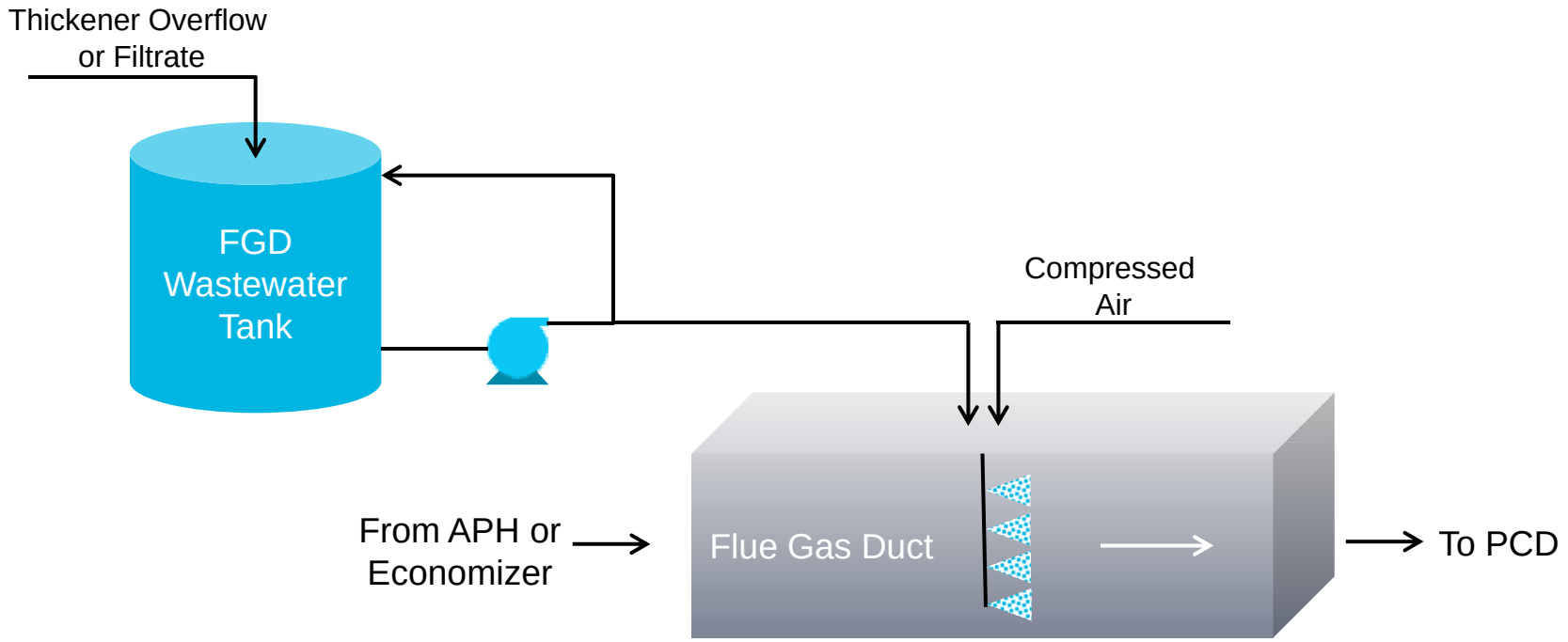
ELG Rule Requirements

Comparison of FGD WW Treatment Alternatives

Control Strategy	Wastewater Treatment	Brine Concentrator/ Crystallizer	Spray Dryer	Duct Injection
Capital Cost	$$$	$$$	$$	$
Operating Cost	$$	$$$	$	$
Footprint	L	L	M	S
ZLD	No	Yes	Yes	Yes
Disposal	NPDES Discharge	Landfill	w / Ash	w / Ash
Ash Quality Impact	No	No	?	?
Future Regulatory Risk	Yes	-	-	-

Duct Wastewater Injection

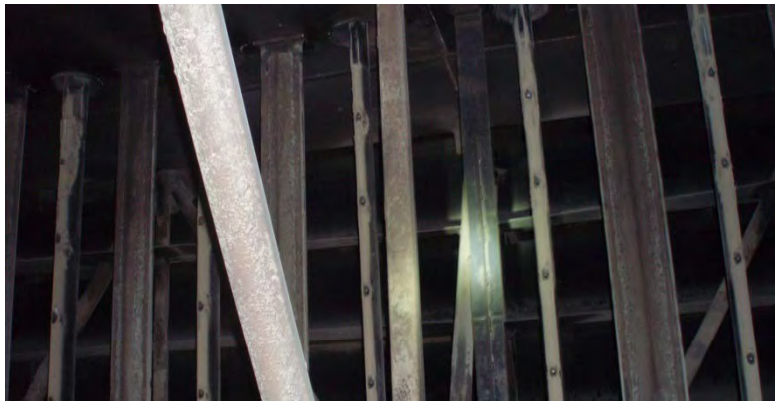
Simplified Process Flow Diagram



Duct Wastewater Injection

AECOM's Related Experience

- **SBS Injection™ Technology** injects a concentrated salt solution into the flue gas stream, AECOM has perhaps more experience than any company at successfully injecting salt solutions directly into flue gas ductwork
- AECOM has extensive **CFD** capabilities that have been employed routinely in the design and evaluation of evaporative processes
- AECOM has **proprietary injection technology** (lances and nozzles) that have been continuously updated to maximize performance and reliability



SBS Injection™ Technology

- Duct Injection of Soda Ash Solution
  - Removal of SO_3 / H_2SO_4
  - 50,000 -200,000 ppm TDS
- First Deployed Commercially in 2003
  - More than decade of operation
- Installation List:
  - 32 Boilers across 14 Plants
  - 18,000 MW
- Systems Installed Upstream:
  - SCR
  - Air Heater
  - PCD (ESP/FF)

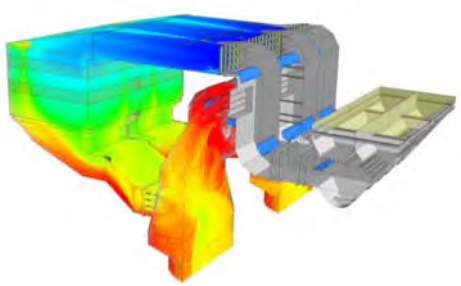
Utility	Plant	State	MW	Design SO_3	Injection Location	Reagent	Startup Date
FirstEnergy	Mansfield 1-3	PA	3 x 860	80	Air Heater Inlet	Sodium Sulfite	2003
TVA	Widows Creek 7	AL	550	54	Air Heater Inlet	Sodium Sulfite	2003
NIPSCO	Bailly 8	IN	365	59	Air Heater Outlet	Sodium Carbonate	2004
Vectren	Culley 3	IN	287	48	SCR Outlet	Sodium Carbonate	2004
PPL	Montour 1-2	PA	2 x 765	42	Air Heater Outlet	Sodium Carbonate	2004
Duke Energy	Gibson 1-5	IN	5 x 650	110	Air Heater Outlet	Sodium Carbonate	2005
DP&L	Killen 2	OH	635	34 / 36	Econ Outlet / SCR Outlet	Sodium Carbonate	2007
IP&L	Harding St 7	IN	465	58	SCR Outlet	Sodium Carbonate	2007
NIPSCO	Bailly 7	IN	180	59	SCR Outlet	Sodium Carbonate	2008
DP&L	Stuart 1-4	OH	4 x 620	90	SCR Inlet	Sodium Carbonate	2008
Duke Energy	Gibson 1-5	IN	4 x 650	110	SCR Inlet	Sodium Carbonate	2009 - 2014
FirstEnergy	Pleasants 1-2	WV	2 x 700	74	SCR Outlet	Sodium Carbonate	2012
Hoosier Energy	Merom 1-2	IN	2 x 540	100	SCR Inlet	Sodium Carbonate	2012
IP&L	Petersburg 1-4	IN	1890	35 - 85	SCR Inlet / Air Heater Inlet	Sodium Carbonate	2015
Vectren	AB Brown 1-2	IN	2 x 265	30	FGD Inlet	Sodium Carbonate	2015
AEP	Conesville 6	OH	444	40	APH Inlet	Sodium Carbonate	2017

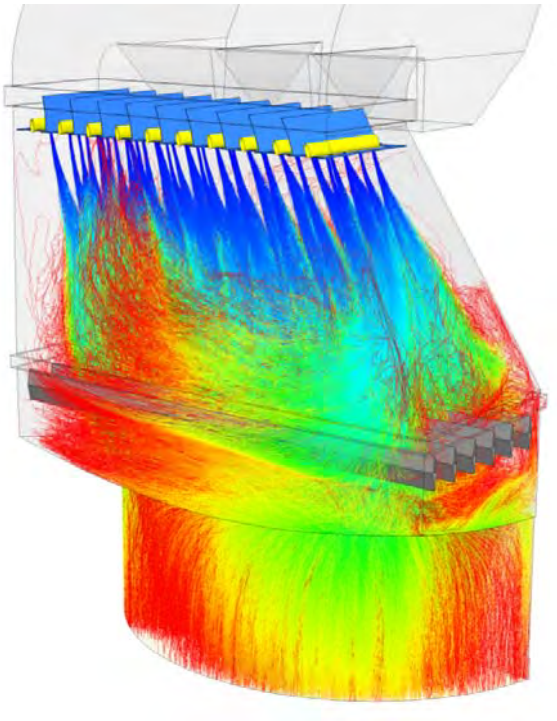
Duct Wastewater Injection

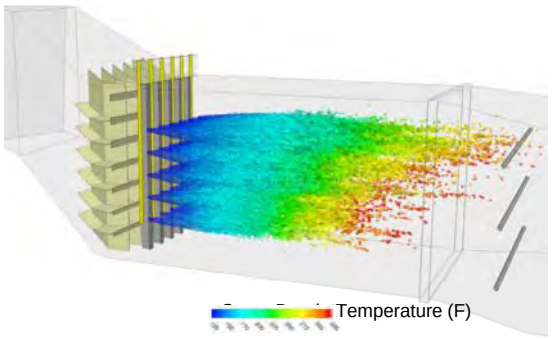
CFD Simulation Tools Used to Predict Evaporation

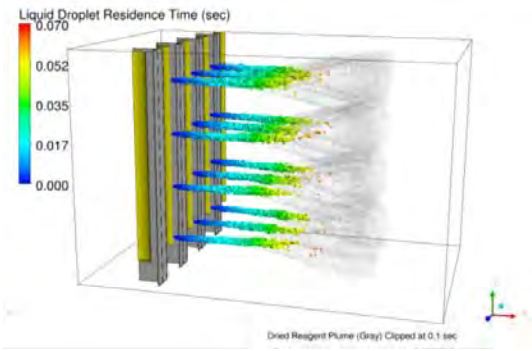
Key Considerations

- Injection nozzle characteristics
- Solution composition
- Droplet particle size distribution
- Flue gas turbulence/mixing









Duct Wastewater Injection

Advantages and Disadvantages

– Advantages:

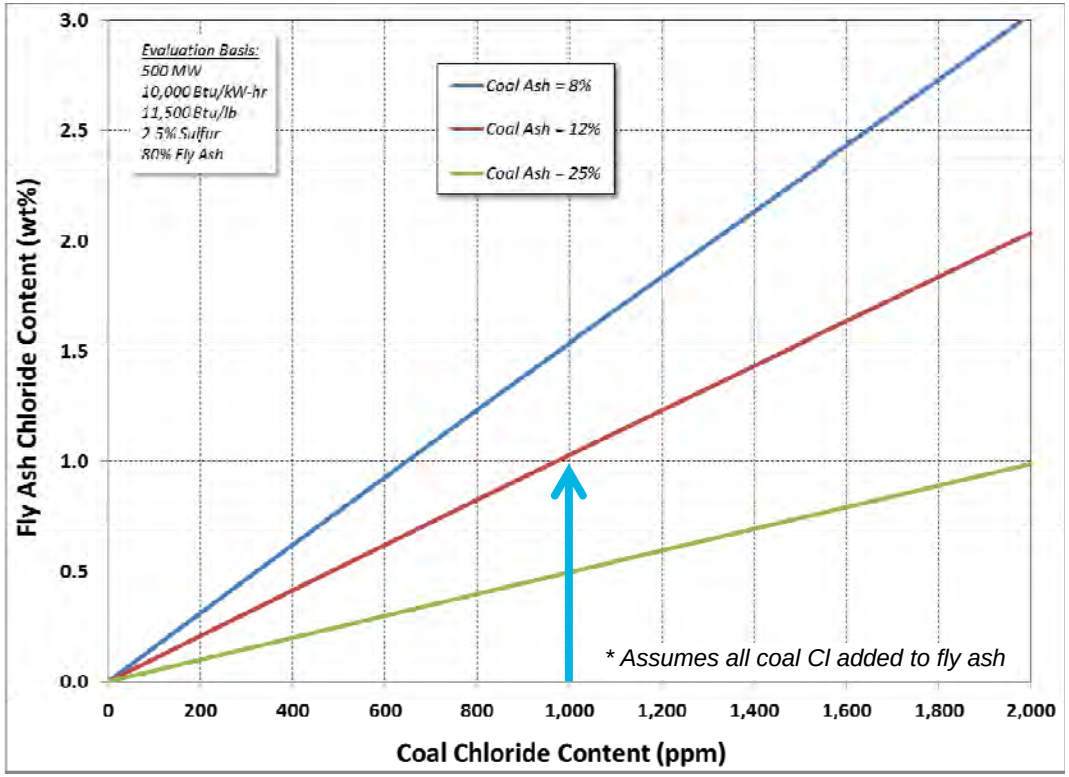
- Low CapEx and OpEx
- No chemical / biological treatment
- Utilizes waste heat for evaporation (typically post-air heater)
- Small footprint (easy to retrofit)
- Can be operated “intermittently”
- Can be “turned down” with load
- Can handle wide range of WW TDS
- Does not generate a “new” solid waste stream
- No impact on gypsum sales

– Disadvantages:

- Requires installation and operation of duct injection equipment
- High compressed air demand
- Injection lances require periodic inspection and maintenance
- Small increase (1-3%) in quantity of fly ash stream (and thus disposal costs)
- Modest heat rate impact if injection is upstream of the air heater
- May impact fly ash sales
- Dried chloride salts ($CaCl_2$, $MgCl_2$, NaCl) salts are hygroscopic

Duct Wastewater Injection

Effect of Coal Chloride and Ash Content on Fly Ash Composition*

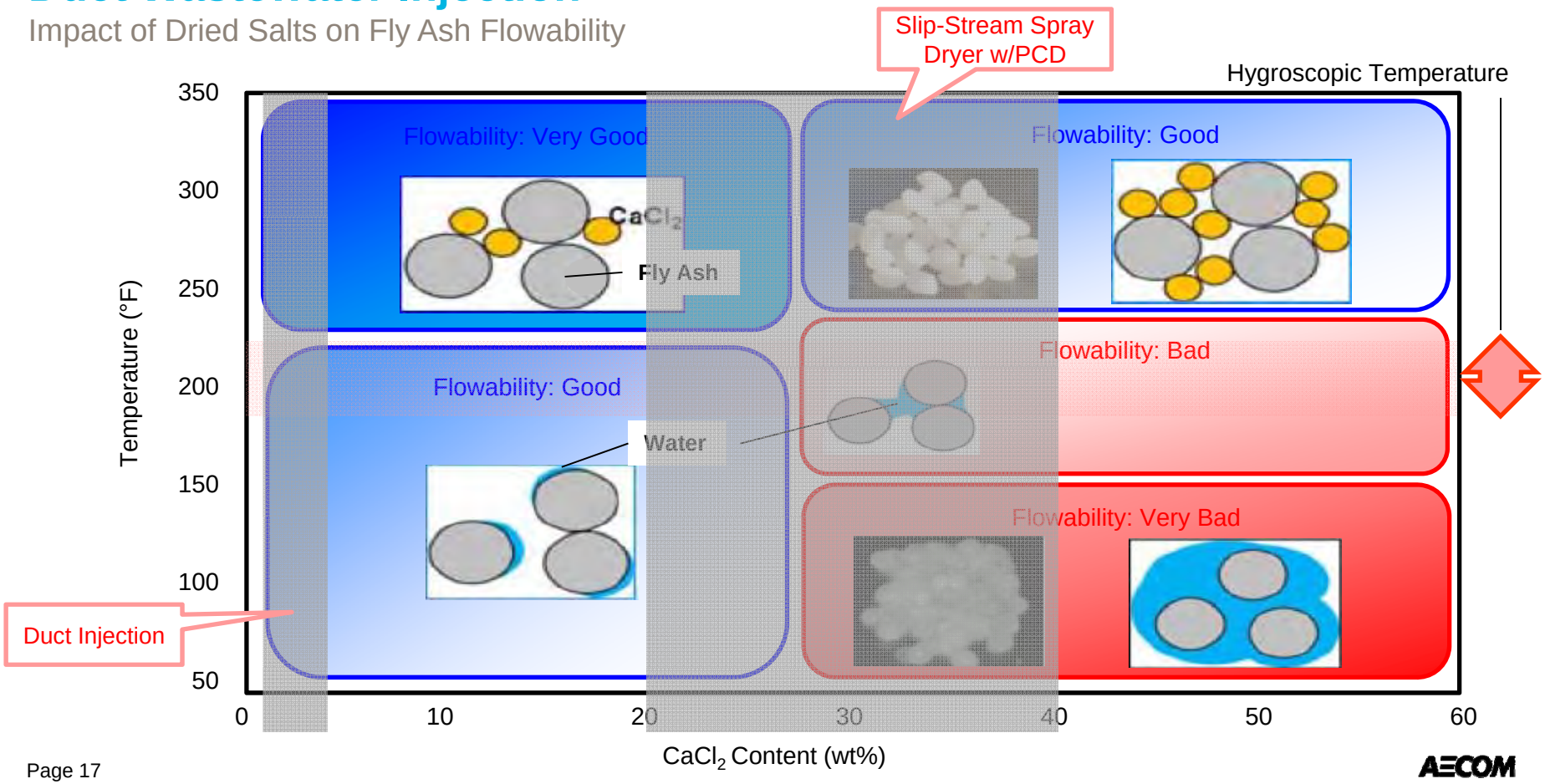


Example:
Coal Cl ~ 1,000 ppm
Coal Ash ~ 12%

Fly Ash Cl ~ 1.0 %
Fly Ash $CaCl_2$ ~ 1.6 %
Fly Ash Total Salt ~ 2.1 %

Duct Wastewater Injection

Impact of Dried Salts on Fly Ash Flowability



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Duct Wastewater Injection

Summary

- ELG rule regulates effluent streams from steam power plants (> 50 MW)
- Requires treatment of FGD wastewater discharge (chloride purge)
  - Physical/chemical precipitation – biological treatment – to meet stringent limits
  - Capital intensive – system operation is challenging – future regulatory risks
- Duct Wastewater Injection offers alternative approach (ZLD)
  - Evaporation using heat (waste) from flue gas stream
  - WW can be injected upstream or downstream of APH
  - Uses existing ductwork and PCD for capture of dried salts with fly ash
  - Low CapEx and OpEx relative to alternatives
  - No ash “handling” issues with low salt content
  - May impact fly ash quality and salability

Thank You

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