REINHOLD ENVIRONMENTAL Ltd.

2014 APC Round Table & Expo Presentation

July 14-15, 2014, in Louisville, KY / Hosted by LG&E/KU

HCl Removal Results From Low to High Cl Coals

Sorbacal®

Lhoist

Reinhold Conference – July 15, 2014
Jim Dickerman – Lhoist North America
Chad Donner – Duke Energy

Workshop Topics

- The importance of chlorides
- Chlorides in coals
- Duke Energy Case Study
- Summary of demonstration data

Why the Interest in Chloride Control?

- Reduce Corrosion
  - Improve process chemistry
  - Significantly reduce blowdown
- MATS compliance
  - HCl emissions of 0.002 lb/MM Btu or <2ppm
  - Surrogate by reducing SO_2 to 0.2 lb/MM Btu

Representative Properties of Various Coal Types

Coal Type	HHV (Btu/lb)	H2O (%)	C (%)	H (%)	N (%)	S (%)	Ash (%)	O (%)	Cl (%)
Anthracite	11890	7.7	83.7	1.9	0.9	0.7	10.5	2.3	---
Bituminous	10800	17.6	69	4.9	1	4.3	10.8	10	0.28
Bituminous	12970	2.2	74.9	4.7	1.27	0.76	13.4	4.97	0.15
CAPP	12281	6.32	73.01	4.77	1.43	0.79	12.5	7.42	0.06
Sub-Bit	9190	24.1	70.3	5	0.96	0.35	5.7	17.7	0.02
Sub-Bit	9540	23.4	72	5	0.95	0.44	5.2	16.4	0.01
Lignite	7090	33.3	63.3	4.5	1	1.1	11.1	19	0.005
Lignite	7080	37.7	66.3	4.9	1	1.2	10.4	16.2	0.005

Required Removal % for MATS HCl limit

(0.002 lb/MM Btu HCl or 0.2 lb/MM Btu SO_2)

	SO_2 (lb/MM Btu)	SO_2 (% Removal)	HCl (lb/MM Btu)	HCl (% Removal)
Anthracite	1.09	81.6%	------	------
Bituminous	6.56	97.0%	0.427	99.5%
Bituminous	1.15	82.6%	0.226	99.1%
CAPP	1.21	83.4%	0.092	97.8%
Sub-Bit	0.58	65.4%	0.033	93.9%
Sub-Bit	0.71	71.7%	0.016	87.5%
Lignite	2.07	90.3%	0.009	78.7%
Lignite	2.11	90.5%	0.009	78.7%

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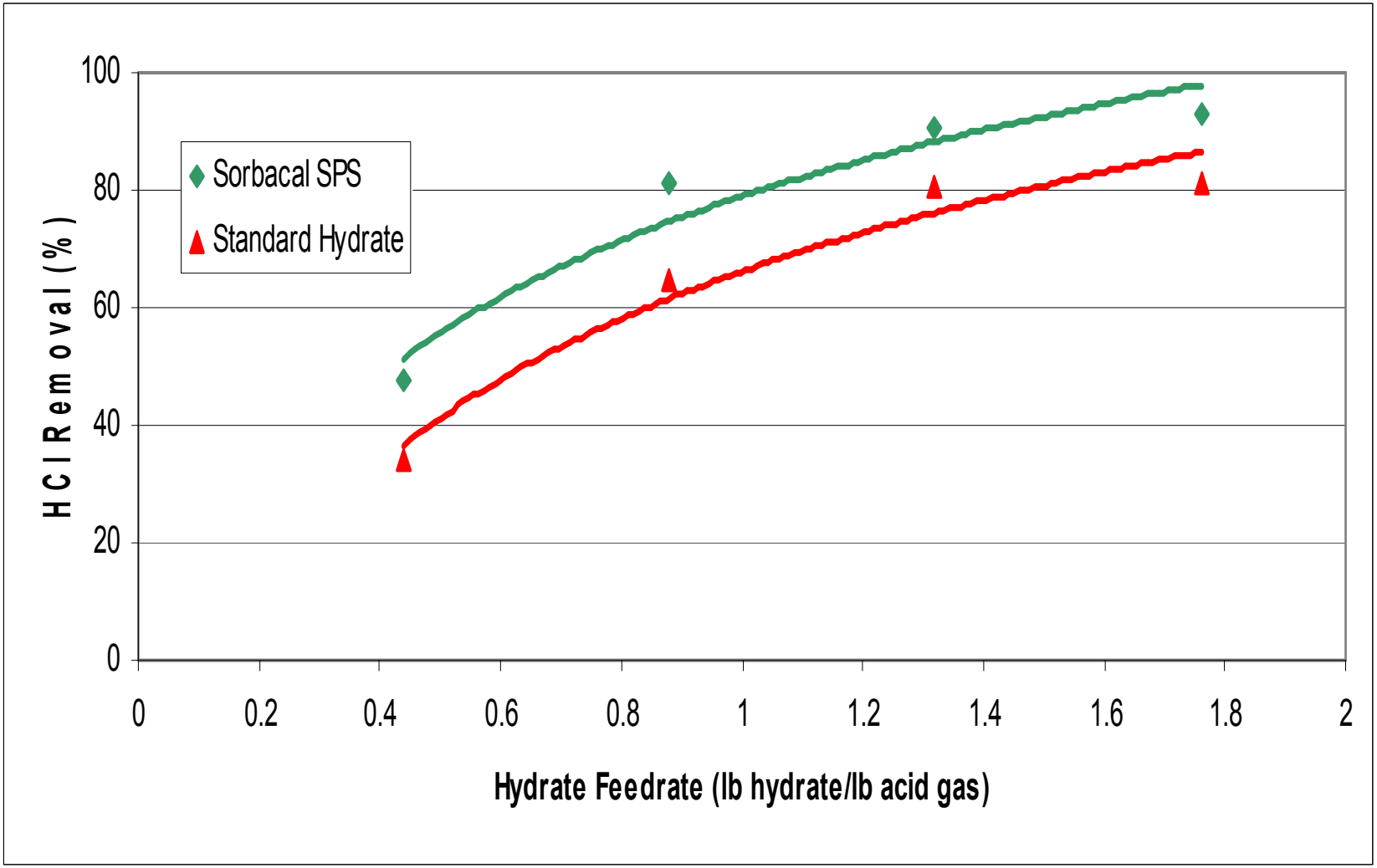
HCl Removal

High Cl Coal (0.33%) - 320°F Injection T - ESP



HCl Removal

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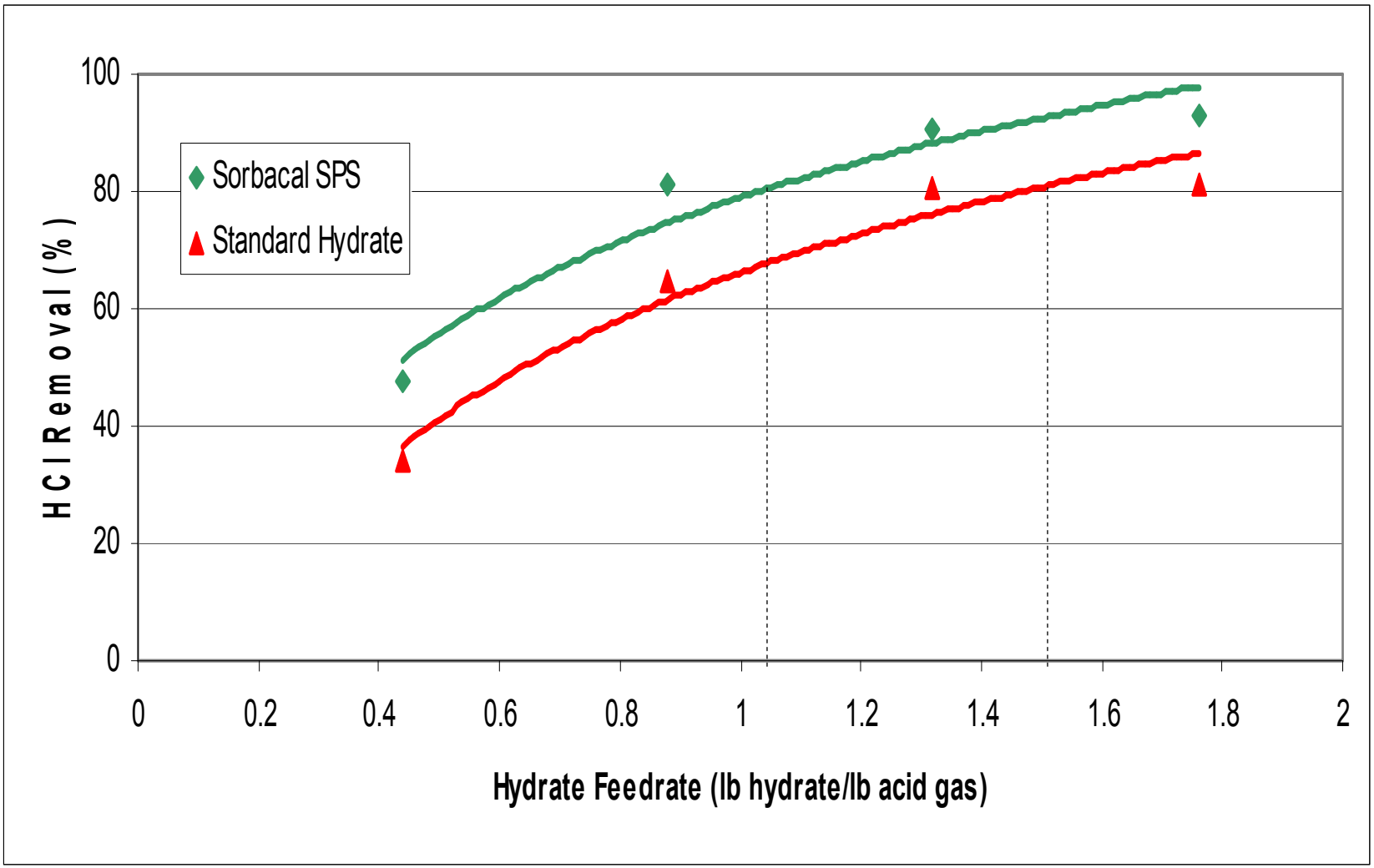
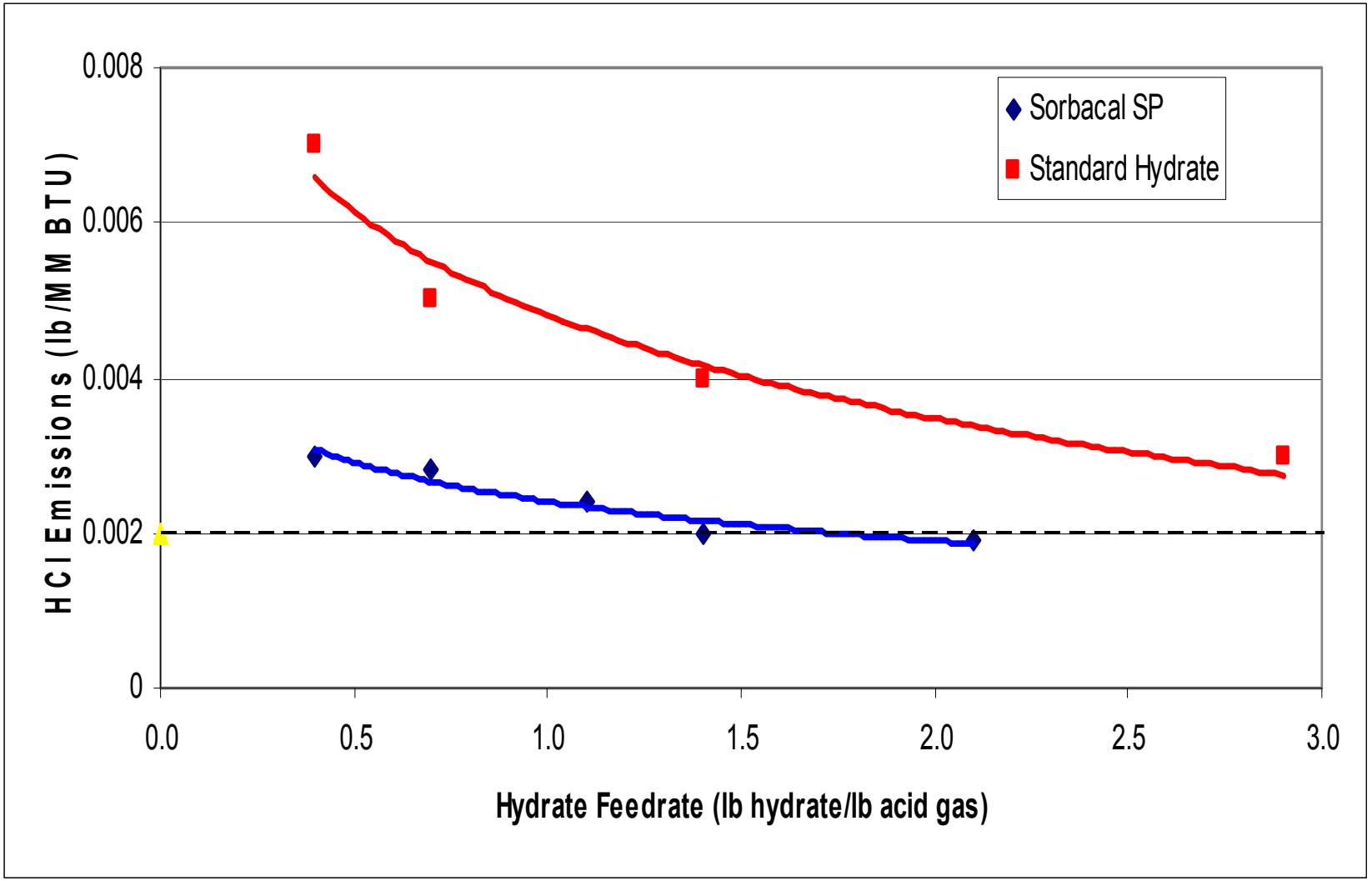


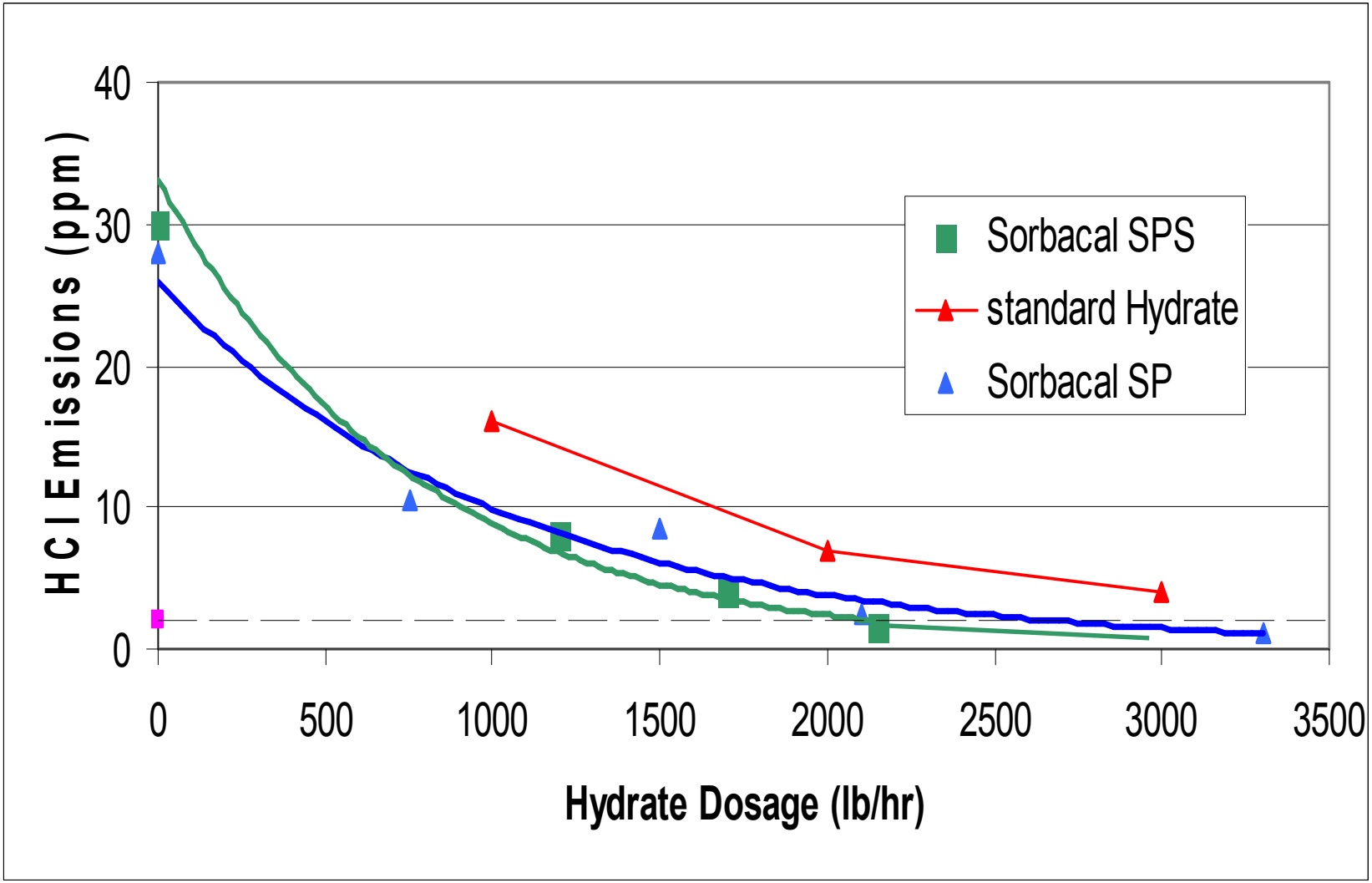
HCl Emissions

Medium Cl Coal (0.1%) – 320°F Injection T - Baghouse



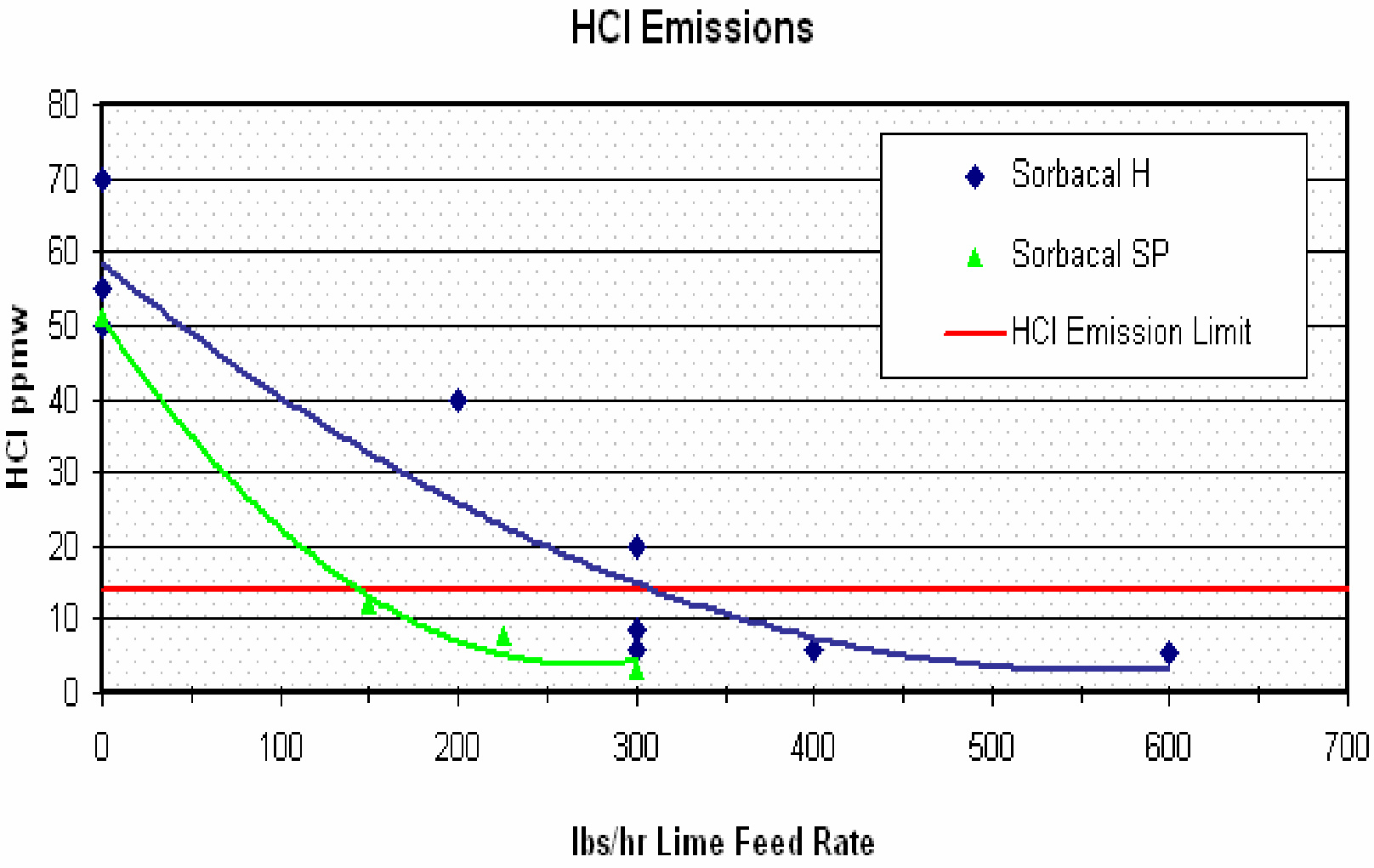
HCl Emissions

CFB Boiler – 660°F Injection T - Baghouse



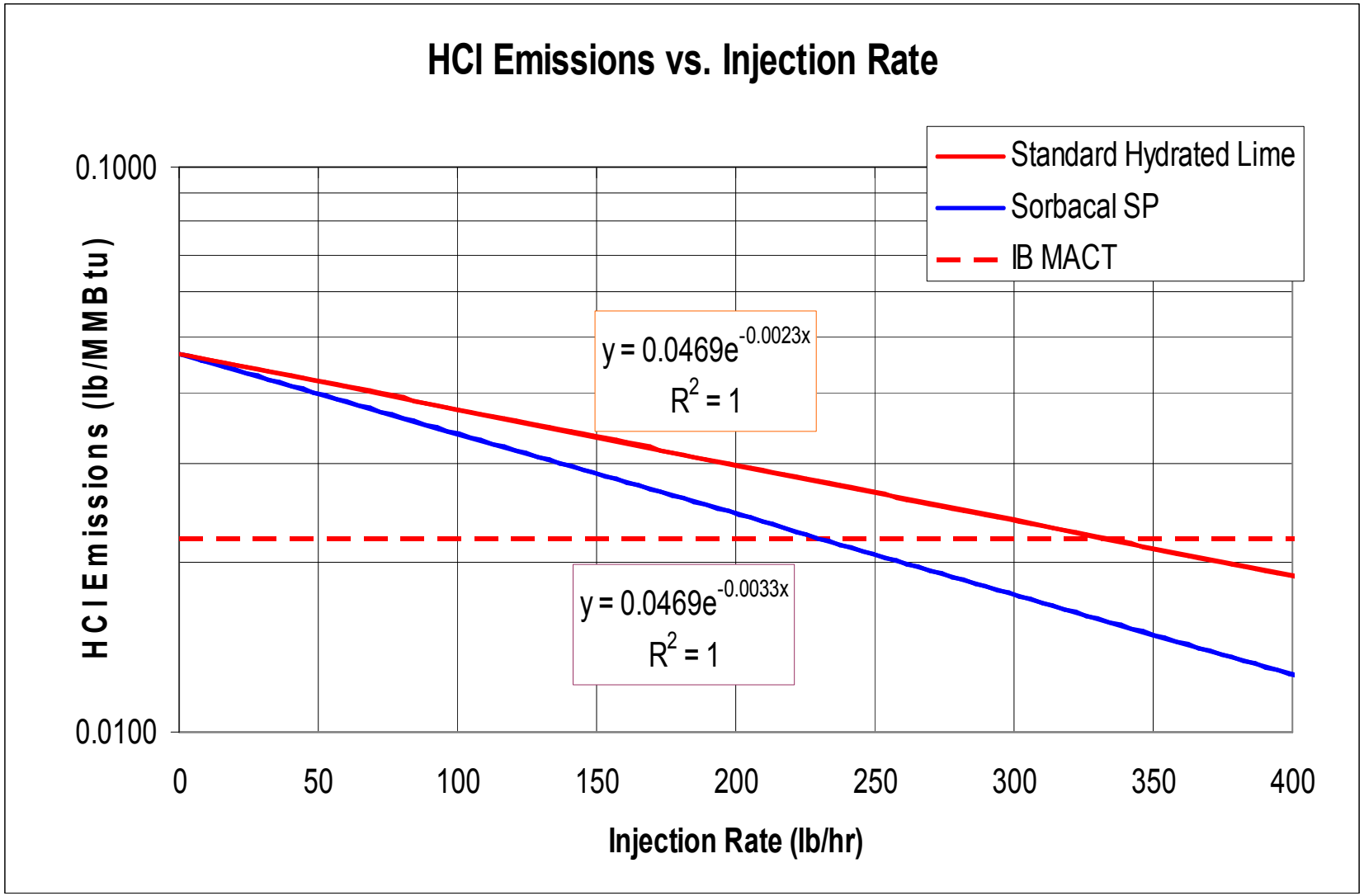
HCl Emissions

Industrial Boiler - 380ºF Injection T - Baghouse



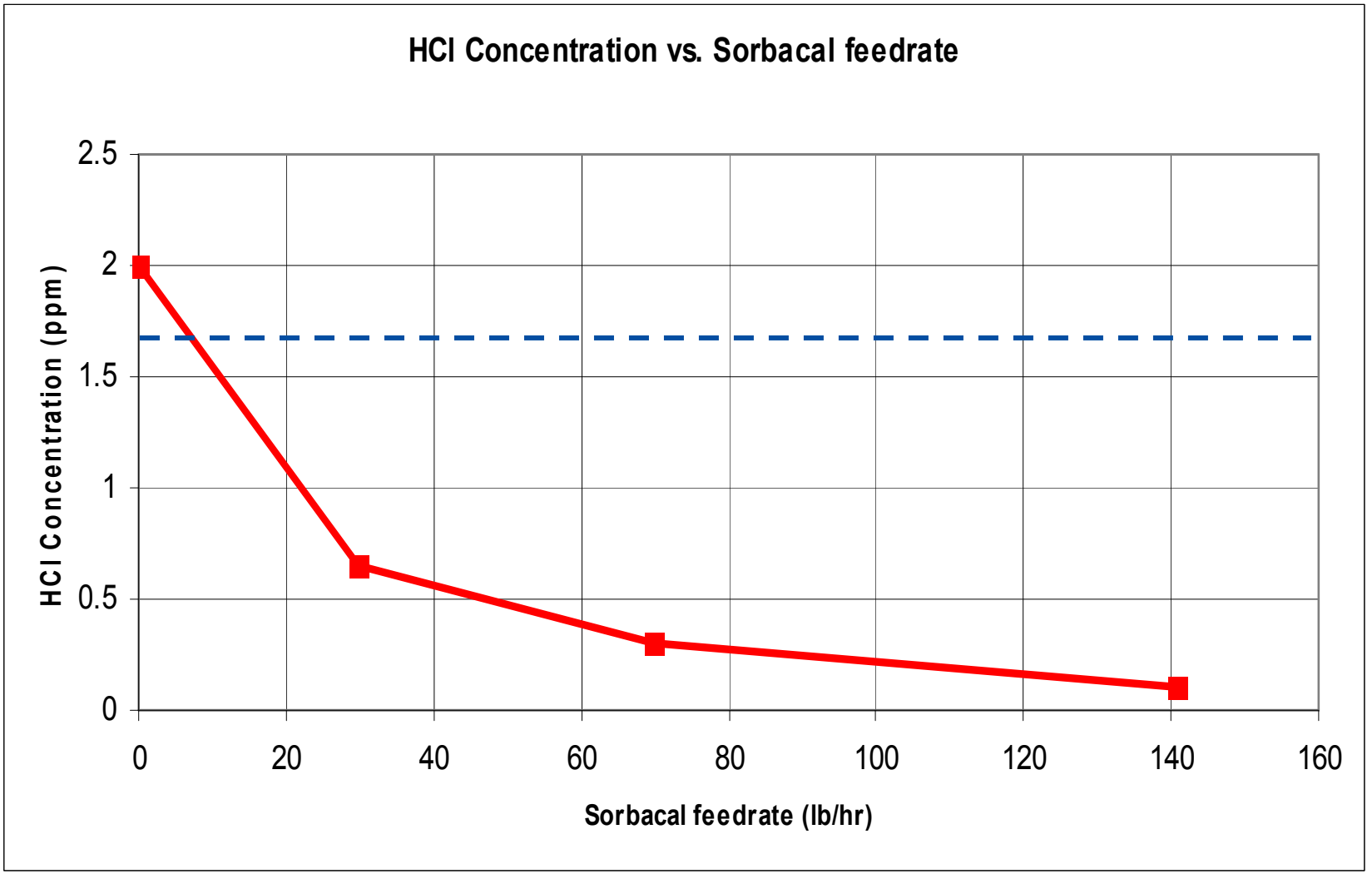
HCl Emissions

CFB Wood-fired boiler - 660°F Injection T - ESP



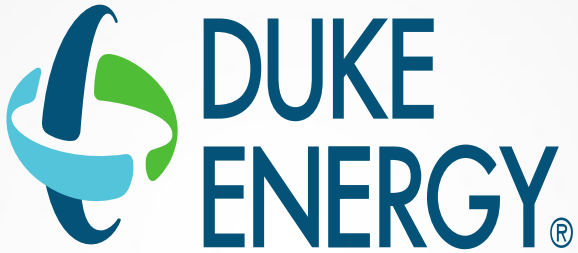
HCl Emissions

Low Cl coal (0.01%) - 320°F Injection T - baghouse



HCl Emission Testing Summary

- Sorbacal® SP performed >30% better than any other hydrate that was evaluated
- Coal Cl content varies widely and is a key factor in the ability to achieve the MATS emission level
- It may be possible to achieve the Industrial Boiler MACT HCl level (0.022 lb/MM BTU) with good standard quality hydrated lime, but Sorbacal® SP can meet the MACT HCl emission level using 30-50% less reagent
- Depending upon the coal Cl content and particulate controls, the utility boiler MATS HCl level (0.002 lb/MM BTU) may require Sorbacal® SP to meet the limit



2014 Reinhold APC Round Table

HCl Removal Case Studies – 714/14

Chad Donner – Sorbent Injection SME

Overview

- Case Studies
  - Zimmer High Chlorine Coal Trial
  - Gallagher Furnace Sorbent Injection Trial
- Impact on Ash Sales
- Questions

Zimmer High Chlorine Coal Trial

Case Studies

Zimmer High Chlorine Coal Trial

- 1400 MW gross B&W wall fired unit with Babcock Power SCR and B&W inhibited-ox mag-lime scrubber
- 7,500 ppm chloride limit in scrubber
- DSI could provide fuel flexibility with high chlorine coals
- High Cl coal = cheap if you can burn it
- Test coal analysis has not been received yet, but HCl in the gas ran 80-100ppm
- Distribution and reagent/gas ratios favored higher removals at the SCR inlet
- High LOI's were seen during testing which could be related to high injection rates

NOTES:
1. HSL = High Surface Area Lime ie Sorbacal SP
2. Dotted lines are for HSL
3. Solid Lines are for Standard Lime , ie Sorbacal H
4. Linear curves are reasonable for les than 50 -60%
5. Red Lines (dotted and solid) are for Solo Pre-SCR Injection
6. Green Lines (dotted and Solid) are for Solo Pre-ESP A&B Injection
6. Coal Sulfur Range is from 5.3 -2.3 #/MMBtu SO2. The highest removals occurred with the lowest Sulfur levels concurrent with the highest HCl levels. Therefore additional analysis is needed to determine the SO2 impacts.

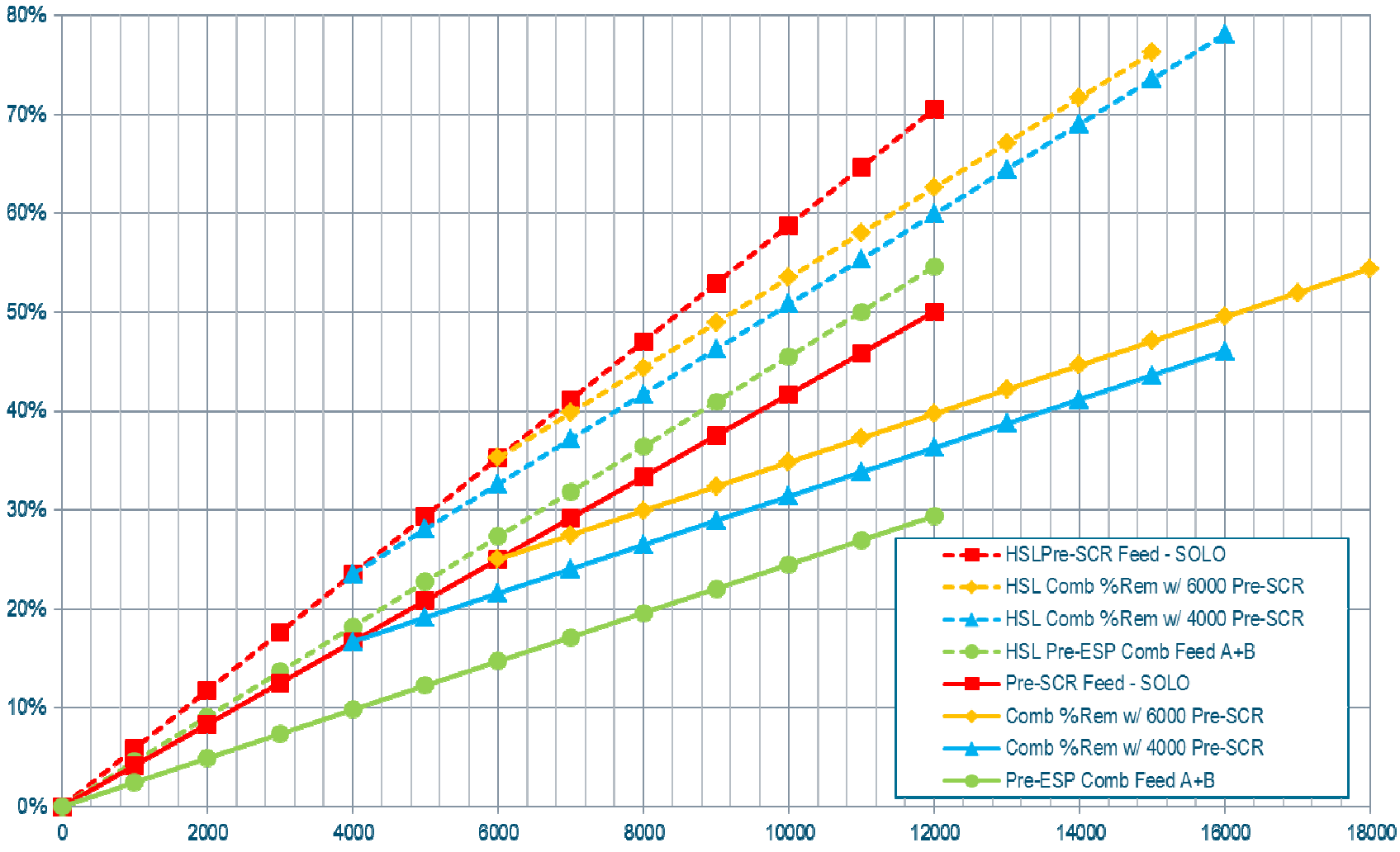
Test data credit to Mark Thomas & Associates

Zimmer High Chlorine Coal Trial

AH outlet injection with 2 parallel injection locations staggered, A&B, 24 lances each

SCR inlet injection utilizing the Delta Wing mixers for ammonia/Nox mixing, 4 lances/box

PREDICTED PERFORMANCE CURVES (PRELIM) FOR HYDRATED LIME INJECTION

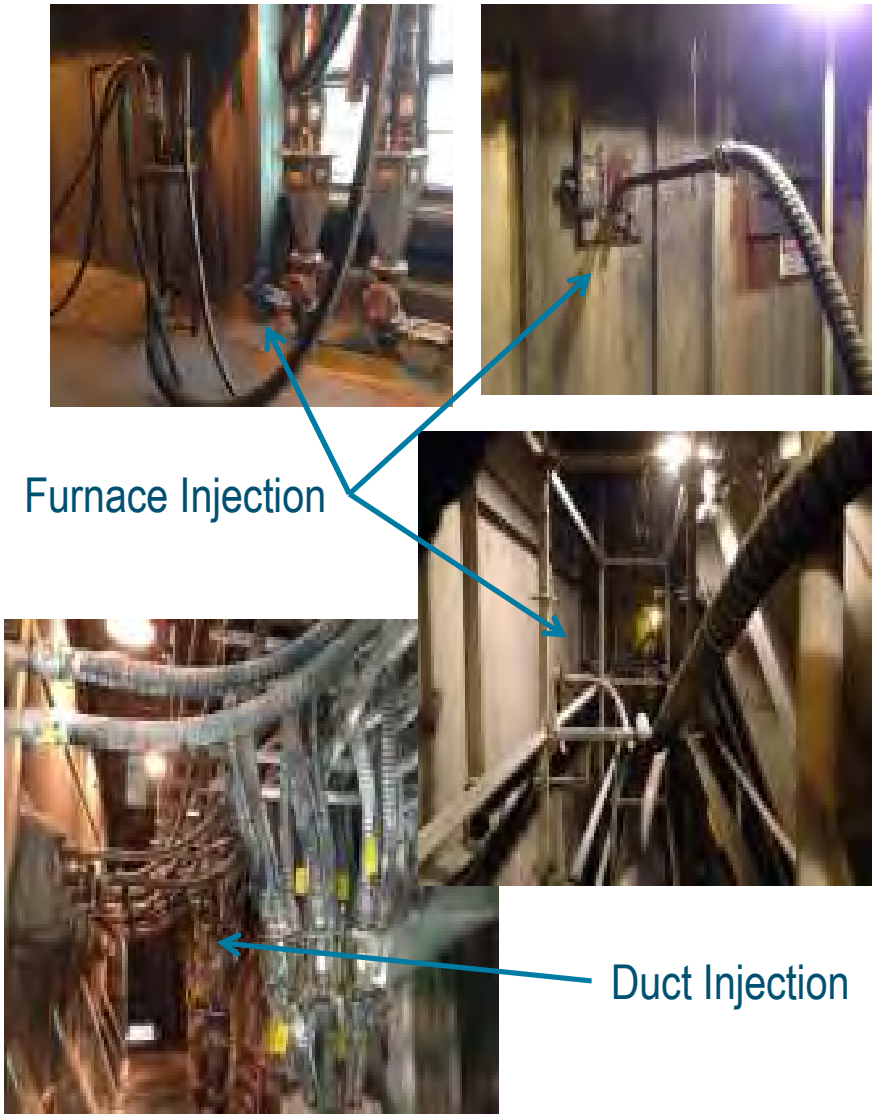


Gallagher Furnace Sorbent Injection Trial

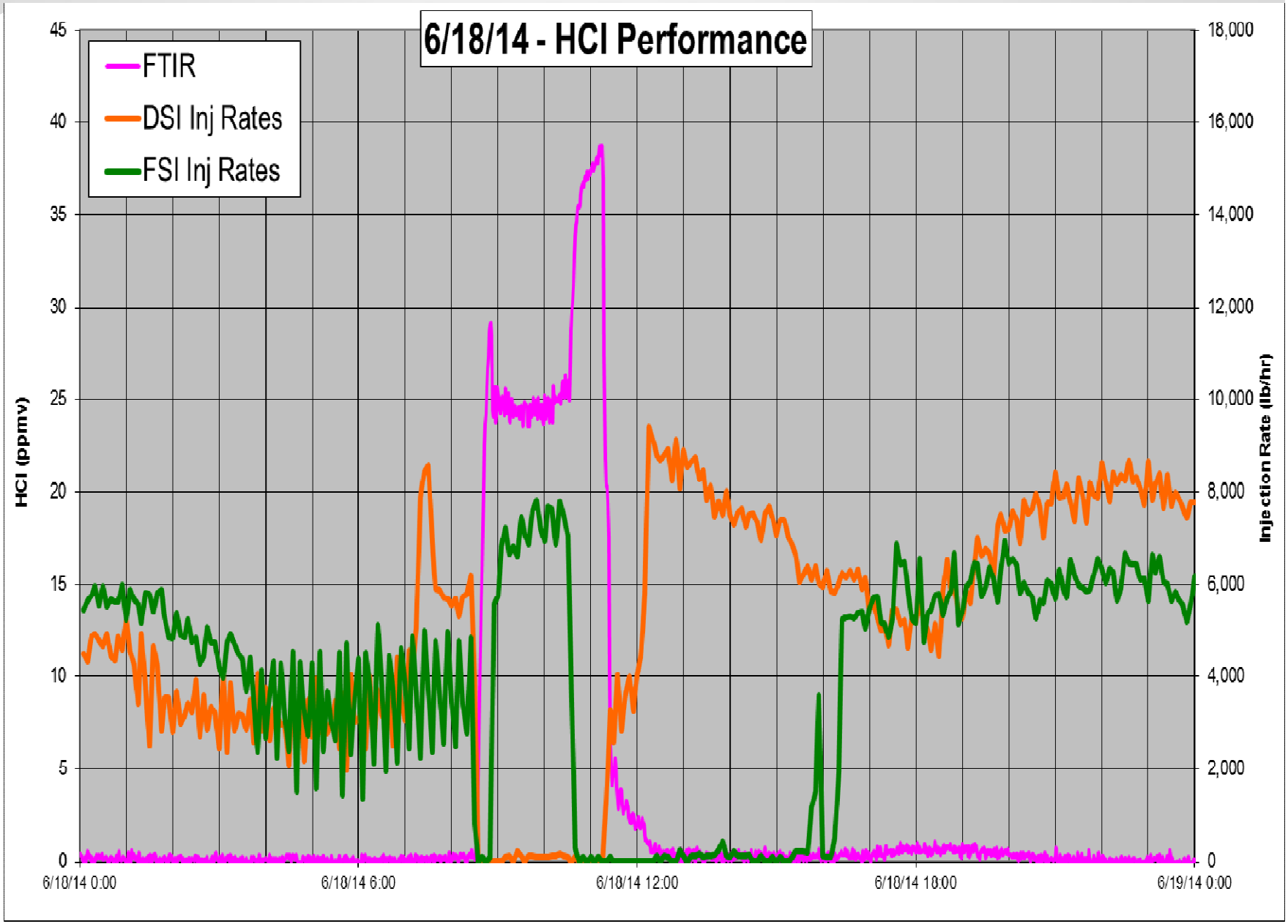
Case Studies

Gallagher Furnace Sorbent Injection Trial

- 150MW Riley Boiler with a Baghouse
- Station has a 0.8lb/Mmbtu SO2 Consent Decree
- DSI system originally designed for Trona and was converted to hydrated lime for SO2 removal
- Increased fuel flexibility (Higher S) and a cold winter lead to material supply and reliability issues
- Numerous attempts have been made to reduce hydrated lime consumption including high reactivity products
- Decided to attempt furnace injection based on input from Lhoist on higher efficiency at higher temps
- Funds were limited and injection was pieced together with parts onsite, 11 lances total in furnace with less than idea distribution



Gallagher Furnace Sorbent Injection Trial



Impact on Ash Sales

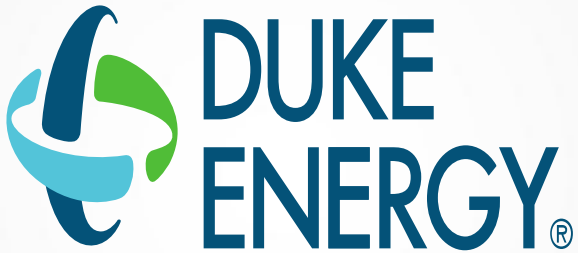
Impact on Ash Sales

- Chlorides
  - Hydrated lime is effective at removing HCl as the previous slides suggest
  - HCl ends up in the flyash as chlorides
  - Duke's current ash marketer has implemented a 850ppm chloride limit for ash sales based on a DOT concrete chlorides limit
  - This poses a risk to ash sales and/or sorbent injection operation as we either reduce injection or forfeit ash sales
  - Interested in other utility's experience with this and other possible information that could show the correlation to chlorides in ash to chlorides in concrete
- %LOI False High Bias
  - Traditional LOI measurement is performed by heating flyash to either 750C or 950C and measuring the weight loss between the two samples
  - Once the industry began injecting sorbents, reaction products are formed that either break down or dehydrate at temperatures below the temperatures required in the protocol resulting in more weight loss thus higher LOI%
  - Less of an issue with Calcium Sulfate compounds which just dehydrate, more of an issue with Calcium Chloride/Carbonate and Sodium/Ammonium reaction products that decompose

Chlorides in Ash

Unit #1 Precipitator Ho			Saleable <2.99	Saleable <2.99	Saleable <0.60	Saleable <0.60	Saleable <32.0	Saleable <32.0	Saleable <850	Saleable <850	Saleable <25	Saleable <25
Date/Time	Load	Lime Rate	LOI 1A	LOI 1B	Foam 1A	Foam 1B	325 1A	325 1B	Cl 1A	Cl 1B	NH3 1A	NH3 1B
6/24/14 0:01	1120		2.79	1.91	0.55	0.28	27.31	28.12	415	415	12	12
6/24/14 2:00	886	325	2.49	2.07	0.52	0.53	24.53	26.65	375	415	15	20
6/24/14 6:00	1120		2.29	1.88	0.48	0.47	24.66	28.52	415	415	18	20
6/24/14 8:00	1170	#N/A	2.05	1.67	0.44	0.34	26.2	23.81	415	375	20	24
6/24/14 10:00	1170		1.94	1.34	0.28	0.17	28.94	23.12	460	375	10	15
6/24/14 12:00	1170		1.92	1.29	0.37	0.26	26.07	20.08	995	850	17	20
6/24/14:00	1170	#N/A	2	1.44	0.26	0.25	27.72	28.75	995	995	9	13
6/24/14 16:00	1170	811.2	1.84	1.22	0.31	0.3	31.02	29.92	785	995	17	25
6/24/14 18:00	1170	664.8	1.76	2.61	0.19	0.19	22.87	23.11	920	850	22	30
6/24/14 20:00	1170	832.1	1.64	1.33	0.24	0.25	26.58	23.62	720	665	15	40
6/24/14 22:00	1170	752.9	1.74	1.16	0.37	0.13	29.2	21.84	995	720	19	37
6/25/14 0:01	1170	702.6	1.67	1.6	0.18	0.17	27.95	23.52	720	665	15	30
6/25/14 2:00	939	479.4	1.32	1.4	0.25	0.17	29.63	20.32	605	665	15	30
6/25/14 6:30	910		1.3	1.22	0.22	0.27	24.62	22.02	720	555	25	19
6/25/14 8:00	1165	665.4	1.58	1.24	0.35	0.34	22.14	22.26	785	665	15	40
6/25/14 10:00	1170		1.67	1.09	0.36	0.57	31.34	27.45	605	605	10	20
6/25/14 11:59	1170	704	1.74	1.2	0.36	0.38	26.16	19.97	995	850	15	40
6/25/14 14:00	1170	616	1.64	0.9	0.28	0.34	22.52	24.77	850	665	17	40
6/25/14 16:00	1170		2.71	1.69	0.52	0.34	24.11	25.82	665	335	15	13
6/25/14 18:00	1170	198	1.48	2.18	0.14	0.25	25.04	23.25	335	300	9	20
6/25/14 20:00	1170	564	1.64	2.2	0.15	0.14	25.87	21.98	415	335	7	15
6/25/14 22:00	1170	467	2.12	1.83	0.24	0.18	23.14	22.24	415	300	6	10
6/26/14 0:01	1170	461	0.96	1.05	0.18	0.17	34.46	22.33	375	265	3	9
6/26/14 2:00	1095	383	1.53	1.2	0.22	0.26	27.7	22.99	460	415	2	9
6/26/14 6:00	1120		1.25	0.71	0.27	0.37	28.79	23.14	415	300	5	10
6/26/14 8:00	1170	off	1.29	1.97	0.3	0.44	28.29	25.46	150	<150	5	8
6/26/14 10:00	1170	off	1.59	2.14	0.33	0.48	28.46	27.84	<150	<150	5	5
6/26/14 11:59	1170	off	2.09	2.3	0.35	0.62	26.68	22.66	<150	<150	24	38
6/26/14 14:00	1170	804	1.33	2.76	0.33	0.57	26.84	26.07	<150	<150	17	34
6/26/14 16:00	1170		1.62	1.69	0.35	0.5	27.92	24.43	460	375	24	38
6/26/14 18:30	1170		1.85	1.28	0.13	0.24	22.68	25.3	415	415	55	35
6/26/14 20:30	1170	206	1.43	1.81	0.16	0.26	27.97	28.54	375	265	20	20
6/26/14 22:30	1170		1.99	2.41	0.23	0.51	29.06	23.74	335	375	20	20

Questions?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Summary of Demonstration Test Results