REINHOLD ENVIRONMENTAL Ltd.

2015 APC Round Table & Expo Presentation

July 13 & 14, 2015, in Atlanta, GA / Hosted by Southern Company

Lhoist North America
Lhoist Group

Reinhold APC Conference

Atlanta, GA

July 14, 2015

Simultaneous HCl and Hg Control with a Single Sorbent and DSI System

Authors: Jim Dickerman & Jerry Hunt

If we continue to do
What we've always done,
We'll continue to get
What we've always got,
And we'll continue to be
What we've always been.

Agenda

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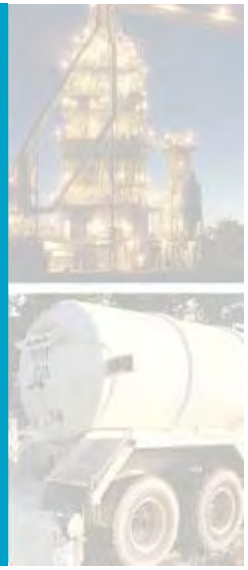
- Introduction to LNA
- Background on Blended Product
- Hydrated Lime Sorbents
- Three (3) Full Scale DSI Tests
- Summary / Conclusions



Who is Lhoist?

Lhoist North America
Lhoist Group

- A family owned company
  - ✓ Founded 1889
  - ✓ Belgium origin
- A Multinational
  - ✓ World's largest lime company
  - ✓ About 6,000 employees, 30 nationalities
  - ✓ Nearly 100 plants in 25 countries
    - Lhoist North America
      - 24 Manufacturing plants, lime capacity ~ 6 million tpy
  - ✓ 1 Corporate Research & Development (R&D) center
  - ✓ 4 Application, Service and Development (ASD) centers
  - ✓ 5 Fully Equipped Centralized Laboratories (CL)

Lhoist 125 Years

125 YEARS OF EXPERTISE & INNOVATION

1889	1926	The 80's	The 90's	New millennium
Foundation of the Group in Belgium	First expansion to France	Crossing the Atlantic (US)	Further development to Western & Eastern Europe	South America, Asia & Russia

Case Study Development – TRIALS!

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Lhoist Group

- LNA has actively participated in more than 30 trials in the last 18 months
  - ✓ Utility & Industrial
  - ✓ BMACT, MATS, Permit
  - ✓ HCl, SO_3, SO_2, and HF
  - ✓ Trials important to confirm performance
    - Various injection configurations
    - Fuels
    - Sorbents
    - Changes in load/process
    - Site specific equipment needs

No.	Driver	Pollutant(s)	Sorbents	Application	LNA Scope		
					Sorbent	FTIRs	DSI
1	Consent	SO2	SP & SPS	Chemical Manufacturer	X		
2	IB MACT	HCl	H & SP	Pulp & Paper	X		
3	IB MACT	HCl	H & SP	University	X		
4	IB MACT	HCl	H	Misc	X		
5	Existing	HCl	H & SP	EGU	X	X	
6	MATS	HCl, SO2	SP	EGU	X		
7	Consent	SO2	SPS	EGU	X		
8	IB MACT	HCl	H & SP	Paper	X	X	
9	Permit	SO2	SPS	Steel	X		X
10	Permit	SO2	SPS	Steel	X		X
11	Consent	SO2	SPS	Chemical Manufacturer	X		
12	MATS	HCl & Hg	SPAC	EGU	X	X	X
13	Existing	SO2	SP	EGU	X	X	
14	Permit	HCl, HF, SO2	SPS	Tile	X	X	X
15	NAAQS	SO2	SP & SPS	University	X		
16	MATS	SO3	SP	EGU	X		
17	Testing	SO2	SPS	Pilot	X	X	
18	Consent	SO3	SP	EGU	X		
19	HISWI	HCl	SP	Medical Waste	X		
20	Permit	HCl, HF, SO2	SPS	Tile	X	X	X
21	Permit	HCl	SP	Glass	X		
22	Permit	SO2	LKD, Std HL & SPS	Lime	X	X	X
23	IB MACT	HCl	Std HL & SP	Misc	X	X	X
24	Consent	SO2	SPS	Cement	X		X
25	Consent	SO2	SLS45	Cement	X		
26	Consent	SO2	SPS	Cement	X		
27	IB MACT	HCl	SP	University	X		
28	Consent	SO2	H	Cement	X		X
29	Consent	SO2	SPS	Brick	X		
30	IB MACT	Hg	SPS10AC	Pulp & Paper	X		X
31	IB MACT	HCl	SP	Pulp & Paper	X		
32	Permit	HCl, HF, SO2	SPS	Tile	X		
33	MATS	SO3	H	Utility	X		

Introduction – Background

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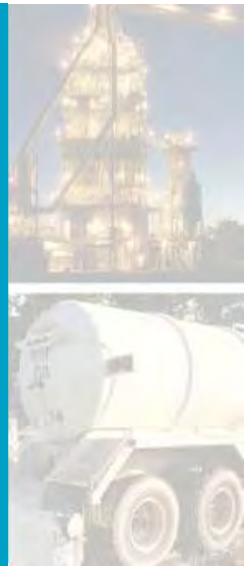
- Mercury Air Toxics Standard (MATS) is federal rule requiring reduction of HCl, FPM and Hg emissions for Utility Boilers. The Industrial Boiler (IB) MACT has similar requirements for Industrial Boilers.
- Common solution for HCl and Hg emission control is Dry Sorbent Injection (DSI) and Activated Carbon Injection (ACI) respectively.



- This presentation discusses development and demonstration of a single blended product of Sorbacal® SP or SPS and BPAC to utilize only a single injection system for simultaneous HCl/SO_2 and Hg compliance.
- Previous DSI and ACI demonstration tests have shown alkaline sorbents may adversely impact PAC efficacy for Hg capture, the impact of which was examined during this presentation.

What is Sorbacal®?

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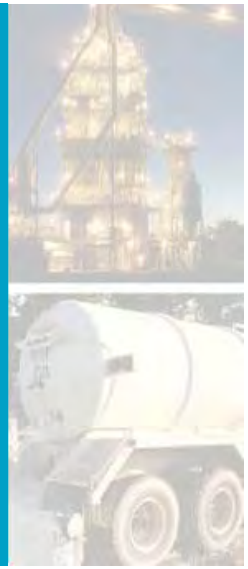
- An engineered hydrated lime developed to have superior performance for removing acid gas species from flue gas.
- Sorbacal® properties
  - Surface area >40 m^2/g
    - versus ~20m^2/g for good quality “standard” hydrates
  - Porosity > 0.2 cm^3/g
    - versus ~0.07cm^3/g for good quality “standard” hydrates
- Performance has been demonstrated to be 30 – 50% better than standard hydrated lime products.



Range of Products

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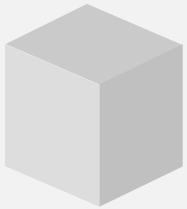
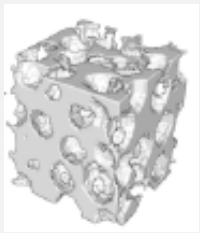
Sorbent	Standard Hydrated Lime	Sorbacal® H	Sorbacal® SP	Sorbacal® SPS	Units
Figure					–
Typical Available $Ca(OH)_2$	92 – 95	93	93	93	%
Typical Surface Area	14 – 18	> 20	~40	~40	m^2/g
Typical Pore Volume	~0.07	0.08	~0.20	~0.20	cm^3/g

Introduction – Blended Product

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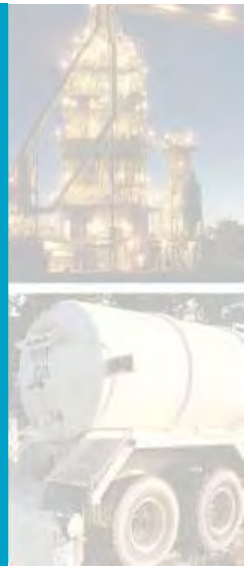
- Hydrated lime / PAC blended sorbents have been applied in waste incineration plants since 1990s.
- PAC is combustible and can auto-ignite which may necessitate additional explosion proof measures incorporated in equipment design.
- Blending PAC with hydrated lime mitigates safety risks when using at least 65% hydrated lime by weight.
- Blends that were tested ranged from 70% Sorbacal® SP and 30% BPAC to 90% Sorbacal® SPS and 10% BPAC. The blended product formula can change depending on flue gas conditions at each facility.



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Full Scale DSI Test #1

Project Approach – Plant Background

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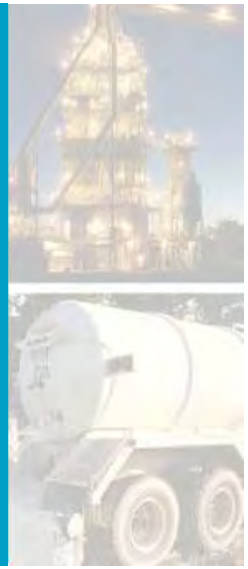
- Older Coal fired Utility facility subject to MATS with several small boilers burning PRB coal.
- MATS requires both Hg and HCl reduction and some of the boilers had existing ACI systems.
- Goal was to **use single injection system** instead of independent injection system for each pollutant.
- Prior testing with sodium sorbents achieved required HCl removal but with significant detriment on BPAC usage.



Project Approach – DSI Testing Background

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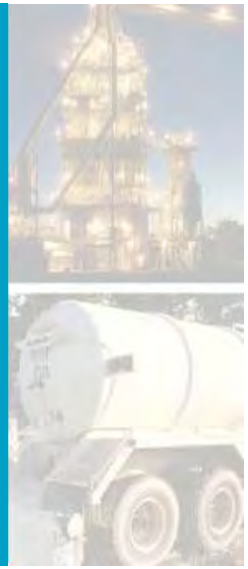
- Proof of concept parametric testing with 70% Sorbacal® SP / 30% BPAC blended product.
- Determine effectiveness for HCl and Hg control using a single injection system.
- Monitor HCl emissions using FTIR analyzer and Hg emissions using EPA Method 30B.
- Develop parametric performance curves.
- Compare blended product Hg curve versus BPAC curves from similar testing.



Results and Discussion – Coal Analysis Results

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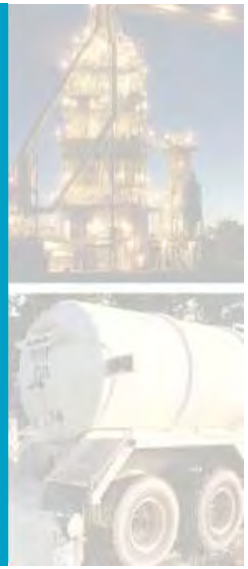
- Coal was blend of three (3) PRB coals

Component	June 2014 PRB Blend	Units
Carbon	58.1	Weight % (As Received)
Moisture	26.3	Weight % (As Received)
Ash	4.5	Weight % (As Received)
Sulfur	0.28	Weight % (As Received)
Chlorine	< 0.01	Weight % (As Received)
Higher Heating Value	9,070	Btu/lb (As Received)



Results and Discussion – Plant Operating Parameters

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Parameter	June 2014	Units
Unit Load	60	MW (gross)
Coal Feed Rate	71,000	lb/hr
Unit Heat Input	640	MMBtu/hr
Baseline SO_2 Emissions	0.56	lb/MMBtu
Flue Gas Moisture	11	% by Volume
Flue Gas CO_2	11	% (wet)
Stack Flow Rate	266,000	ACFM
Flue Gas Temperature at DSI Location	315	°F

Block Flow Diagram of Test Unit

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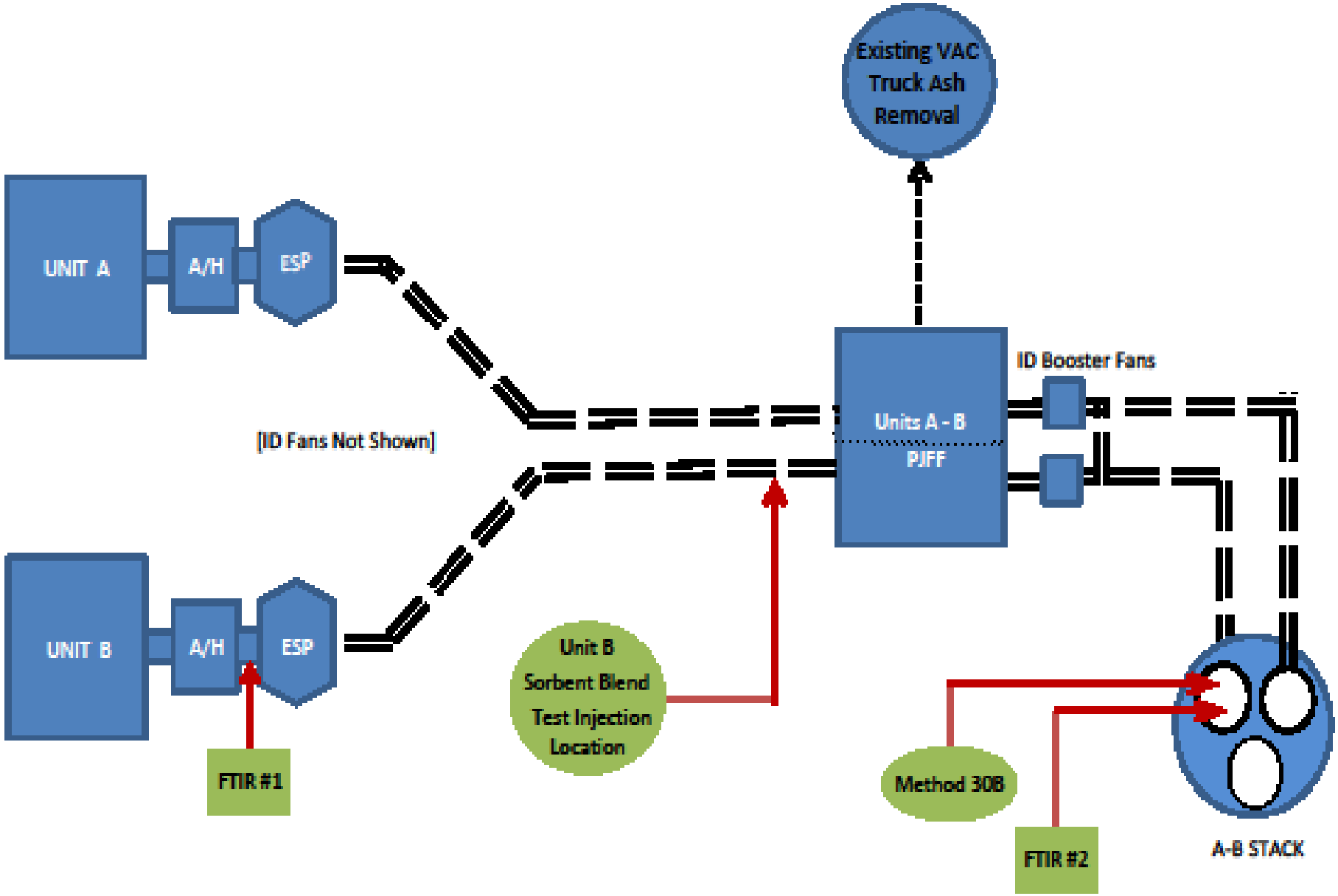

Project Approach – Equipment Set-Up

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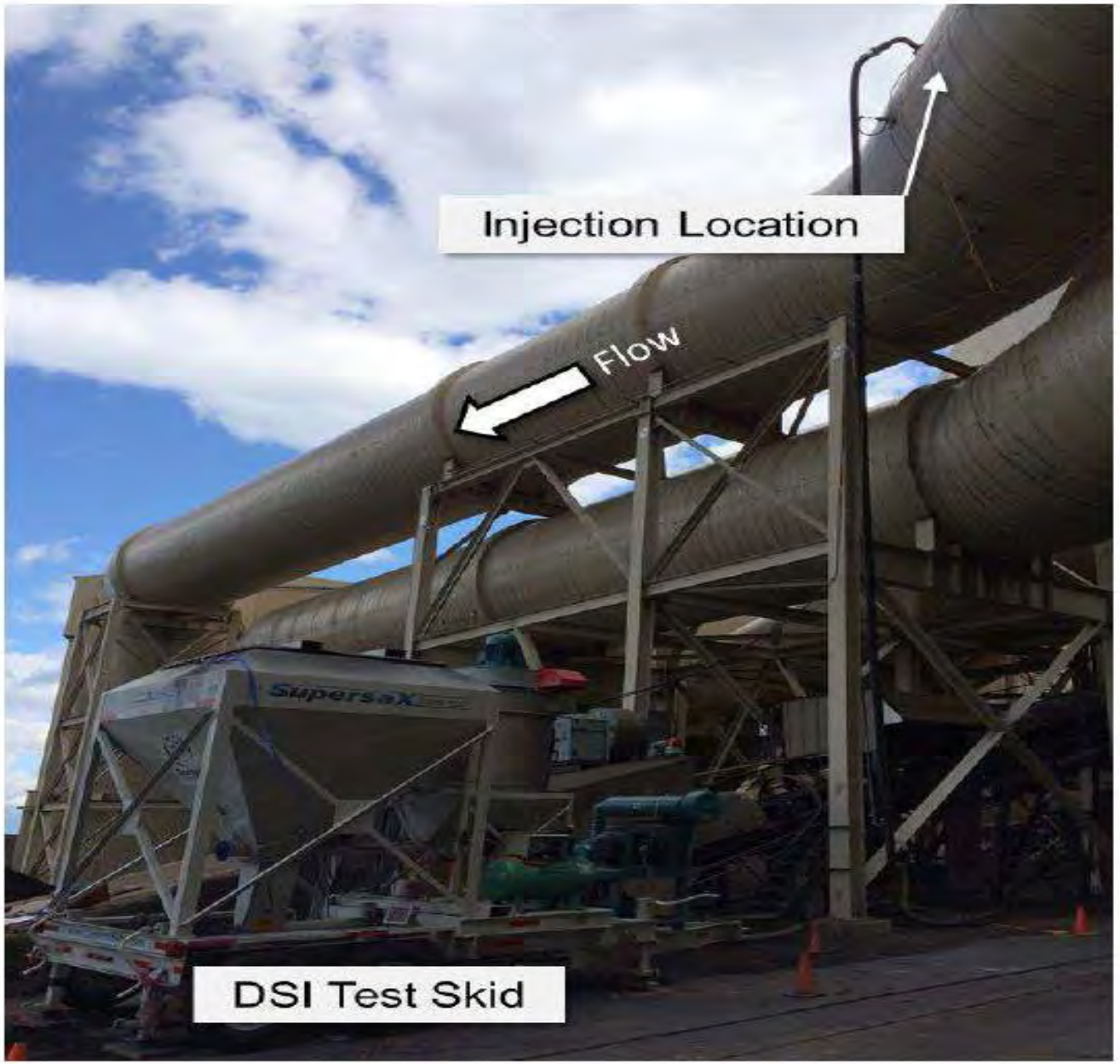

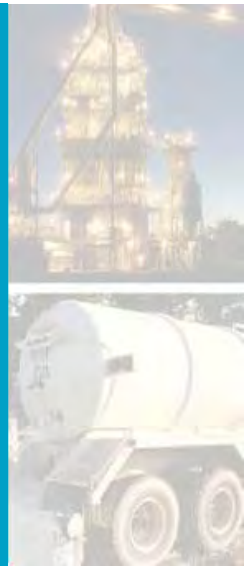

Results and Discussion – Blended Sorbent Analysis

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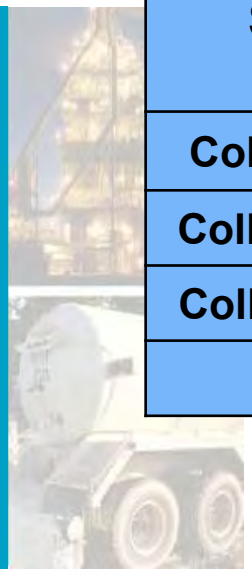
- Analysis performed in LNA's Irving R&D Laboratory

Sorbent Sample	% Sorbacal® SP of Blended Product	% BPAC of Blended Product
Collected 6/3/14 at 7:00	66.7	33.3
Collected 6/4/14 at 17:00	68.5	31.5
Collected 6/5/14 at 11:00	65.7	34.3
Average	67.0	33.1



Results and Discussion – Blended Sorbent Photo

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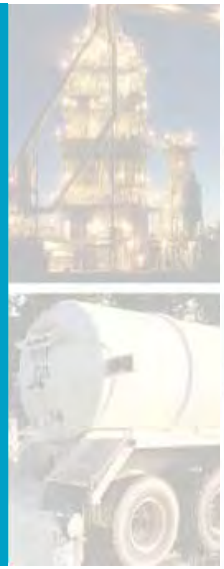

Results and Discussion – Real-Time HCl Emissions

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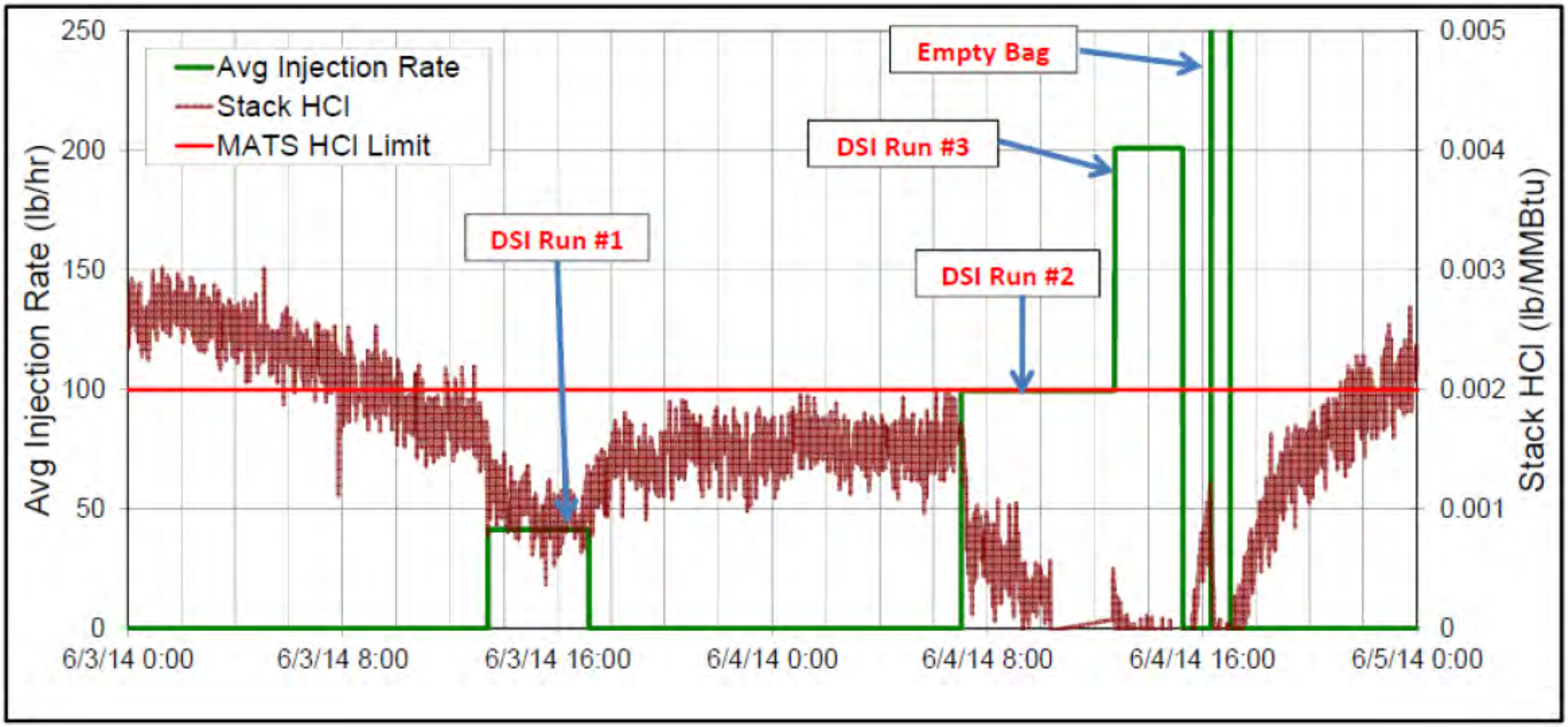

Results and Discussion – Test Results Summary

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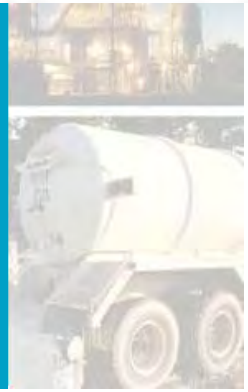
Case	Blended Product Injection Rate lb/hr	HCl lb/MMBtu	Hg - 30B Run #1 lb/TBtu	Hg - 30B Run #2 lb/TBtu	Avg Hg lb/TBtu	Hg Removal %
Baseline	0	0.0015 – 0.0027	3.4918	3.0246	3.2582	0%
DSI Run #1	42	0.0010	0.6745	0.7197	0.6971	79%
DSI Run #2	100	0.0005	0.1737	0.1265	0.1501	95%
DSI Run #3	201	0.0000	0.0866	0.0903	0.08845	97%



Results and Discussion – Hg Parametric Curve

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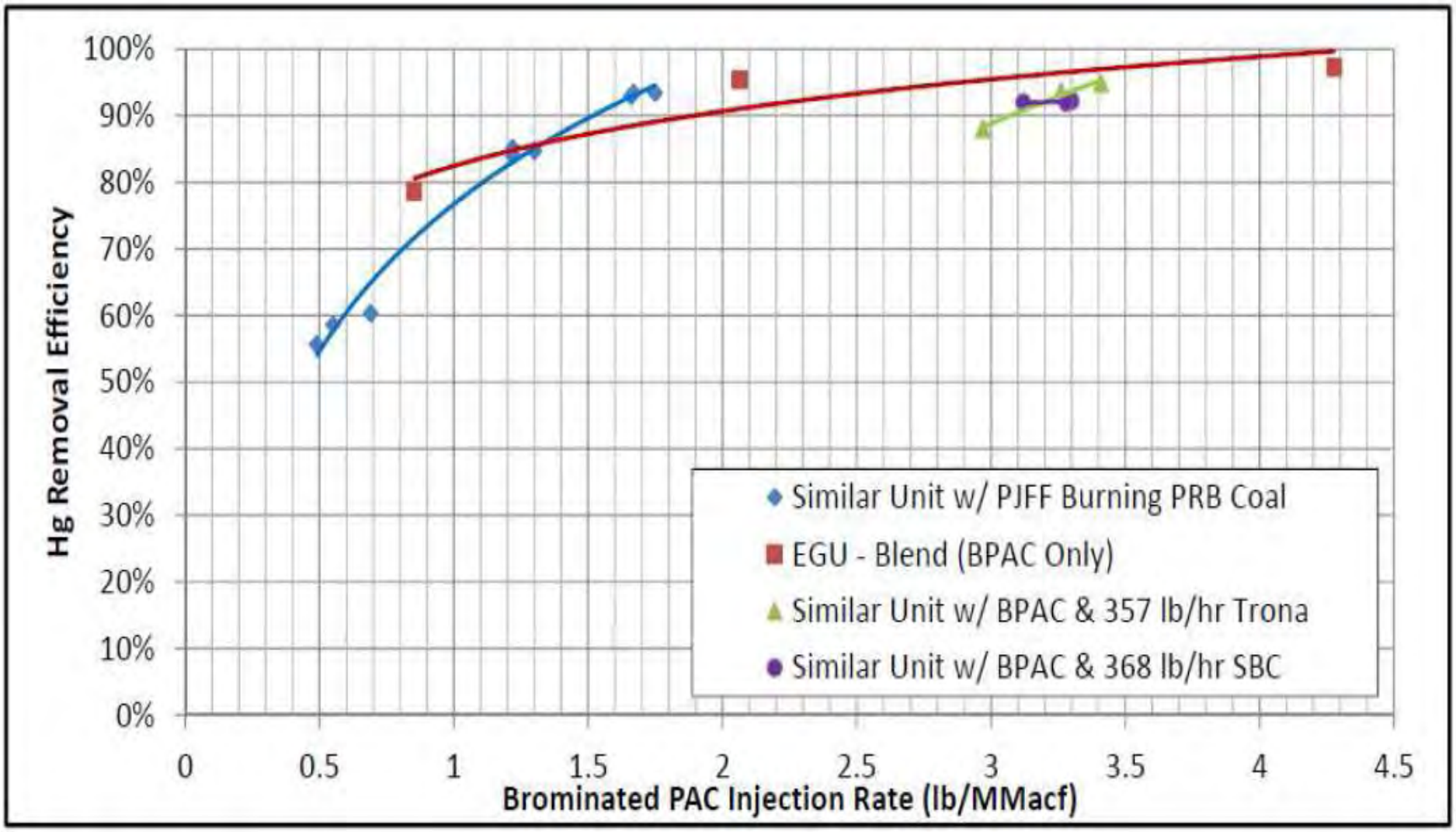

Results and Discussion – Balance of Plant Impact

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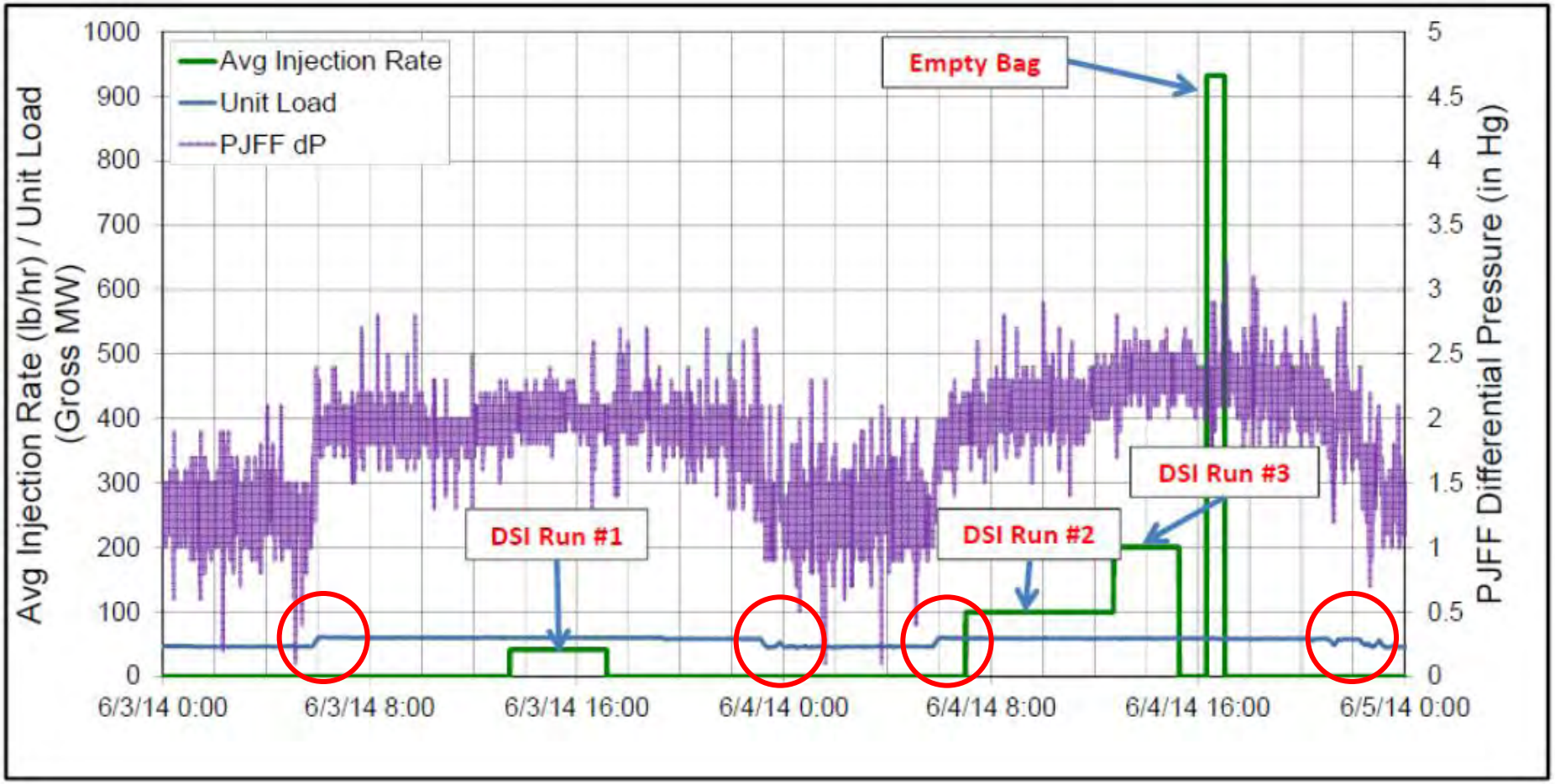

Summary of Results

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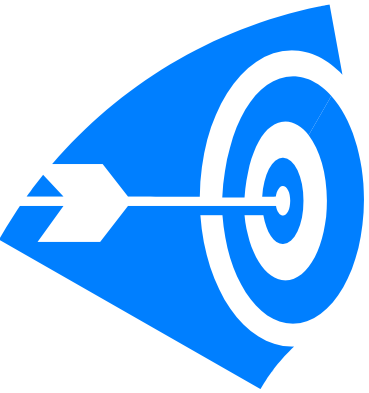

- **Successful reducing HCl and Hg emissions** below MATS limit with single injection skid.
- **No signs of negative impacts** on BPAC performance for Hg control with blended product.
- **Homogeneous** throughout testing suggesting sorbent segregation would not occur.
- Blended product flow characteristics appeared to be **consistent with pure hydrated lime**.
- Potential **capital cost savings of $1+ MM** based using single injection system vs. typical configuration of independent ACI / DSI systems.

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Full Scale DSI Test #2

Project Approach – Plant Background

Lhoist North America
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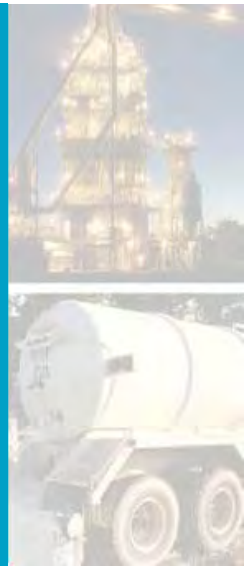
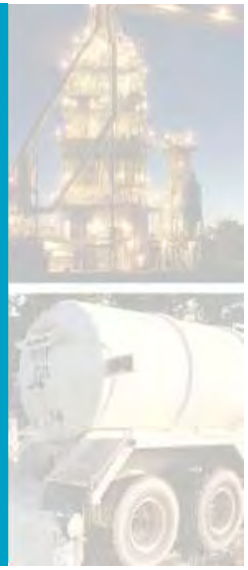
- Industrial facility with 50 MW circulating fluidized bed (CFB) boiler burning biomass to generate steam and power.
- Plant has permanent DSI system installed injecting Sorbacal® SPS to achieve permitted SO_2 emission limit (8 lb/hr over 1 hour average).
- Prior stack testing has shown need for Hg emission reduction for for IB MACT compliance. Typical Hg removal required is 10-20% range (if needed at all).
- Goal to demonstrate Hg compliance (0.8 lb/TBtu) and maintain SO_2 compliance utilizing existing DSI system.



Project Approach – DSI Testing Background

Lhoist North America
Lhoist Group

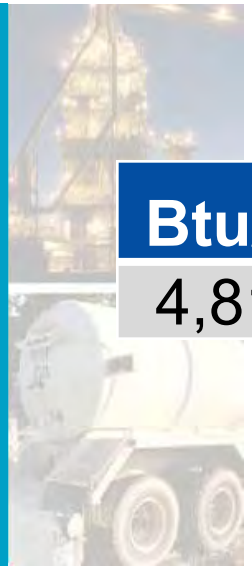
- Proof of concept parametric testing with blended sorbent (90% Sorbacal® SPS / 10% BPAC).
- Determine effectiveness for SO_2 and Hg control using a single injection system.
- Monitor SO_2 emissions using installed CEMS and Hg emissions using EPA Method 30B.
- Develop Hg parametric performance curve.



Results and Discussion – Fuel Analysis Results

Lhoist North America
Lhoist Group

- Biomass fuel typically composed of following,
  - ✓ Wood
  - ✓ Bark
  - ✓ Wood Waste
  - ✓ Forest Residue
  - ✓ WWT Sludge
- Typical “as received” fuel composition,



Btu/lb	% Ash	% Sulfur	% Moisture	ppm Hg	ppm Cl
4,817	5.17	0.012	39.91	0.0035	102

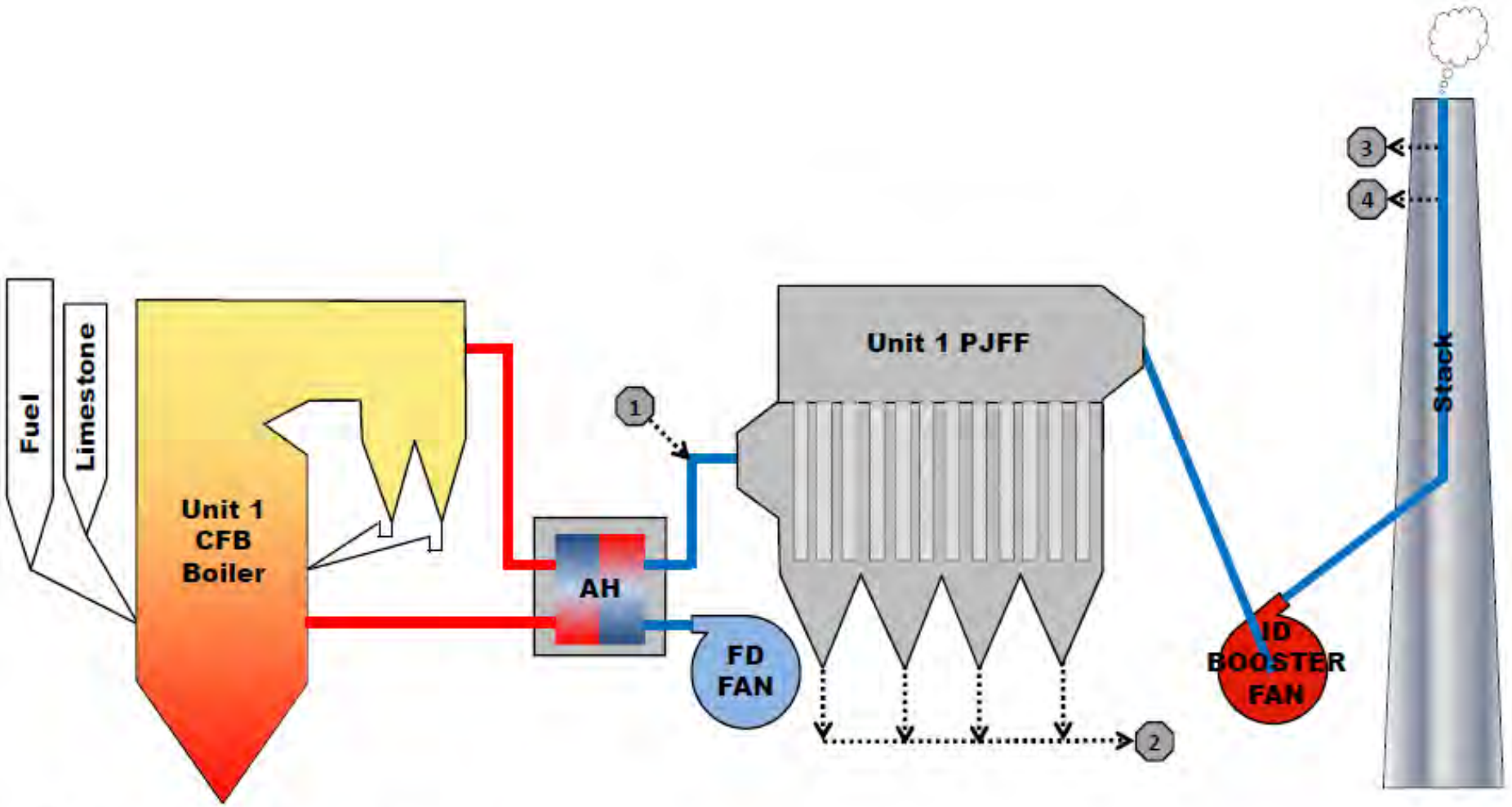
Results and Discussion – Plant Operating Parameters

Lhoist North America
Lhoist Group

Parameter		Units
Unit Heat Input	524	MMBtu/hr
Plant Operating Load	~60% MCR	
Flue Gas Moisture	23.3	% by Volume
Flue Gas CO_2	15.7	% by Volume
Stack Flow Rate	191,119	ACFM
Flue Gas Temperature at DSI Location	310	°F

Block Flow Diagram of Test Unit

Lhoist North America
Lhoist Group



1. Blended Sorbent Injection Location
2. Ash and Sorbent Disposal
3. Method 30B
4. SO_2 CEMS

Project Approach – Equipment Set-Up

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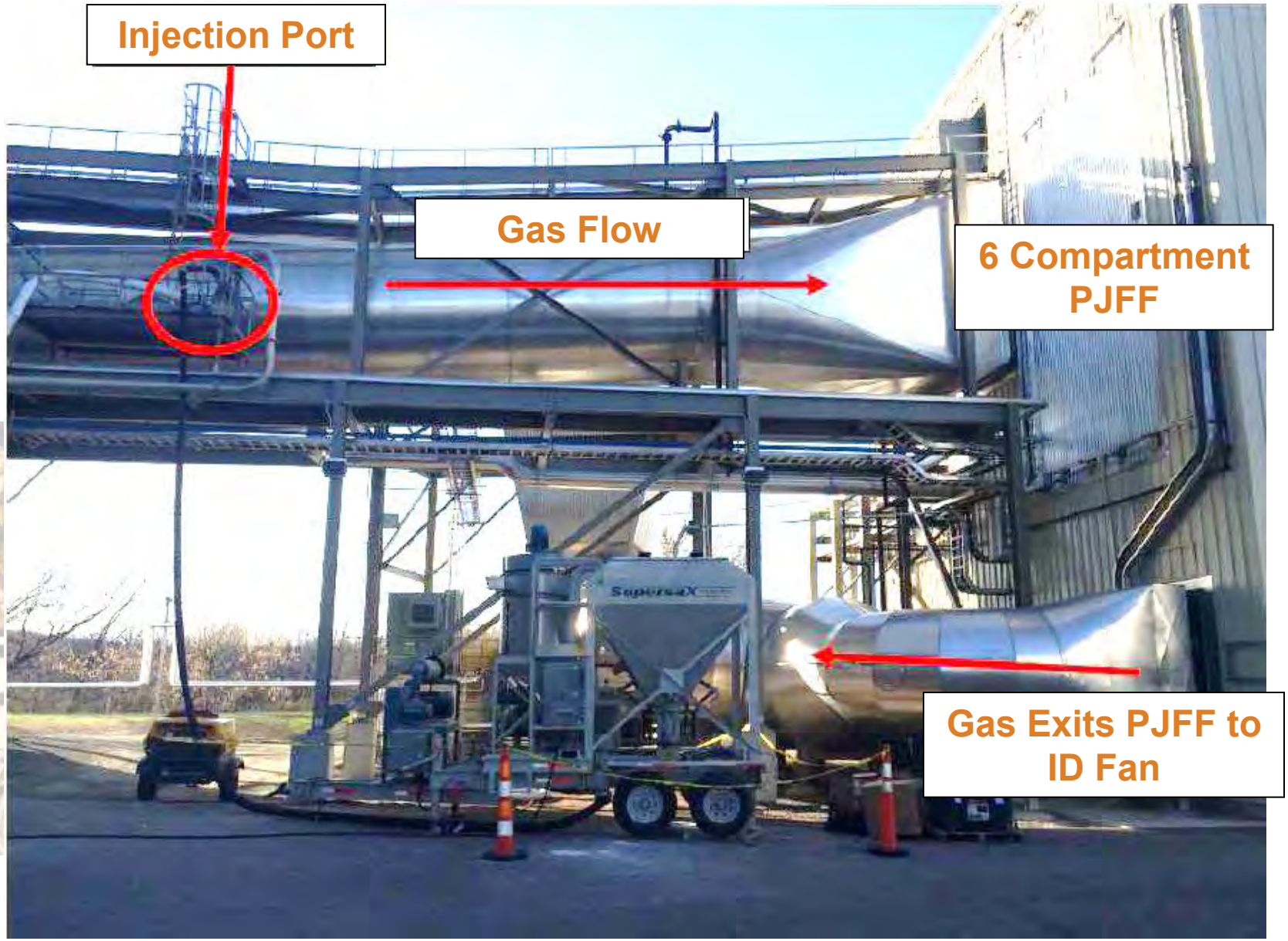

Results and Discussion – Blended Sorbent Analysis

Lhoist North America
Lhoist Group

- Following samples collected for analysis,
  - ✓ BPAC
  - ✓ Sorbacal® SPS
  - ✓ Blended product from blending facility
  - ✓ Blended product from super-sack on-site at trial
- Results verifying blend percentage pending.

Results and Discussion – Test Results Summary

Lhoist North America
Lhoist Group

Condition	Method 30B Results lb/Tbtu	Hg Removal %	Sorbent Inject Rate lb/hr	BPAC Inject Rate lb/MMAcf
Baseline Run #1	0.2840	-	0	0.00
Baseline Run #2	0.3150	-	0	0.00
Avg Baseline	0.2995	0.00%	0	0.00
Low Injection Run #1	0.1820	39.23%	26	0.22
Low Injection Run #2	0.1570	47.58%	26	0.23
Low Injection Run #3	0.1940	35.23%	26	0.23
Mid Injection Run #1	0.1050	64.94%	62	0.54
Mid Injection Run #2	0.1000	66.61%	62	0.54
High Injection Run #1	0.0730	75.63%	275	2.43
High Injection Run #2	0.0720	75.96%	275	2.42

Results and Discussion – Real-Time SO_2 Emissions

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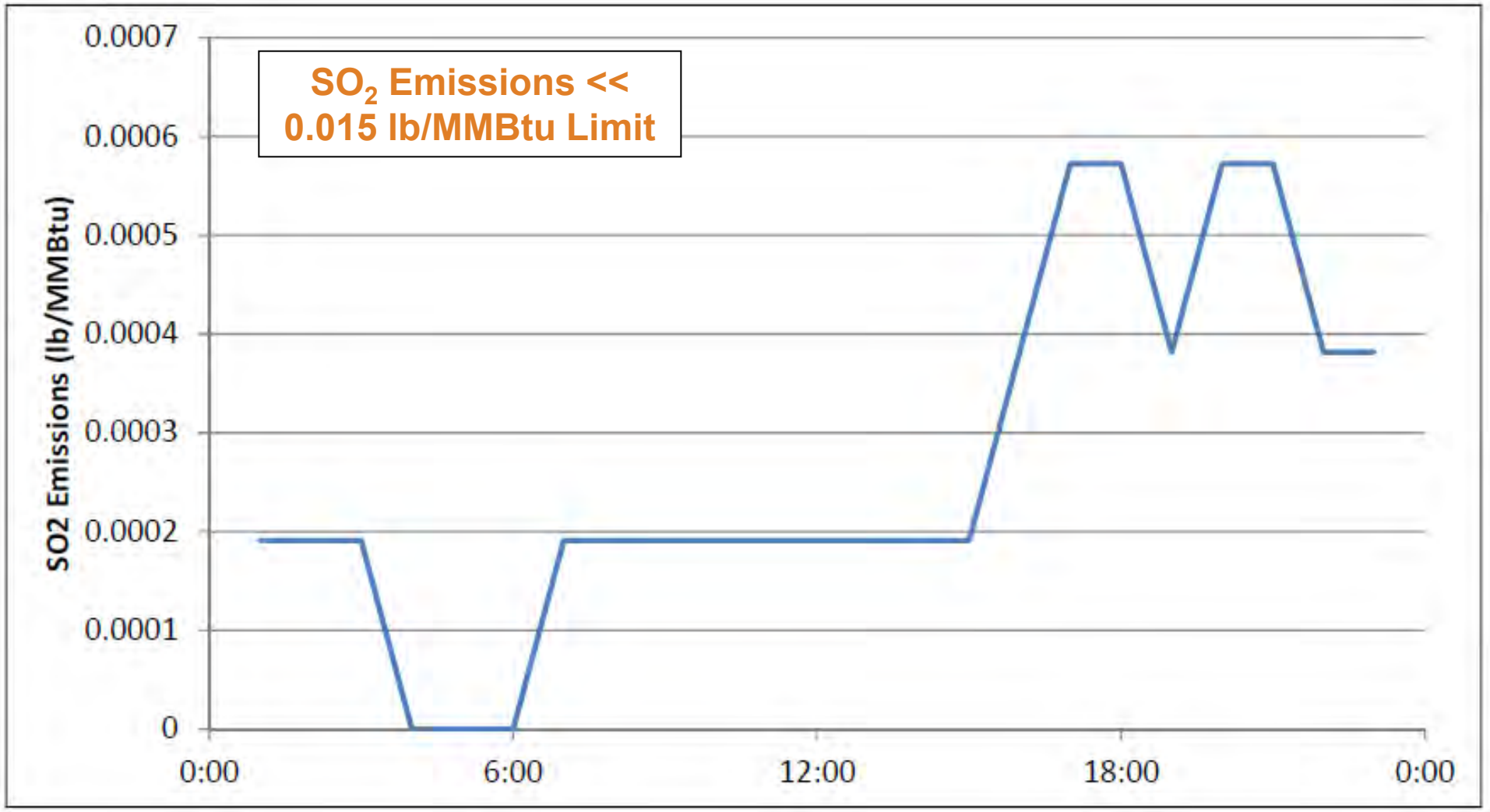

Results and Discussion – Hg Parametric Curve

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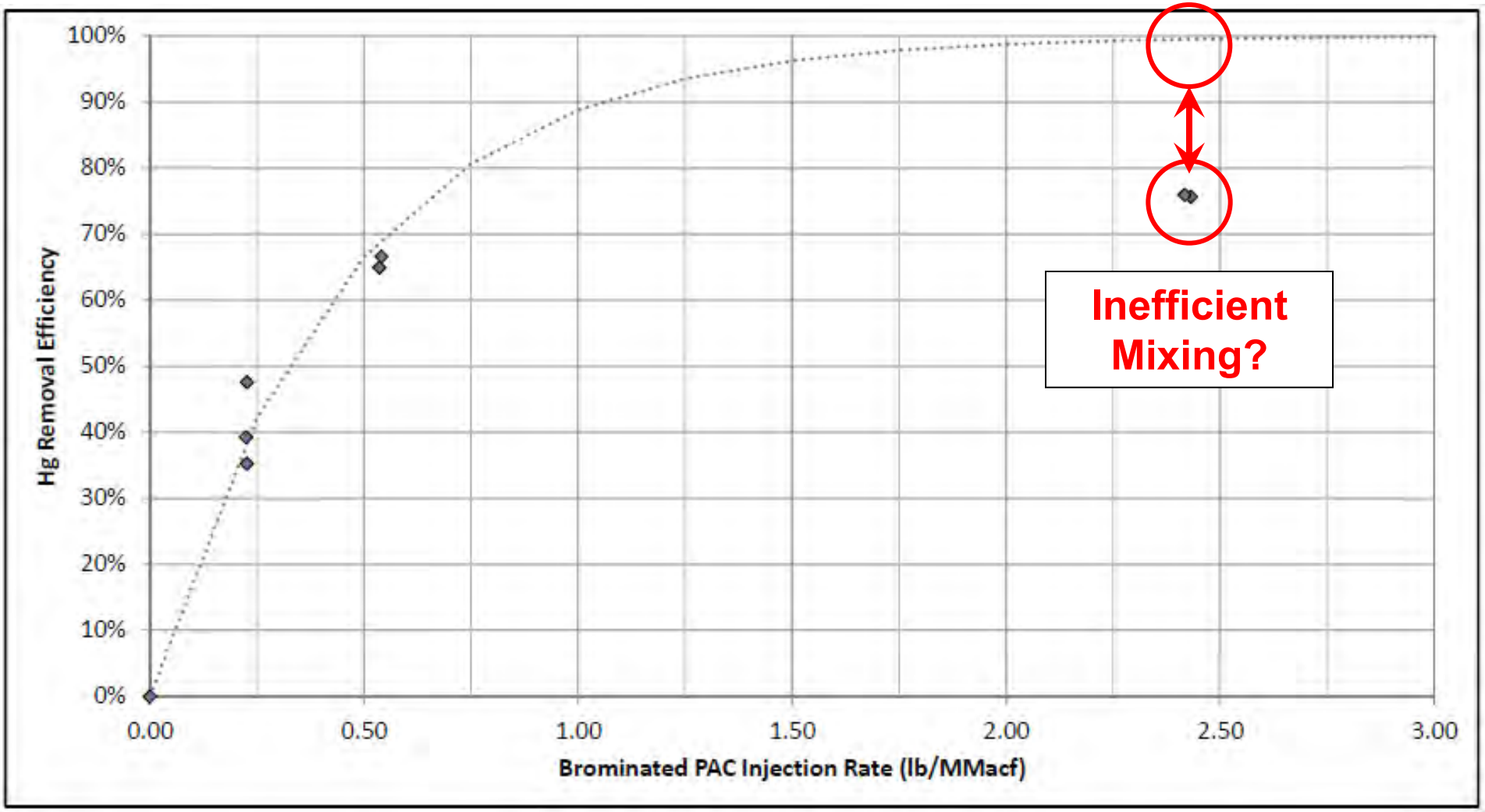

Results and Discussion – Balance of Plant Impact

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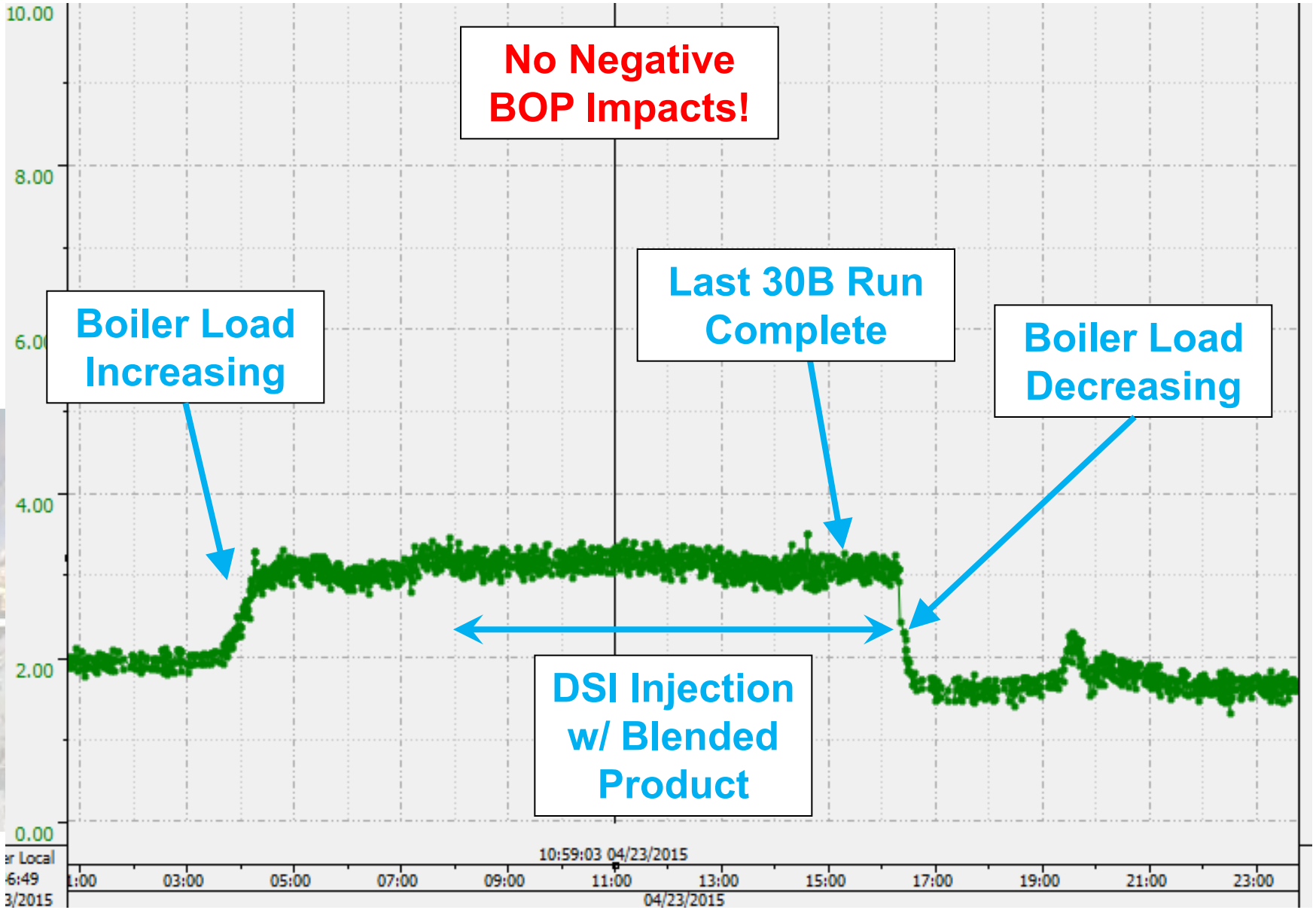

Summary of Results

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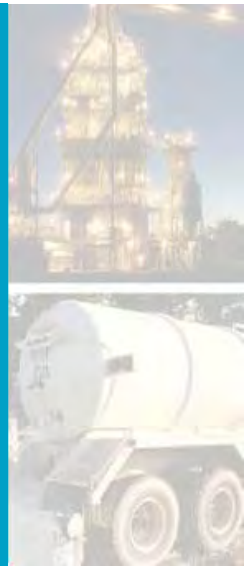
- Blended product **successful maintaining SO_2 compliance and achieving up to ~75% Hg removal** to ensure IB MACT compliance with single injection skid.
- No negative BOP impacts.
- **Homogeneous** throughout testing suggests no sorbent segregation.
- Flow characteristics consistent with pure hydrated lime.
- Capital cost savings by proving **new ACI system not required** to reduce Hg emissions for IB MACT compliance.



Full Scale DSI Test #3

Project Approach – Plant Background

Lhoist North America
Lhoist Group

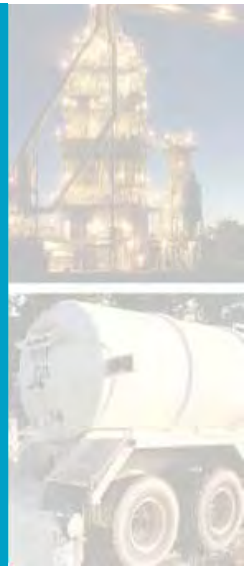
- Industrial facility produces steam/water for WWT facilities. Installed DSI system and fabric filter to comply with IB MACT.
- As IB MACT changed plant now required Hg emission reduction which was not originally required.

- Plant now has existing DSI system but requires both HCl and Hg compliance for IB MACT.
- Goal was to demonstrate simultaneous HCl and Hg compliance for IB MACT using single injection system to **avoid installation of new ACI system**.

Project Approach – DSI Testing Background

Lhoist North America
Lhoist Group

- Proof of concept parametric testing with blended sorbent (90% Sorbacal® SP / 10% BPAC).
- Determine effectiveness for HCl and Hg control using a single injection system.
- Monitor HCl emissions using FTIR and Hg emissions using EPA Method 30B.
- Develop HCl and Hg parametric performance curves.



Results and Discussion – Fuel Analysis Results

Lhoist North America
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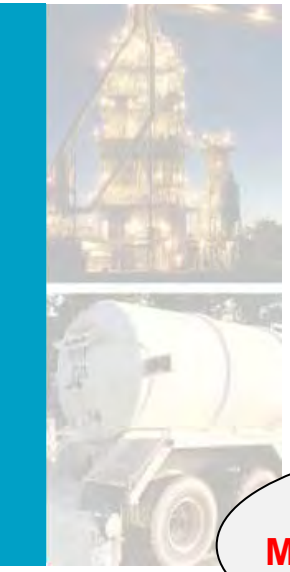
- Following coal properties based on analysis of samples collected during testing,

Constituent	Average	Range	Units
Sulfur	0.87%	0.74% to 1.31%	Weight % (AR)
Chlorine	1,039	794 to 1,403	ppm (AR)
Mercury	118	53 to 183	ppb (AR)
Emissions based on 8.70 TPH coal feed and 185 MMBtu/hr (assumes no native capture)			
SO_2	1.64	1.39 to 2.46	lb/MMBtu
HCl	0.101	0.077 to 0.136	lb/MMBtu
Mercury	11.11	4.99 to 17.22	lb/TBtu



Avg Hg 4.00 lb/TBtu Measured Prior to Start Testing w/ M30B

Avg HCl 0.098 lb/MMBtu Measured Prior to Start Testing w/ FTIR

Results and Discussion – Plant Operating Parameters

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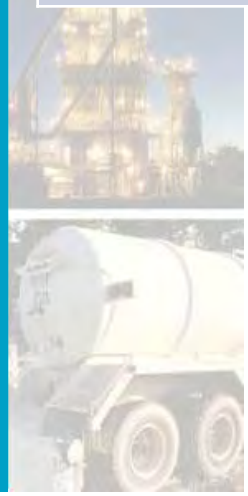
Parameter	Full Load	Low Load	Units
Unit Heat Input	185	57	MMBtu/hr
Flue Gas Moisture	6.4	6.0	% by Volume
Stack Flow Rate	100,670	31,224	ACFM
Flue Gas Temperature at DSI Location	375-390	280-360	°F
Coal Feed Rate	8.70	2.58	TPH



Block Flow Diagram of Test Unit

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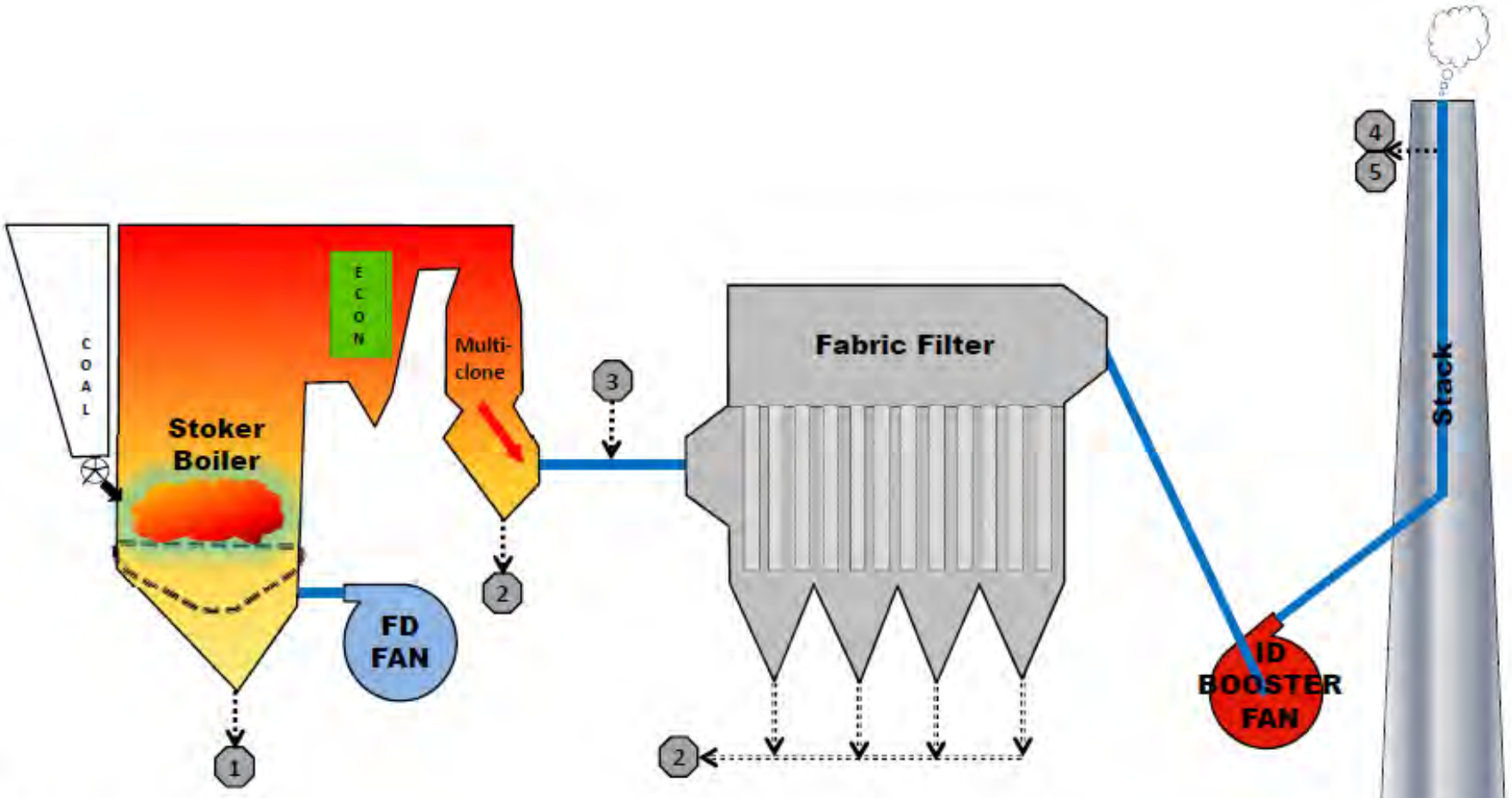

1. Bottom Ash Disposal
2. Fly Ash Disposal
3. Blended Sorbent Injection Location
4. Method 30B
5. FTIR

Results and Discussion – Blended Sorbent Analysis

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Multiple Samples Analyzed

Sample	SP:BPAC
1	12.8
2	13.2
3	13.9
4	12.8
5	13.5
6	13.2
7	12.7
8	13.8
9	13.2
10	12.9
11	13.2
12	13.2
13	13.1
14	12.8
Average	13.2
Standard Dev	0.4
Maximum	13.9
Minimum	12.7

Homogeneous Product

Results and Discussion – HCl Parametric Curve

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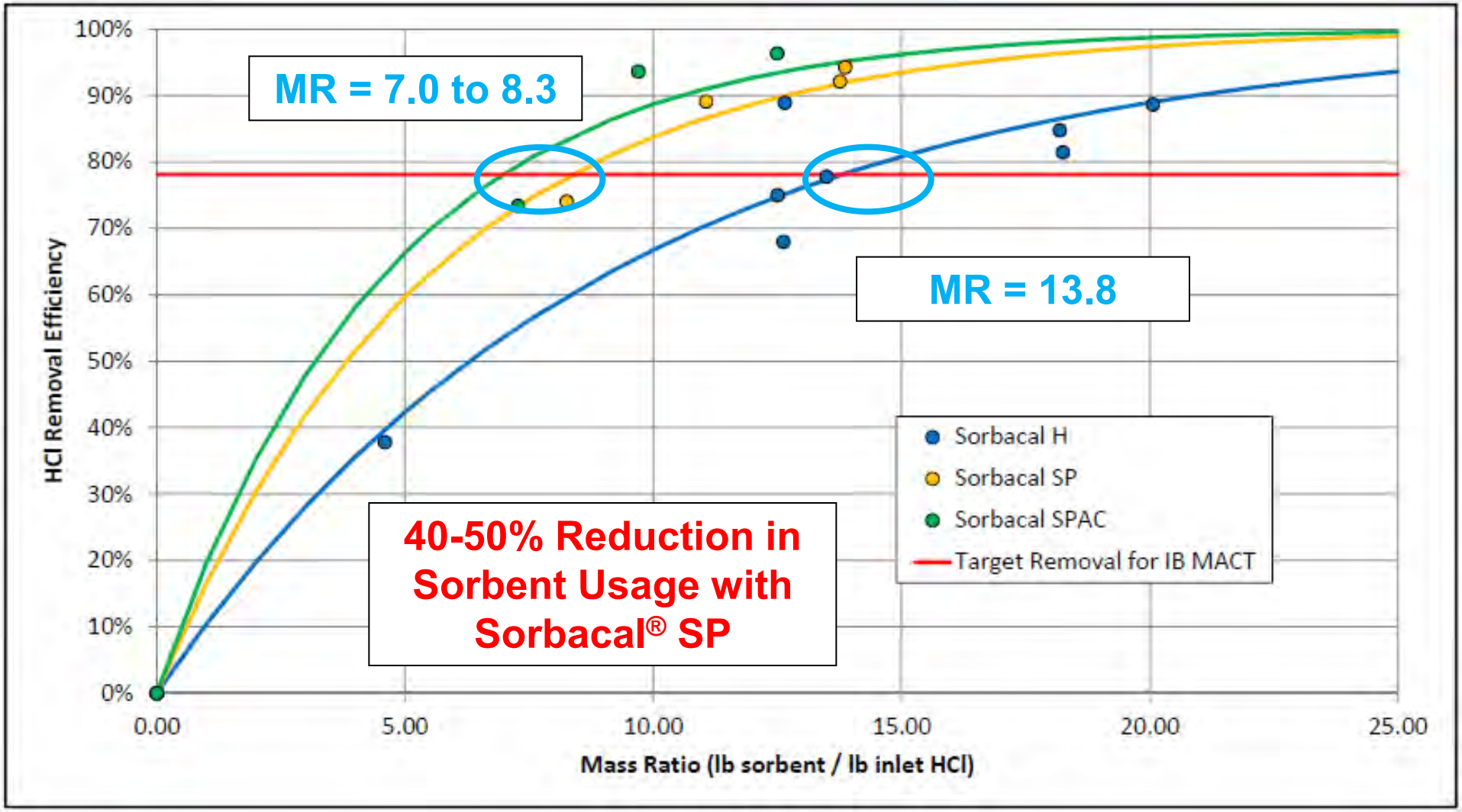

Results and Discussion – HCl Parametric Curve (Reduced Load)

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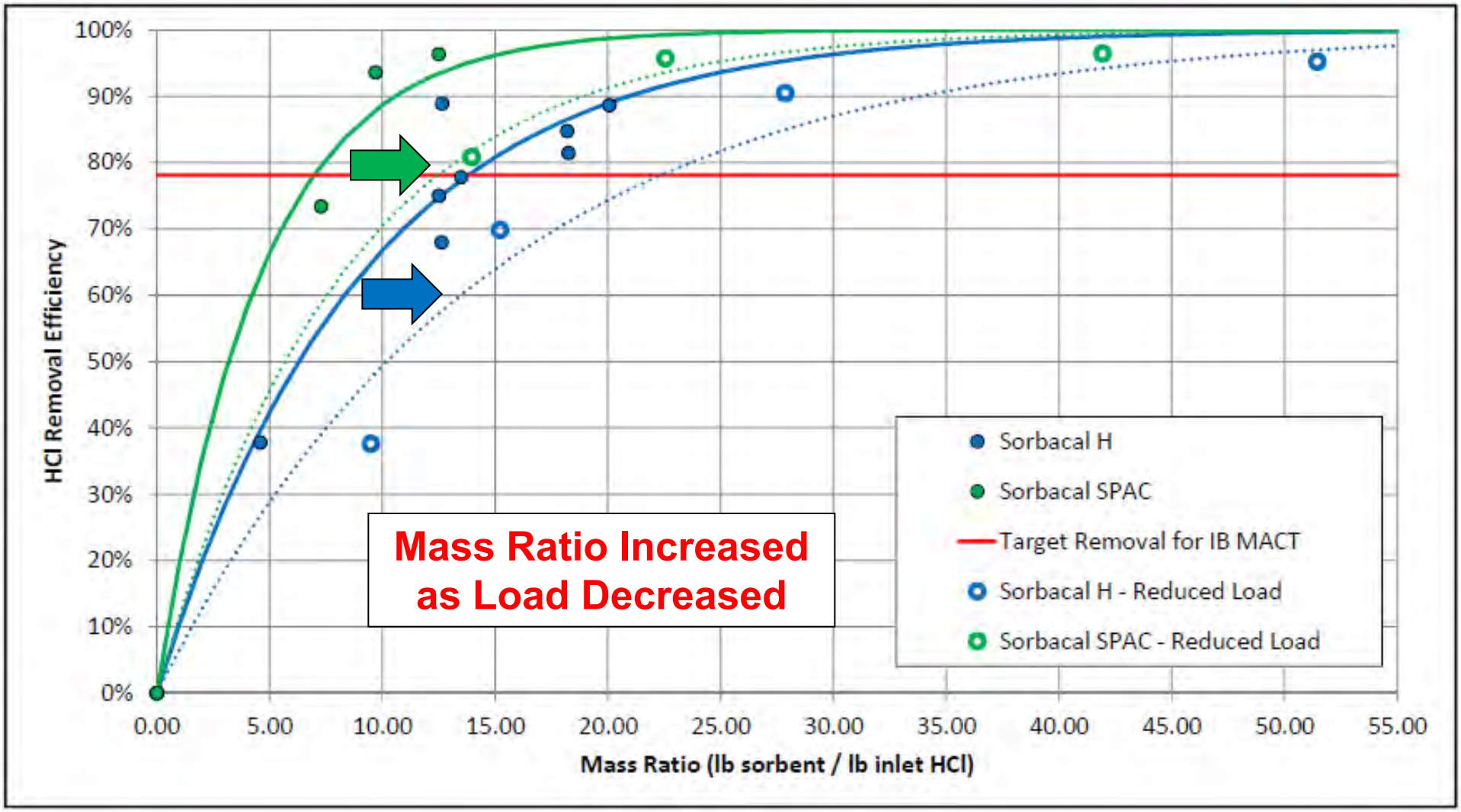

Results and Discussion – Hg Parametric Curve

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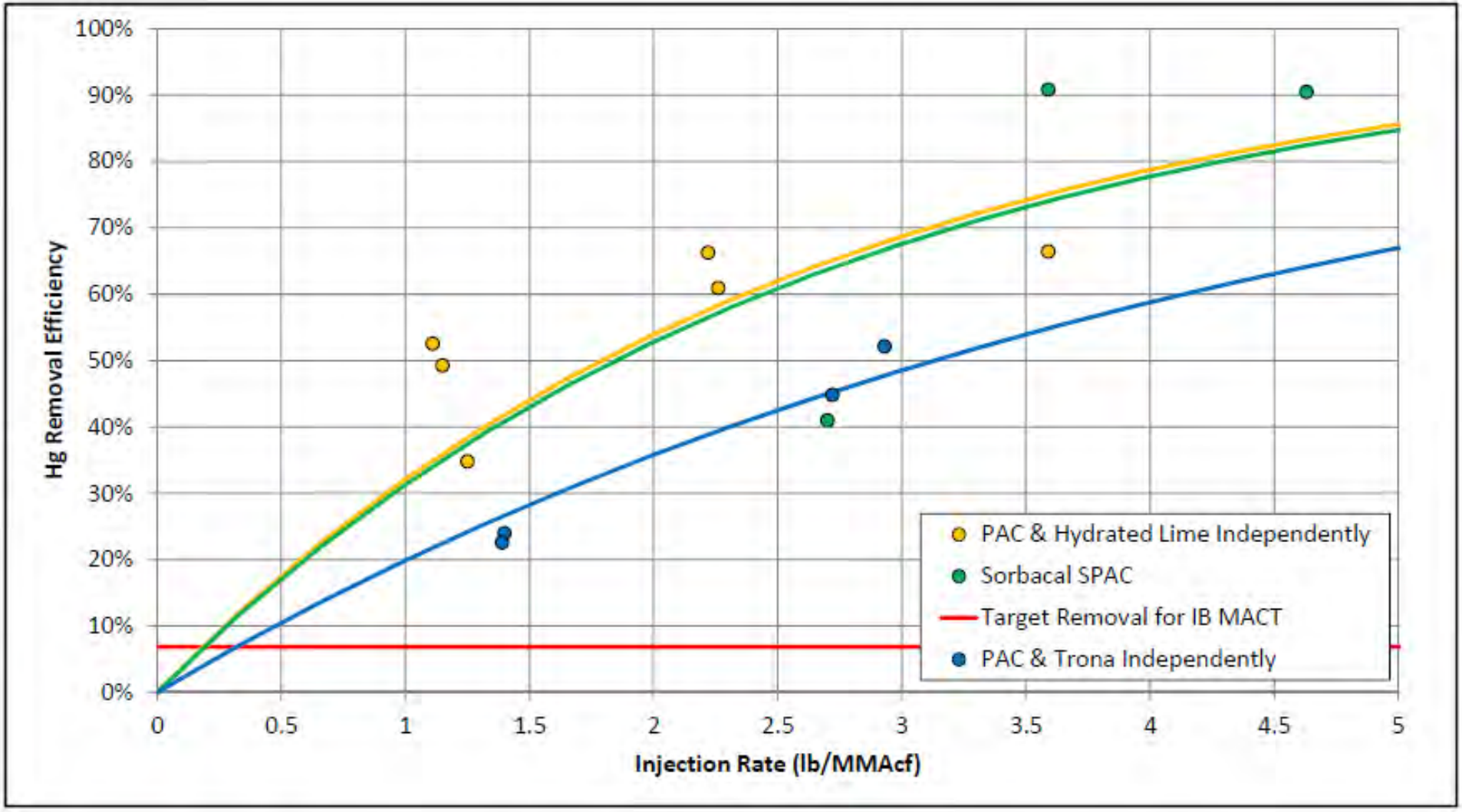

Results and Discussion – Hg Parametric Curve (Reduced Load)

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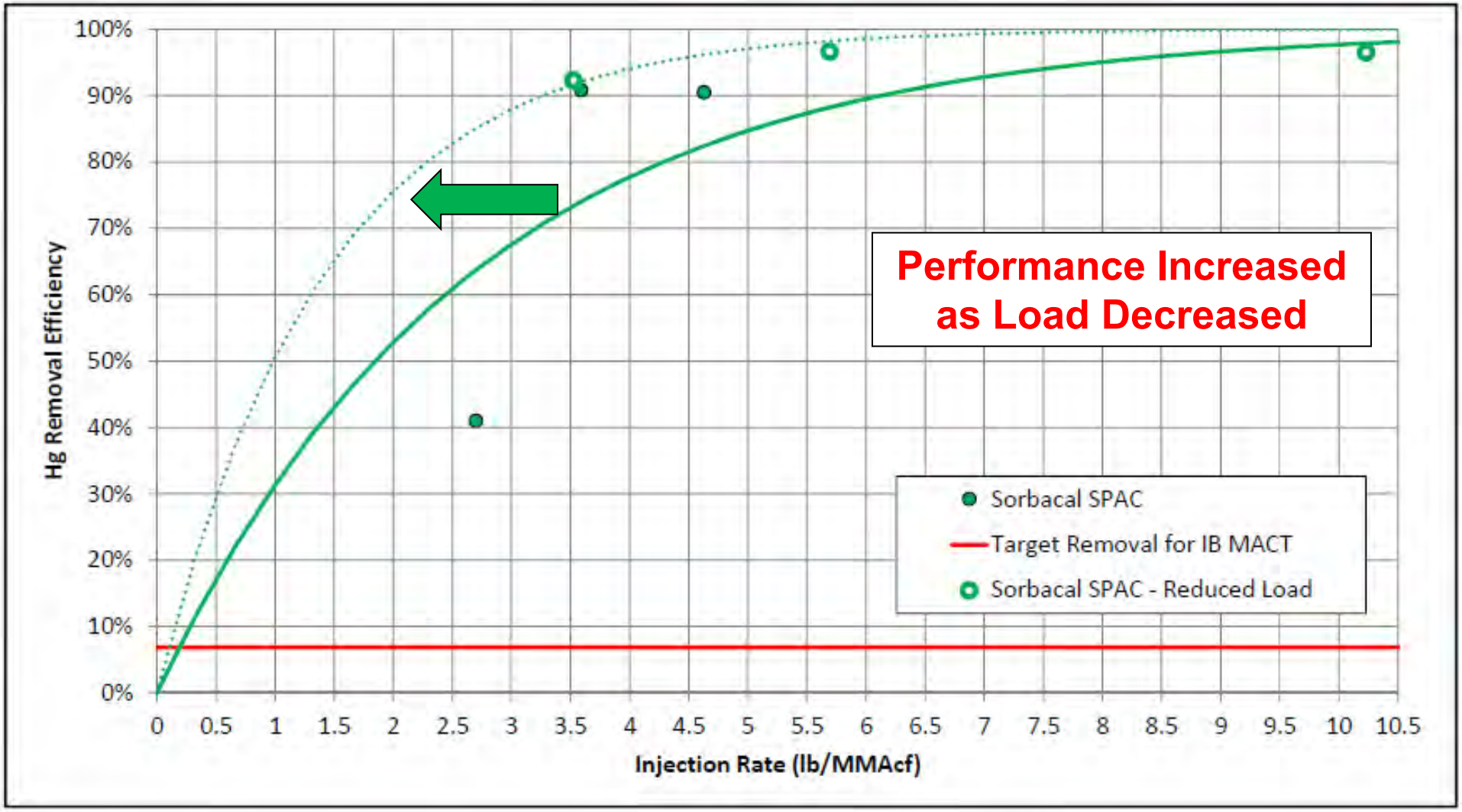

Results and Discussion – Balance of Plant Impact

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- No net impact on stack opacity
- No net impact on Fabric Filter operation
- No net impact on ID fan operation
- No net impact on ash handling

Summary of Results

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- Blended product successful in simultaneously reducing HCl and Hg emissions below permit and IB MACT limit with single injection skid.
- **No negative impacts on BPAC performance** for Hg control.
- Remained **homogeneous** throughout testing suggesting sorbent segregation would not occur.
- Flow characteristics appeared to be **consistent with pure hydrated lime**.
- Capital cost savings by **avoiding installation of new ACI system** for Hg emission reduction for IB MACT compliance.

Overall Summary / Conclusions

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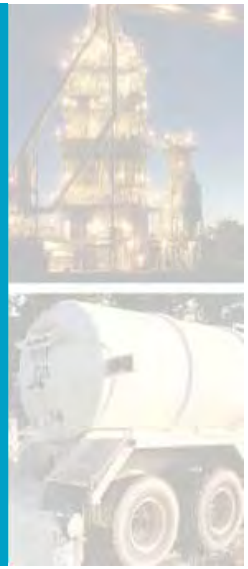
- Blended Sorbacal®/BPAC product **successful** for SO_2/HCl and Hg control in three (3) full scale trials.
- Trials **demonstrated capital cost savings** by avoiding installation of dedicated ACI system.
- Utilized Sorbacal® SP/SPS blends with BPAC ranging from 10 to 30% (by weight).



- Blended products were **homogeneous** with **flow properties consistent of hydrated lime**.
- Blended products **performed as well as BPAC** alone.
- No negative BOP impacts observed.
- **Plants moving forward with blended product solution for compliance.**

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Thank you!!

If you have any questions feel free to contact,

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