REINHOLD ENVIRONMENTAL Ltd.

2017 NOx-Combustion-CCR Round Table Presentation

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Benefits of SCR Field Mercury Oxidation Testing

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Managing SCR Hg Oxidation Performance

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First Energy's approach to MATS compliance – Maximize SCR Co Benefits

- Four Plants – 10 Units

Managing SCR Hg Oxidation is critical to their MATS compliance strategy

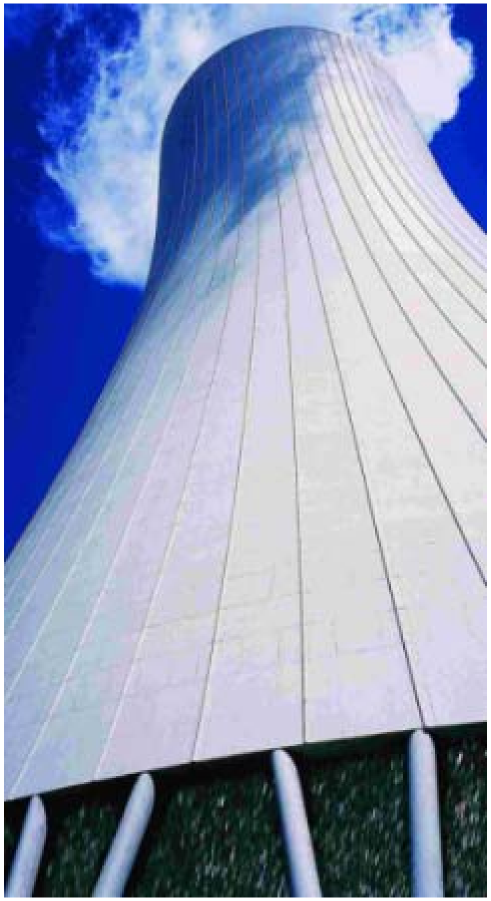
STEAG SCR-Tech and First Energy have been working together on SCR Management since 2008

SCR field Hg oxidation performance testing is one of the tools being utilized

Field Testing Benefits

Accounts for complex Hg Chemistry that is not easily tested in the lab

- Fly Ash interactions
- Flow distribution/pluggage/temperature distribution
- Other unknowns



Provides basis for assessing accuracy/reliability of Hg Oxidation models

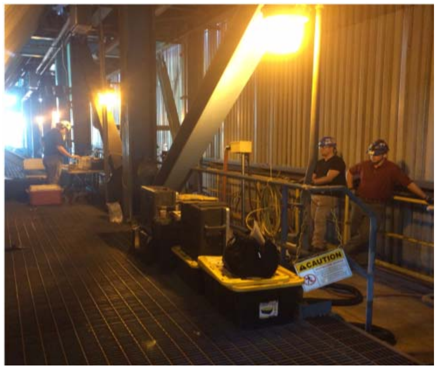
Provides basis for establishing SCR Performance needed to meet and maintain MATS limit.

- Define contribution from APH/ESP

Field Testing Challenges

Hg speciation analysis at the SCR outlet presents unique challenges

- High temperature
- High ash content in flue gas
- Potential for un-wanted Hg reactions in the sample system



The challenge is to develop a sample train that does not influence Hg Chemistry!

Remove fly ash at duct temperature without altering chemistry

Sample Conditioning Methods

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Variables Evaluated

- Material type
- Contact time
- Filter pore size
- Mechanical Integration with Trap
  - Filter temperature
  - Surface chemistry interactions
- Inertial vs. Standard

Materials	Methods
A	A-C72, A-C144, A-C287, A-C422
B	B-C9-P10-A, B-C9-P20-A, B-C16-P7-A, B-C3-P20-A, B-C117-P1-A, B-C182-P1-A
C	C-C3-P10-A, C-C16-P10-A
D	DO-C16-P40-A, DN-C16-P40-A
E	E-C77, E-C144, E-C144-A2, E-C422-A1
F	Ff-C15-P20-A, Ff-C15-P40-A, Fc-C25-P5-A, Fcw-C25-P5-A
G	G-C0-P10-A, G-C0-P25-A, G-C1-P25-A
H	H-C3-P10-A, H-C3-P20-A
I	I-C144, I-C422-A1

Definitions

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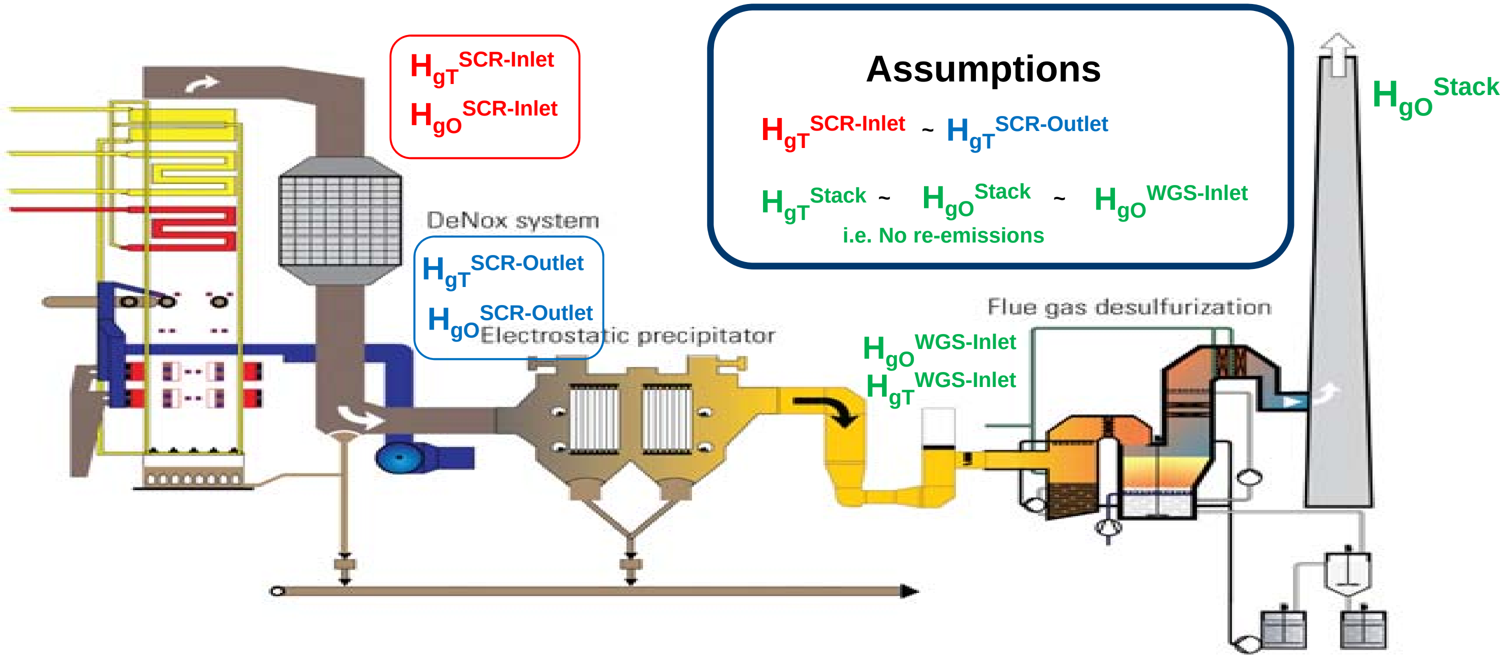

$$\%\ \text{Oxidized @ SCR} = \left[1 - \frac{H_{gO}^{SCR\text{-}Outlet}}{H_{gT}^{SCR\text{-}Outlet}}\right] \times 100$$

Measured in Plant

$$\%\ \text{Oxidized @ WGS Inlet} = \left[1 - \frac{H_{gO}^{WGS\text{-}Inlet}}{H_{gT}^{SCR\text{-}Outlet}}\right] \times 100$$

$$\%\ \text{Oxidized Across SCR} = \left[\frac{H_{gO}^{SCR\text{-}Inlet} - H_{gO}^{SCR\text{-}Outlet}}{H_{gO}^{SCR\text{-}Inlet}}\right] \times 100$$

Measured in Lab

$$\%\ \text{Oxidized Across APH/ESP} = \left[\frac{H_{gO}^{SCR\text{-}Outlet} - H_{gO}^{WGS\text{-}Inlet}}{H_{gO}^{SCR\text{-}Outlet}}\right] \times 100$$

SCR Performance Needed to Achieve MATS Limit?

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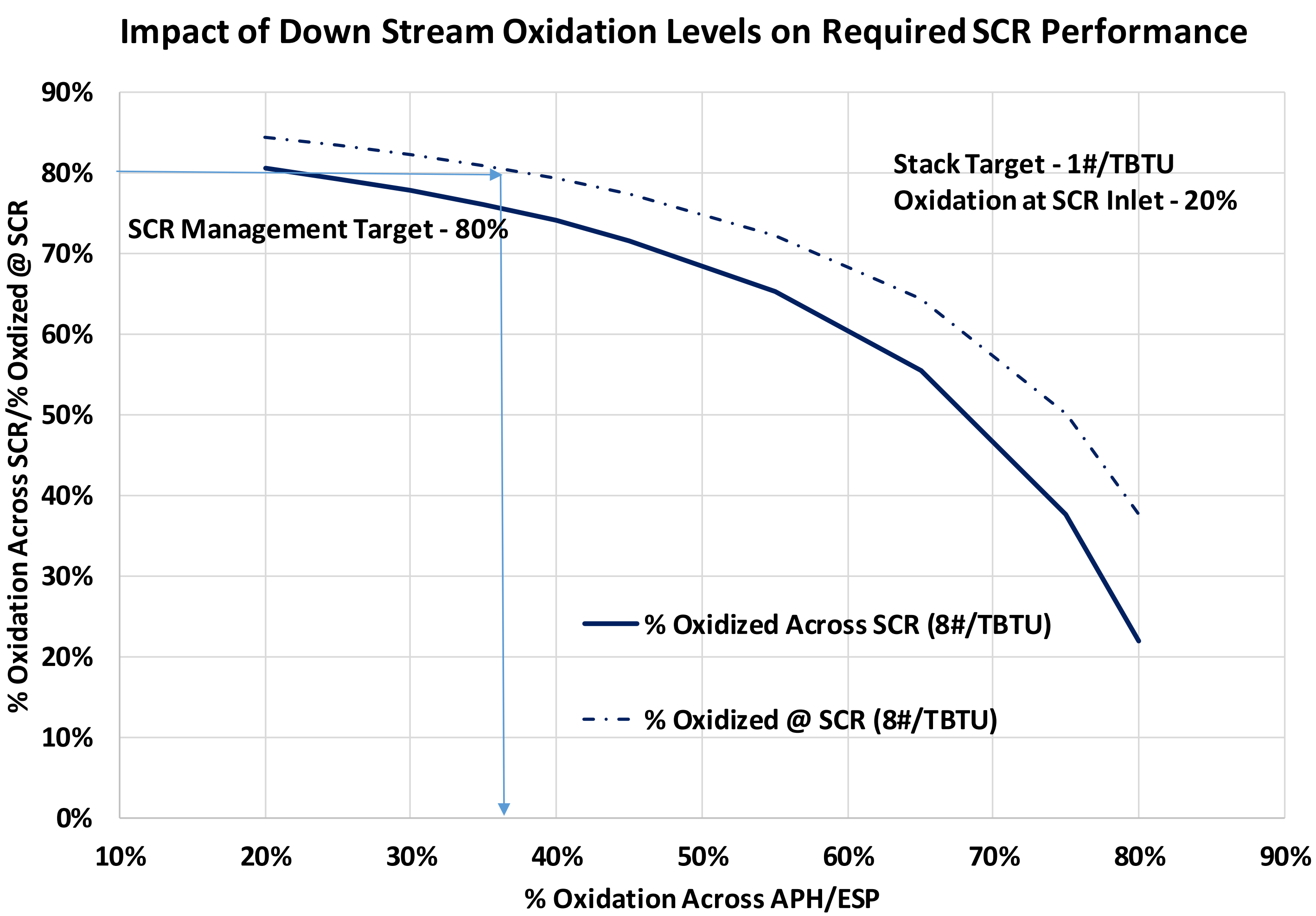
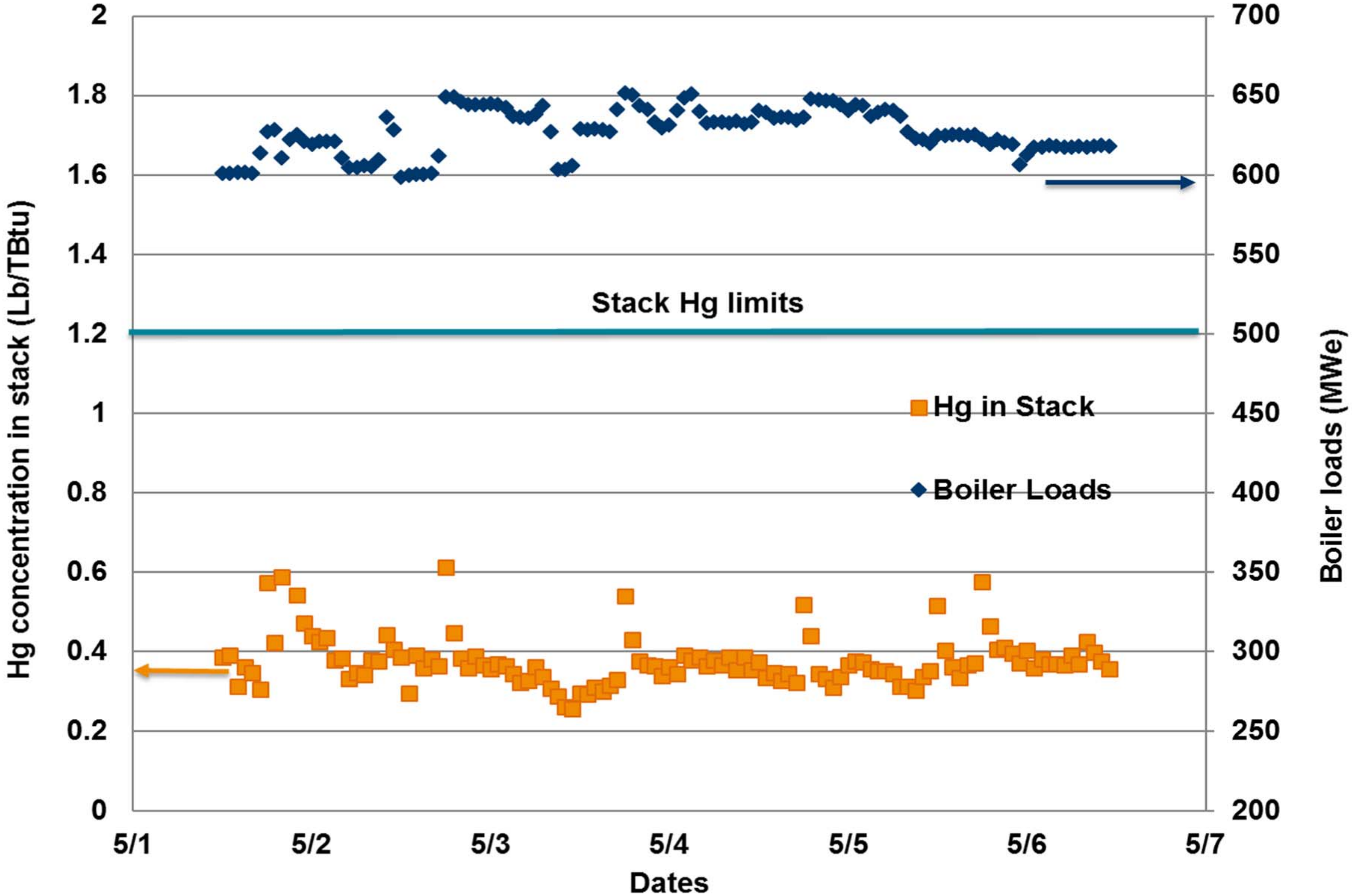


Harrison Unit Background Information

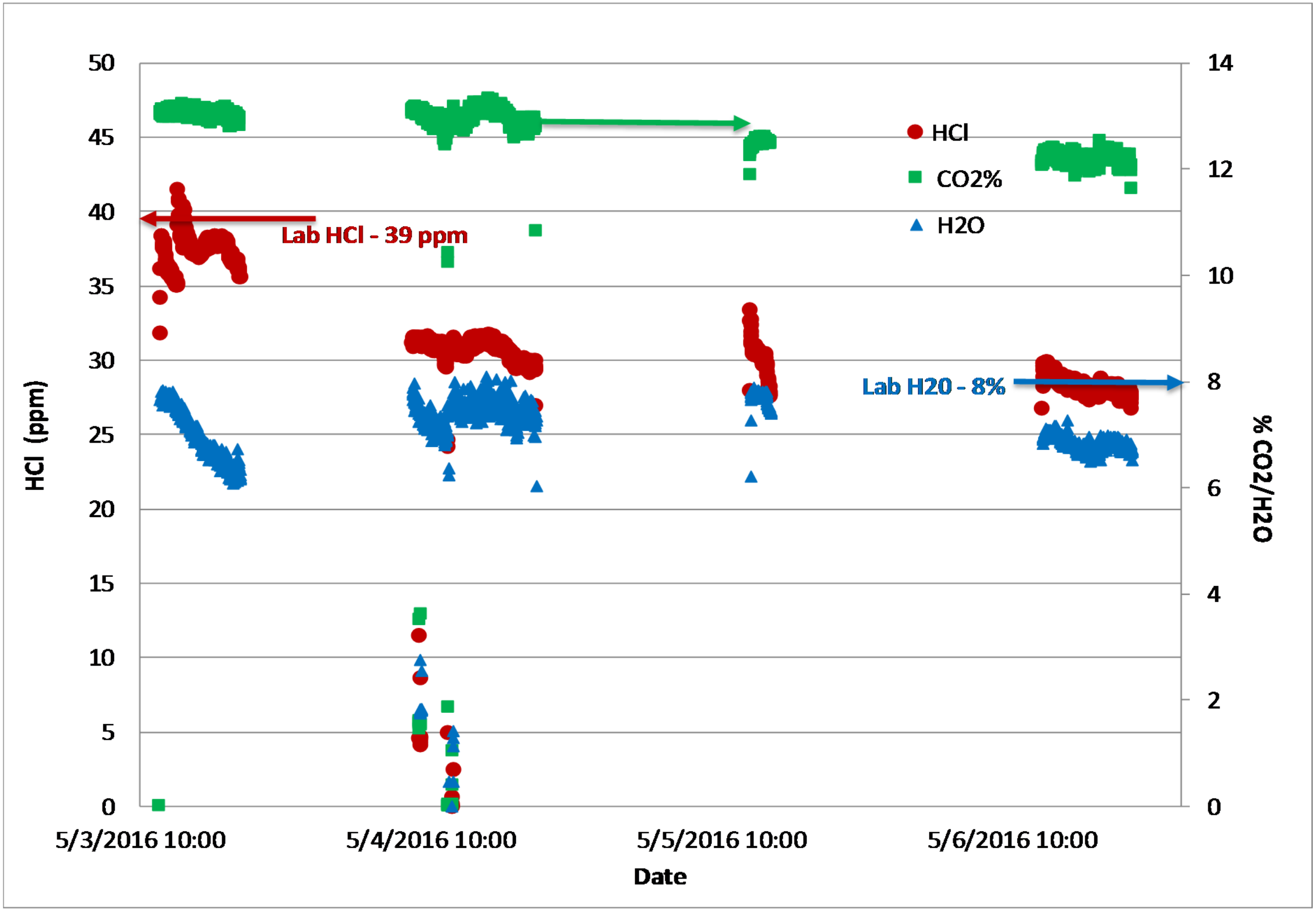
Unit	Hg Test Date	Date of last AIG Tuning	Layer	Type	Pitch (mm)	Length (mm)	Hours	Layer DENOx Potential
HAR U3	May-16	Dec-15	1	Corrugated	6.4	750	9,334	1.56
			2	Corrugated	6.4	810	3,504	1.91
			3	Corrugated	6.4	810	9,334	1.51
HAR U1	Sep-16	Apr-16	1	Corrugated	6.4	750	9,344	1.58
			2	Corrugated	6.4	810	9,344	1.56
			3	Corrugated	6.4	810	9,344	1.56
HAR U2	Dec-16	Dec-16	1	Corrugated	6.4	750	12,264	1.6
			2	Plate	5.7	920	0	2.05
			3	Plate	5.7	920	0	2.05

- **Stack NO target – 0.0[illegible]#/MMBTU**
- **Estimated NO inlet -0.5#/MMBTU**
- **Required SCR Catalyst DENOX Potential – 3.5**
- **Mercury Oxidation Target – 80%**

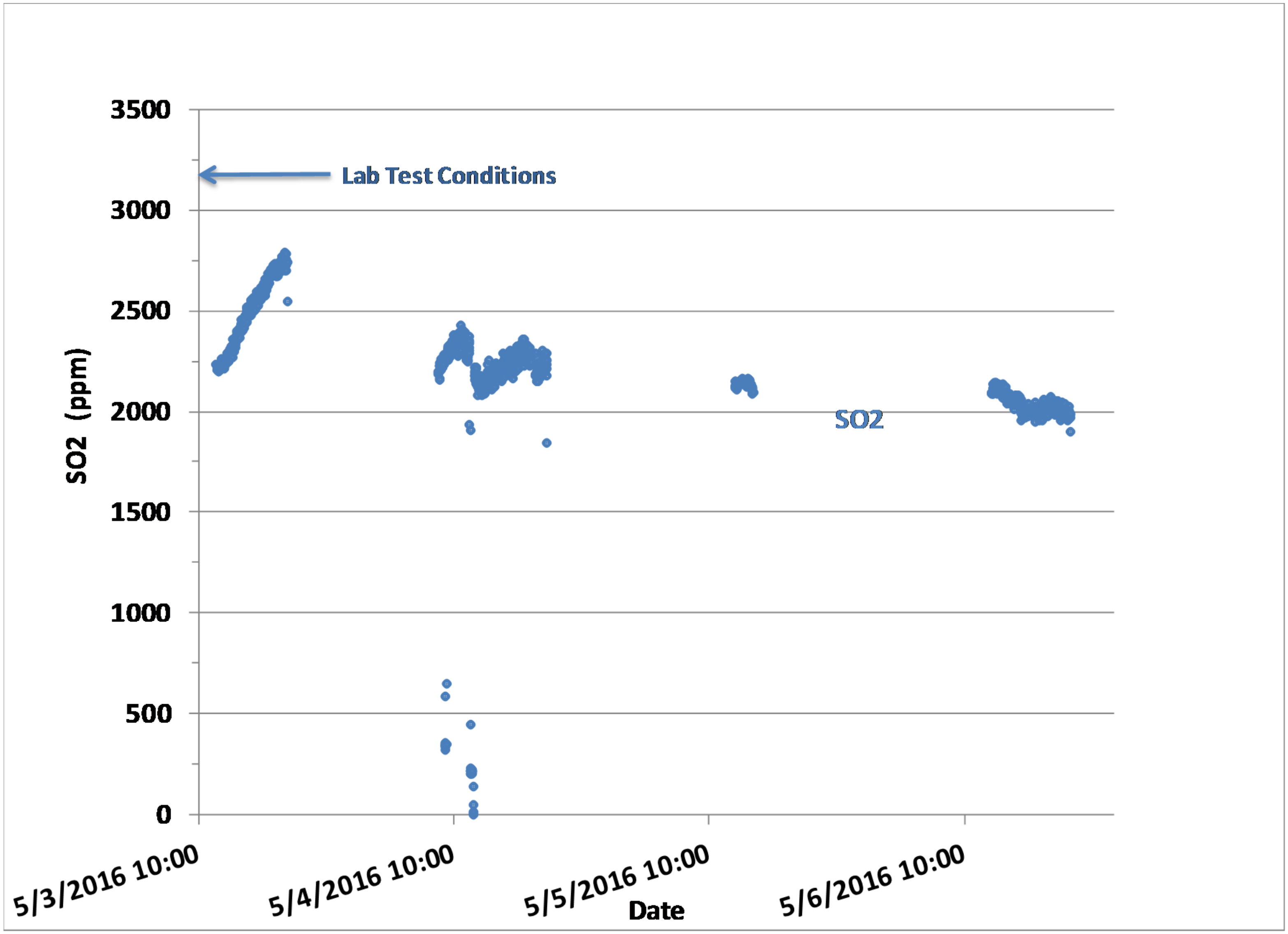
Harrison 3 Test – May 2016



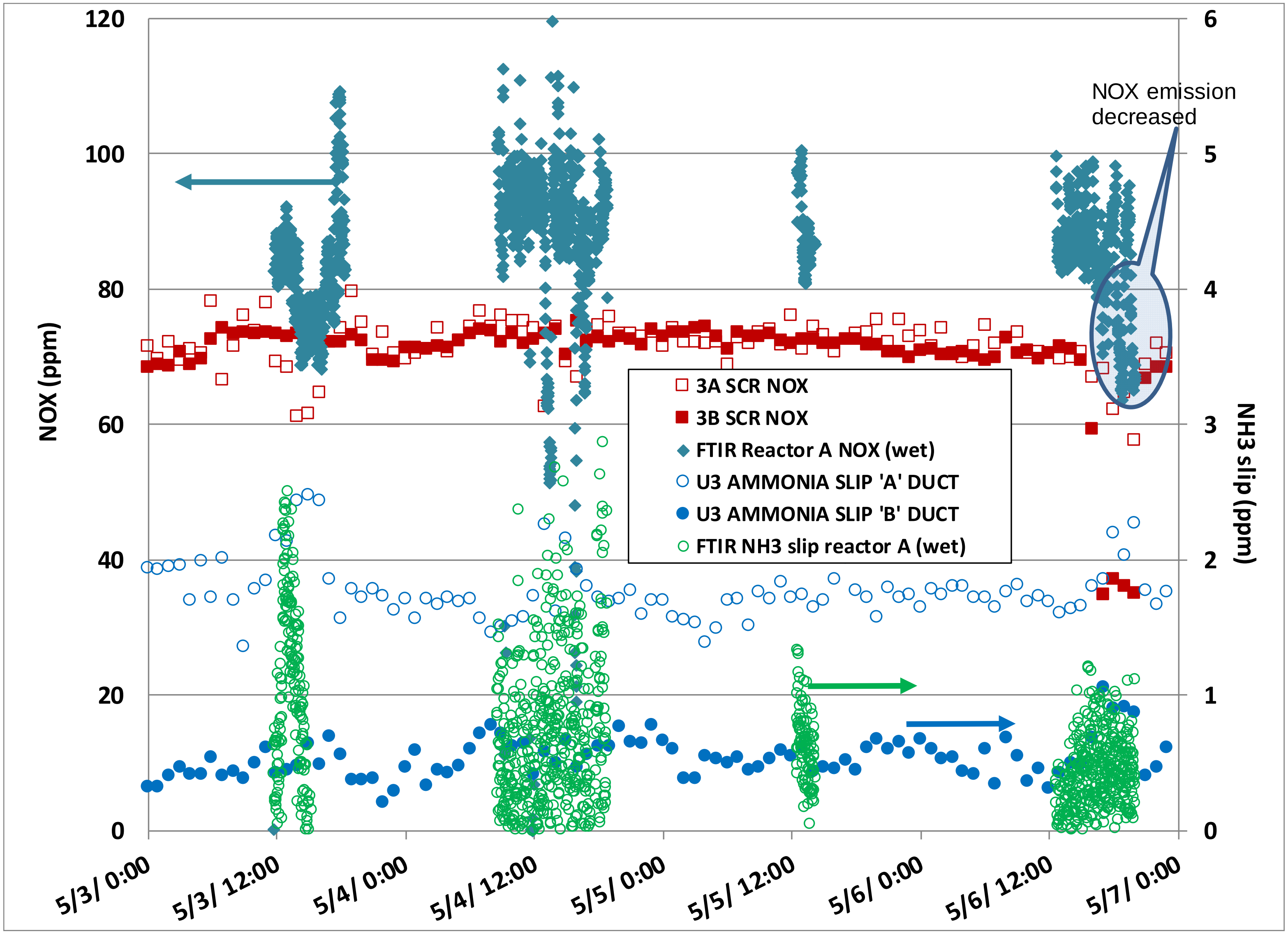
FTIR Flue Gas Analysis – HCl, CO_2, H_2O



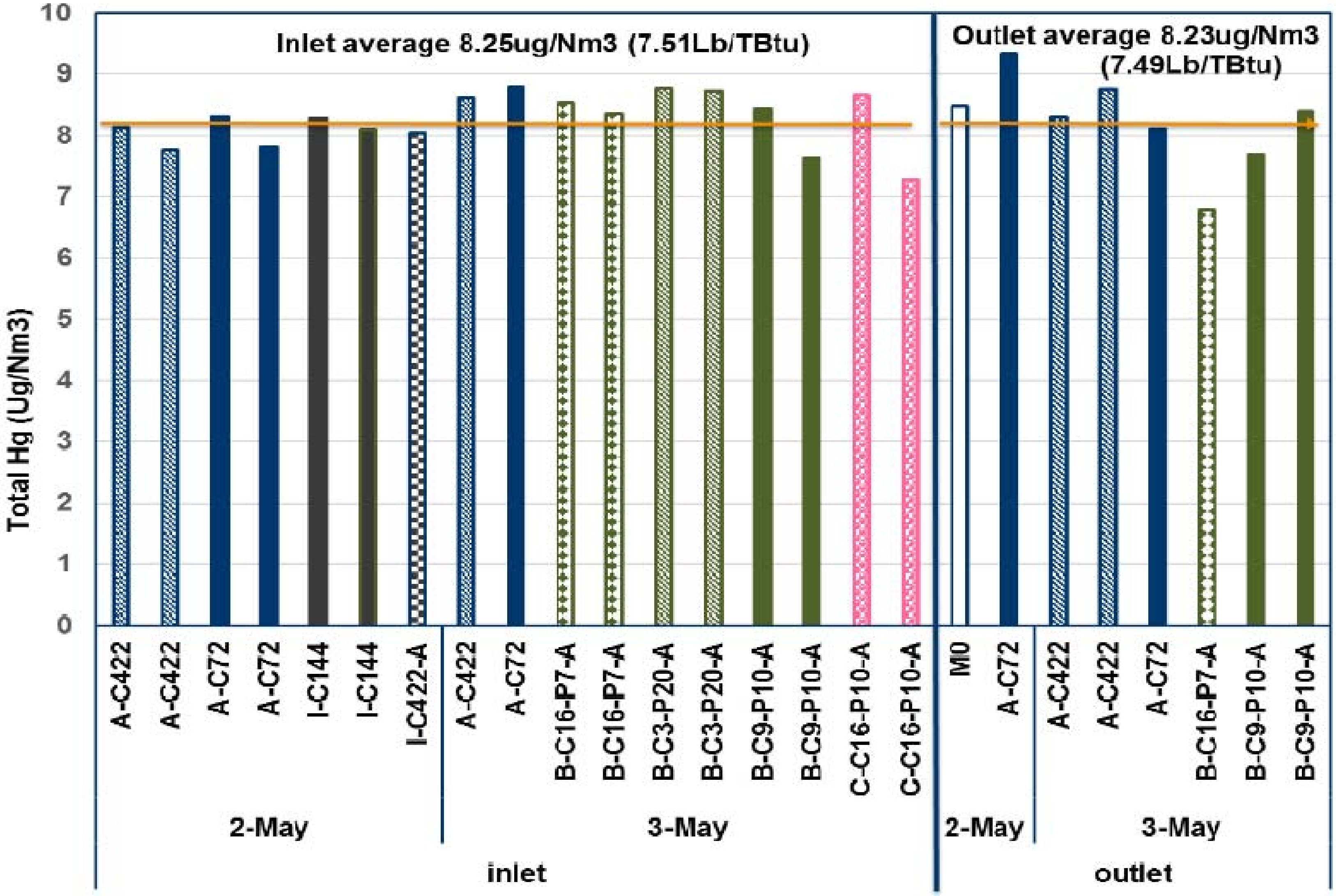
FTIR Flue Gas Analysis – SO_2



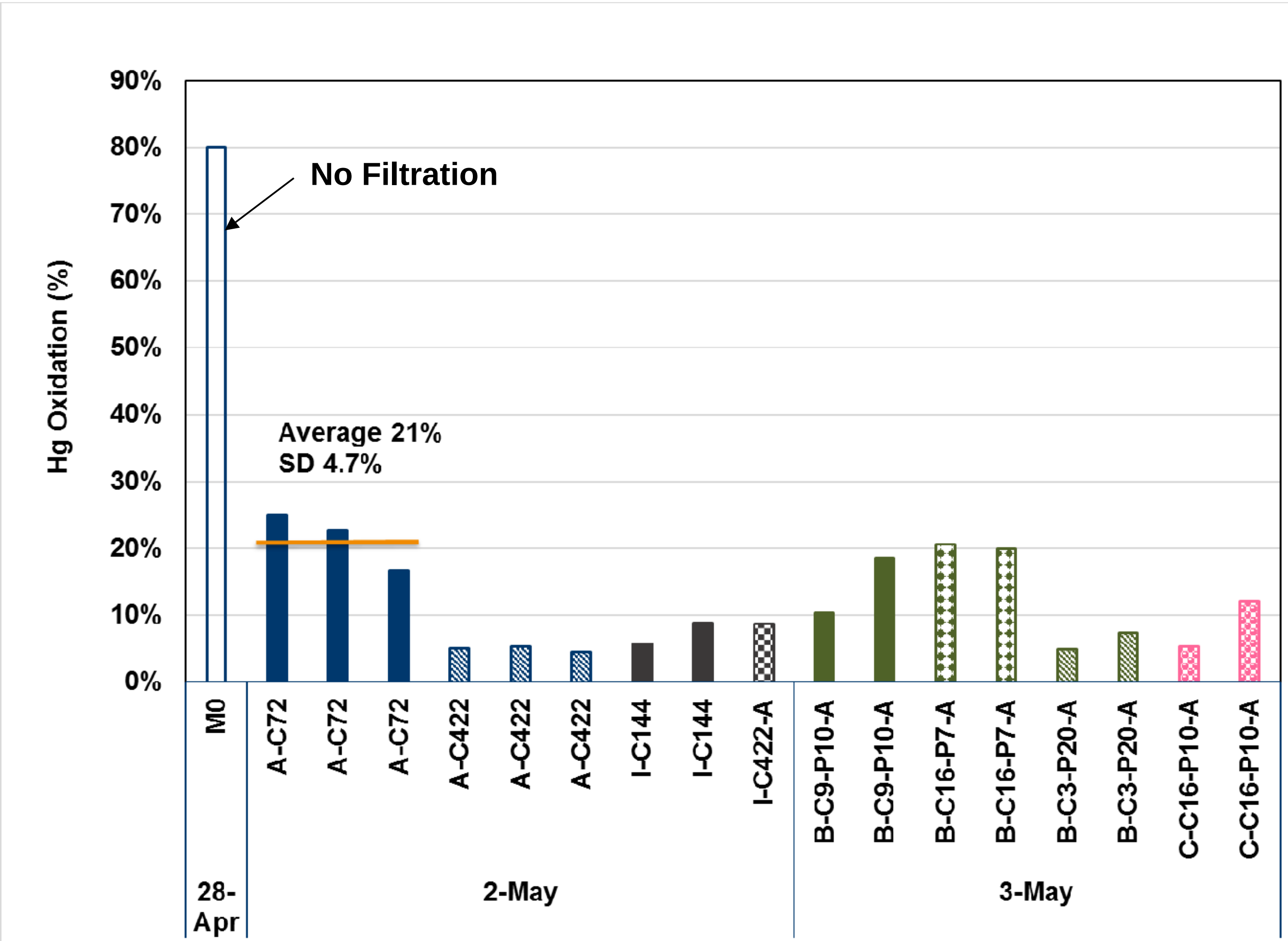
FTIR Flue Gas Analysis – NO_x, NH_3



Affect of Methods on Total Mercury Values



Affect of Methods on SCR Inlet Speciation



Method Affect on Speciation at SCR Outlet

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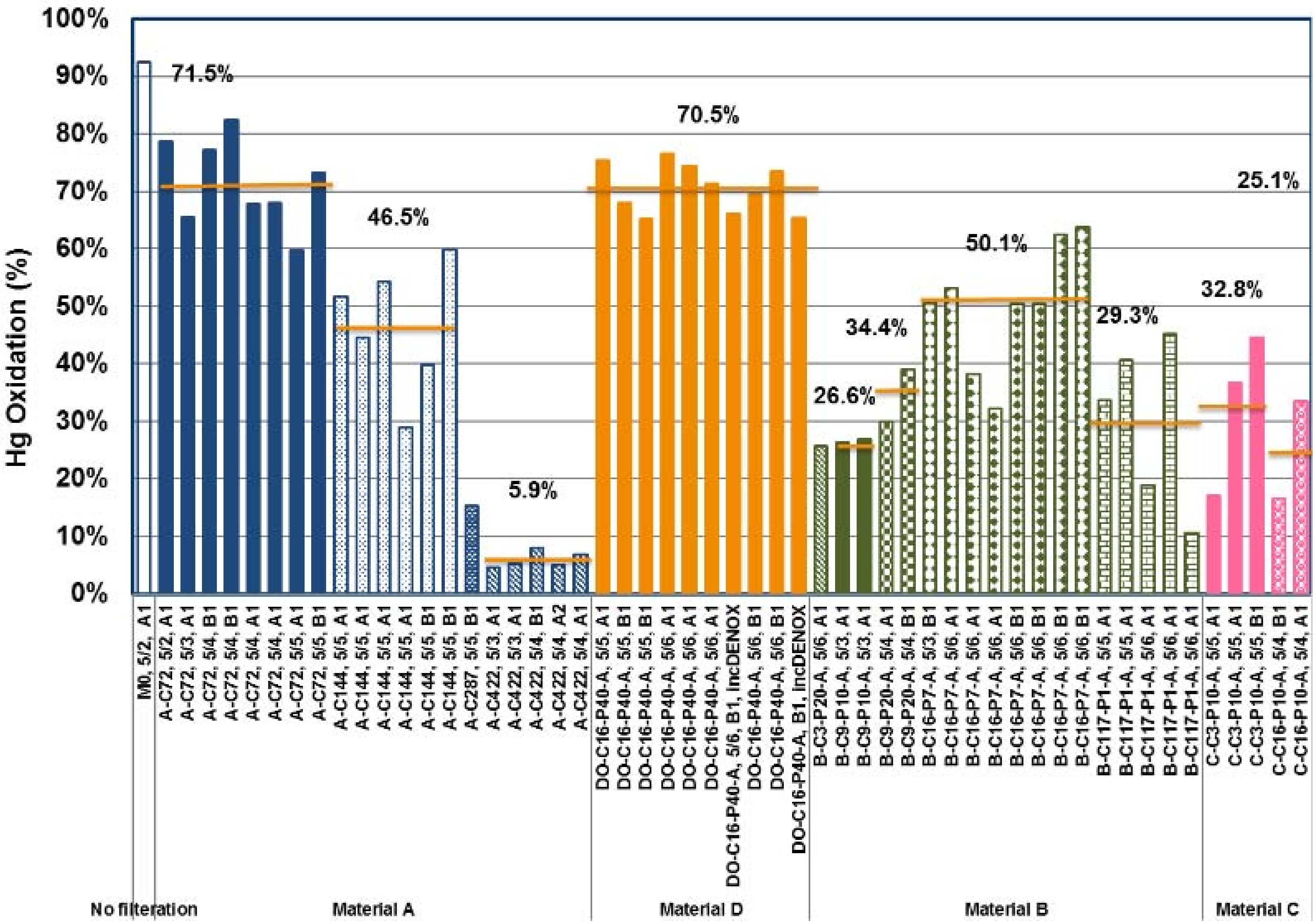

Affect of Increased DENOX on SCR Oxidation

Harrison 3	Reactor A		Reactor B	
Conditions	Standard DeNOx	DeNOx increased	Standard DeNOx	DeNOx increased
Outlet NOx (ppm)	71.3	64.7	69.9	44.8
Outlet NH3 (ppm)	1.72	1.97	0.5	0.8
Hg oxidation @outlet	75.5%	71.3%	71.5%	65.6%

STEAG SCR-Tech Test Results vs Historical Data

	STEAG SCR-Tech	Previous Study
Average SCR inlet HgT (Lb/TBtu)	7.51	8.82
Average SCR outlet HgT (Lb/TBtu)	7.49	**6.49**
Sampling time	30 mins	**15 mins**

	STEAG SCR-Tech		Previous Study	
	Reactor A	Reactor B	Reactor A	Reactor B
SCR outlet Hg oxidation from method A (%)	75.5%	71.5%	85.7%	**52.4%**

Harrison 3 Test Summary

Sample Conditioning methods have a significant affect on speciation results

- Material selection and contact time impact results
- Method A-C72 and DO-C16-P10-A appear to provide the most realistic results
- Further evaluation/optimization conducted at Harrison1

Flue gas sampling must be conducted to interpret results

Provides basis for establishing SCR Performance needed to meet MATS limit

- Oxidation levels below target achieved stack levels much lower than MATS limit
- Much higher than anticipated oxidation across APH/ESP

Harrison Unit 1 Test – September 2016

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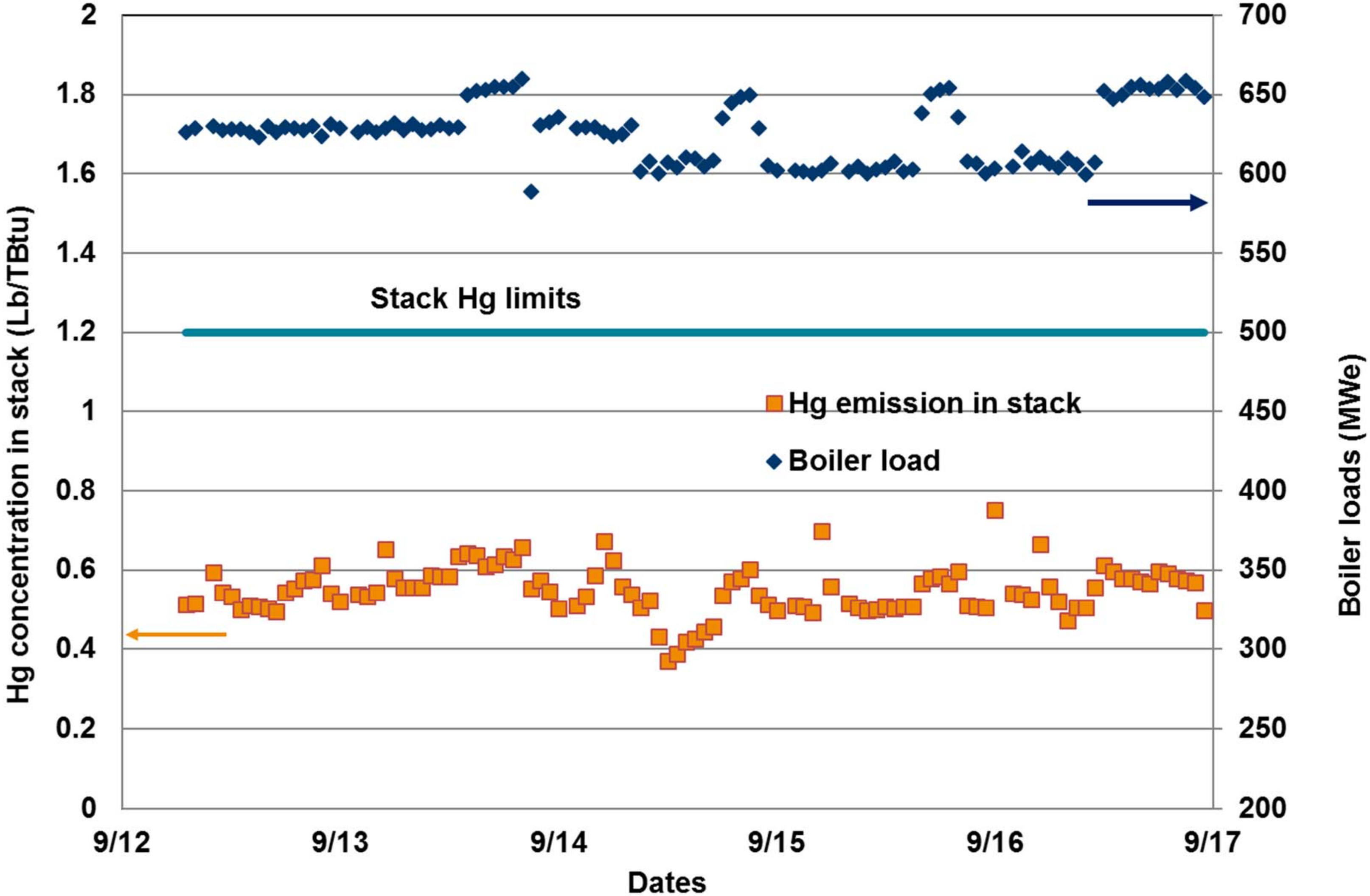
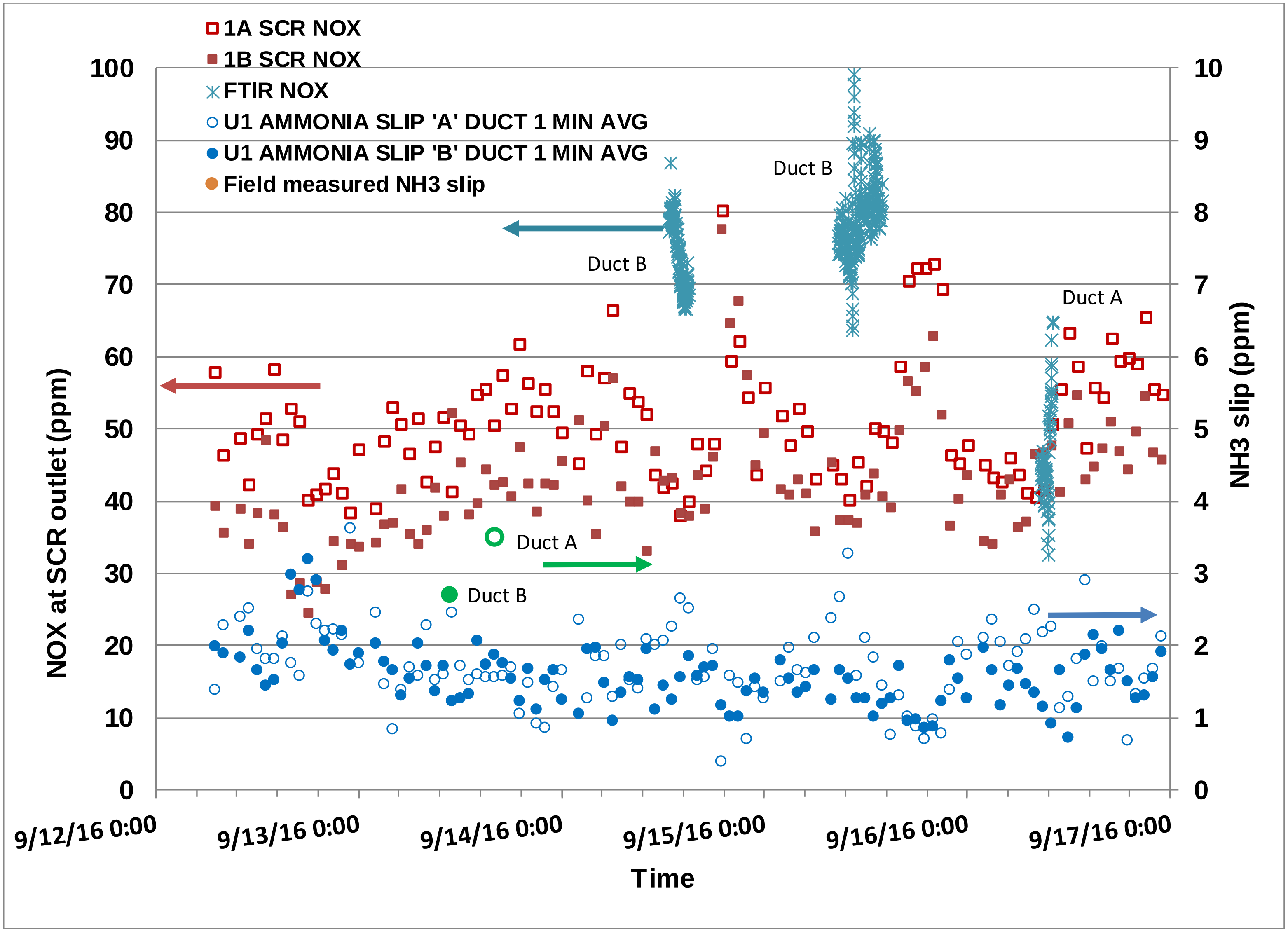


SCR outlet NOx and NH3 slip



FTIR Flue Gas Analysis – HCl, CO_2, H_2O

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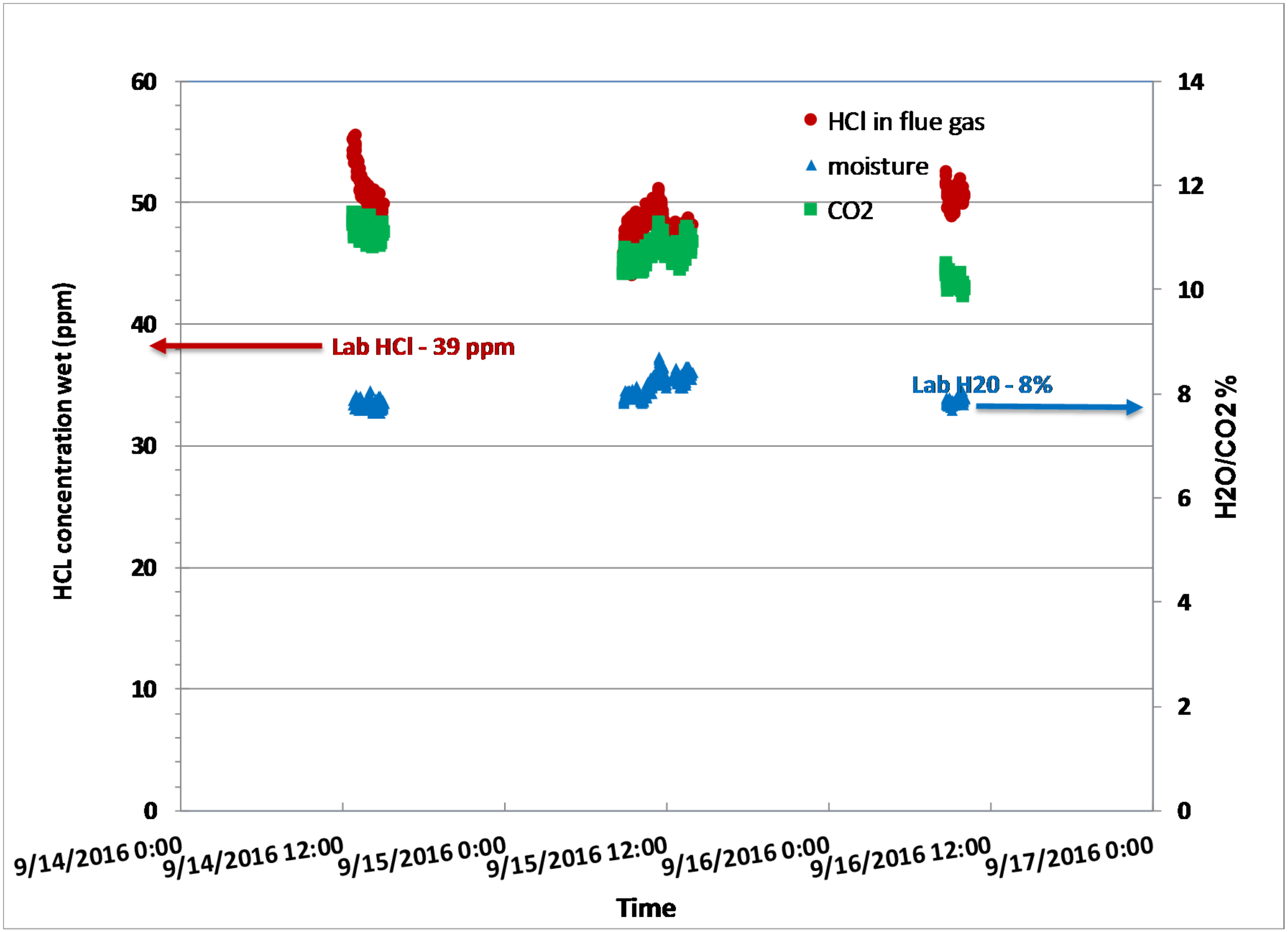
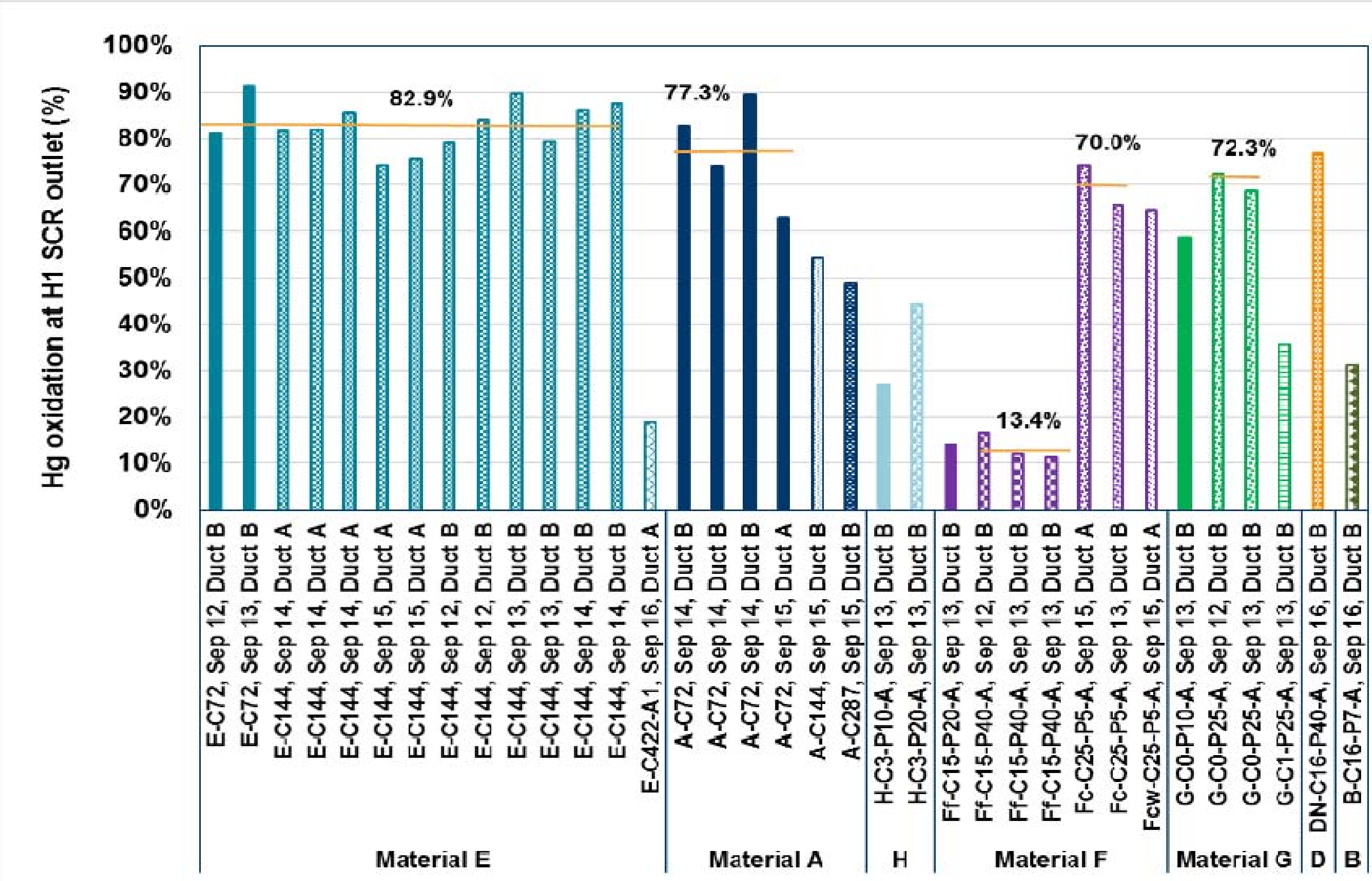


Method Affect on Speciation



Method E-C108 Results – Duct A vs Duct B

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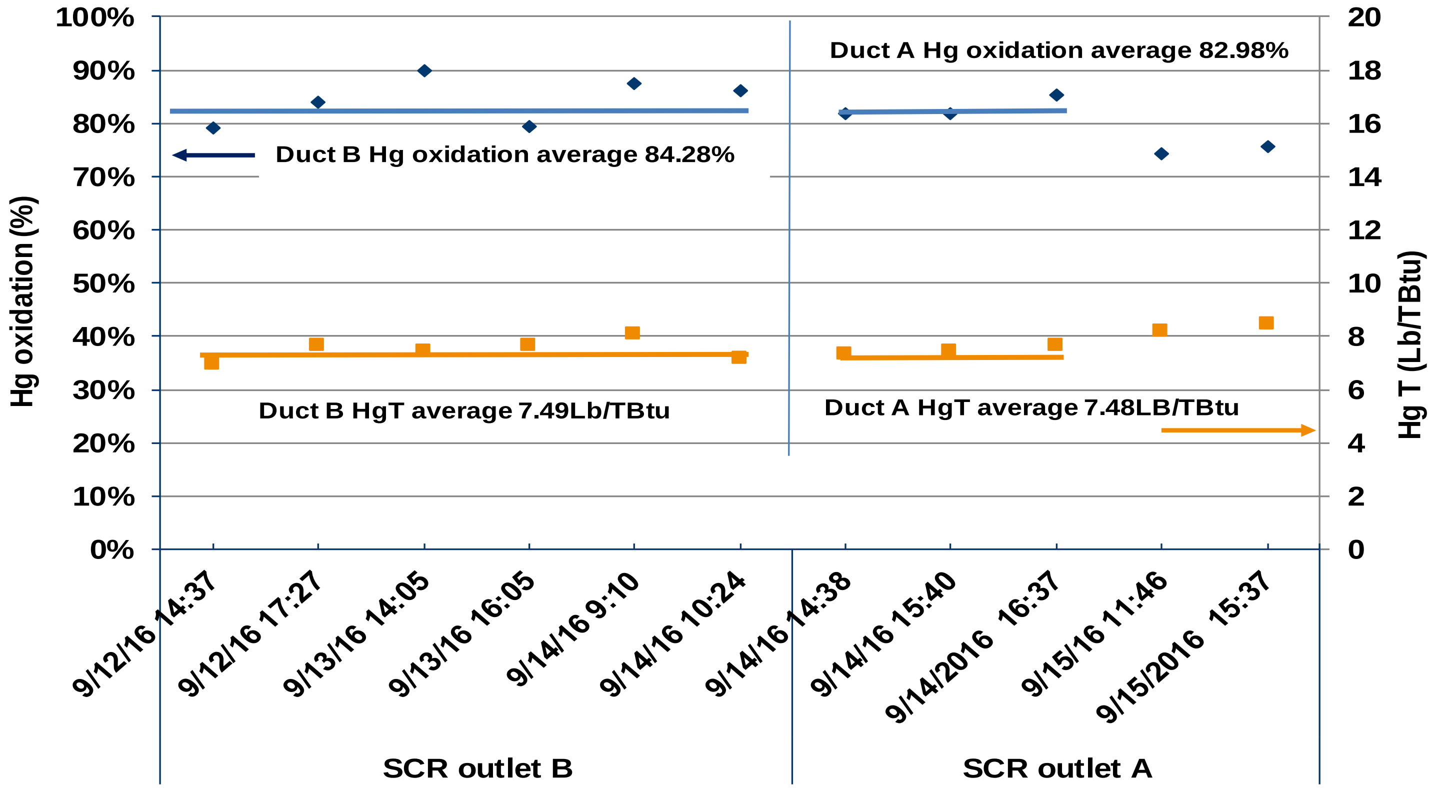
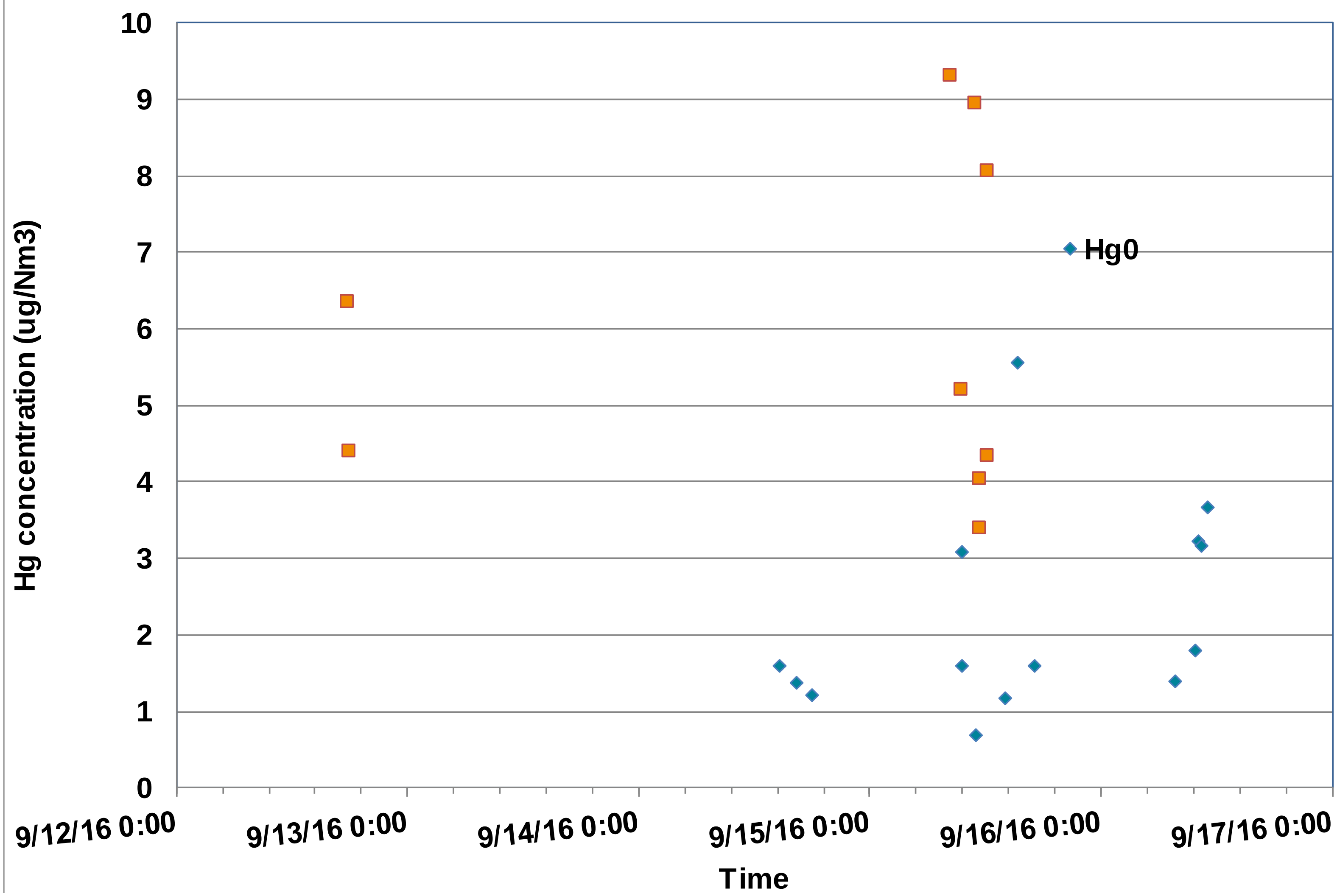


Method E-C144

	Date	HgT	HgO	% Oxidized
SCR Inlet (lb/TBTU)	9/12/2016	8.07	6.39	21%
SCR Outlet(lb/TBTU)	9/15/2016	8.32	2.08	75%
APH Outlet (lb/TBTU)	9/15/2016	7.44	0.87	88%
% Oxidized Across APH - 58%				

30B traps with Standard Qsis probe



Harrison 1 Test Summary

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Method E-C144 appears to provide improved results

- Less reactive material – insensitive to contact time
- Disposable – eliminates contamination issues
- Filter temperature was not equal to flue gas temperature
- Improved method evaluated in Harrison 2 Test

Inlet totals and oxidation levels consistent with Harrison 3 results

Outlet speciation is higher than Unit 3 (~84% vs. 71%)

- HCl Levels are much higher (~50 ppm vs. 30 ppm)

Stack Levels well below MATS Limit (0.53#/TBTU)

Harrison Unit 2 Test– December 2016

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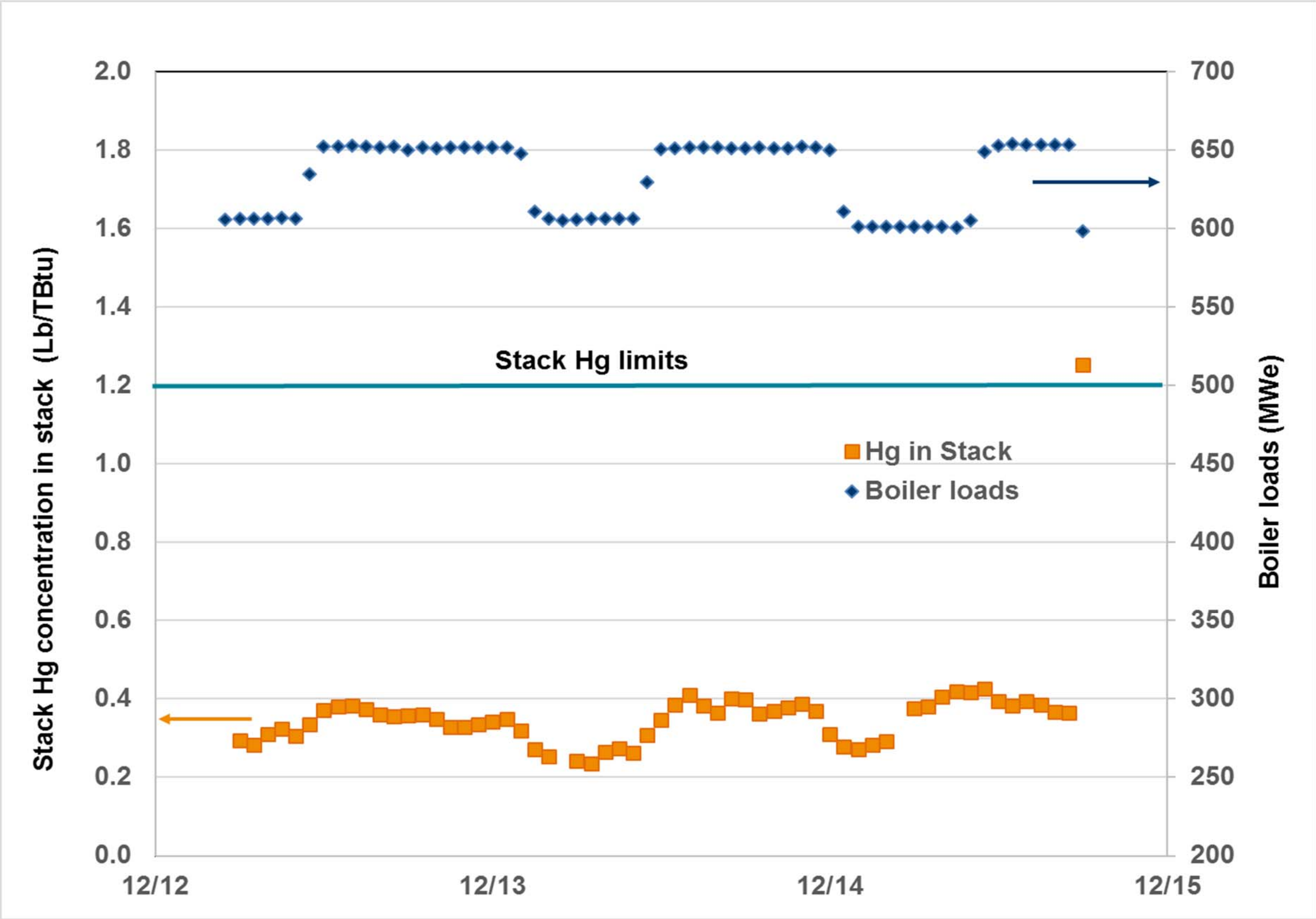
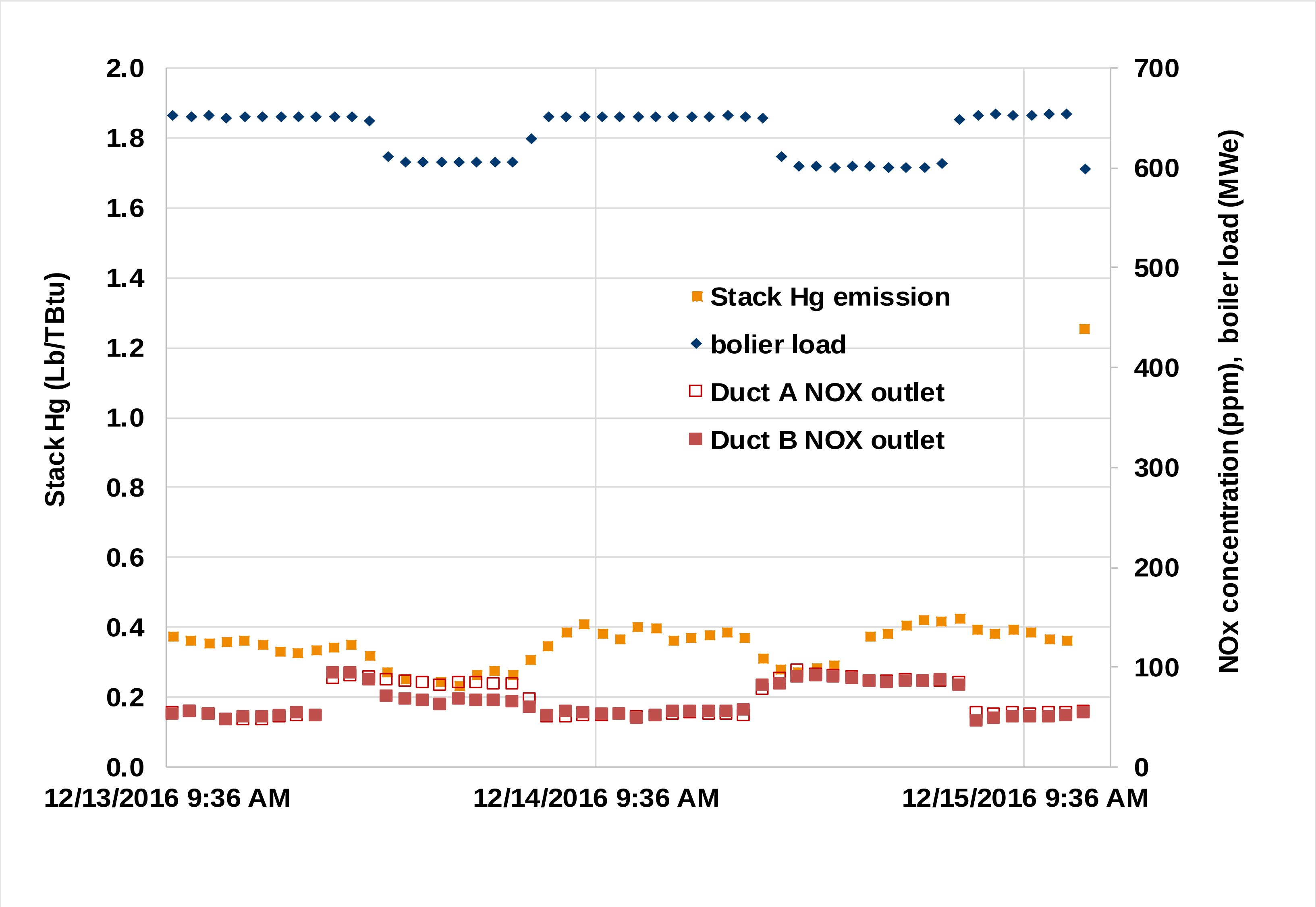


DCS Data analysis



Affect of Temperature Control on Method E-C144 (ie. Method E-C144-A2)

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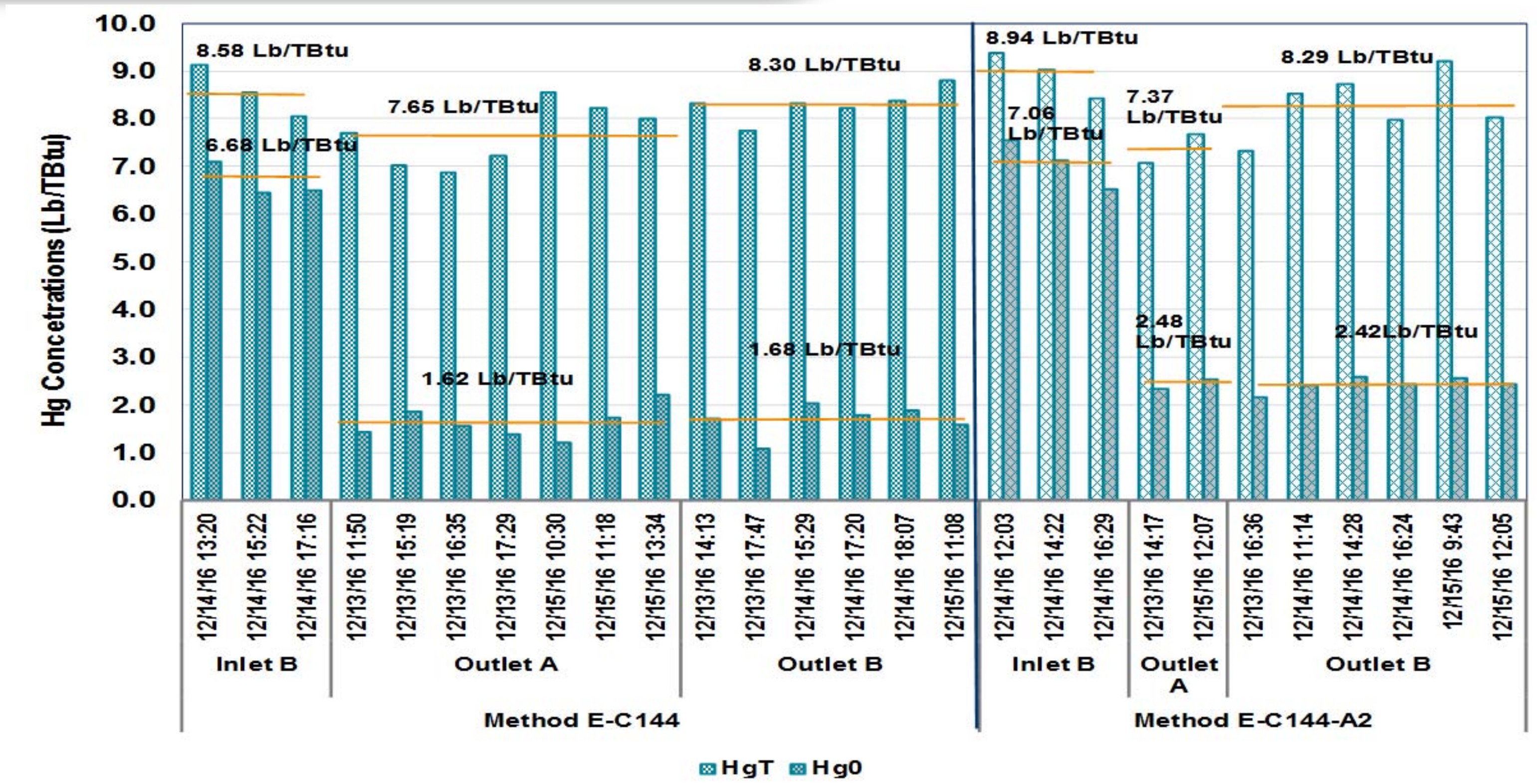

Ash prefiltration methods		E-C144		E-C144-A2	
Duct		A	B	A	B
SCR inlet	Hg T (Lb/TrBtu)		**8.58**		**8.94**
	Hg0 (Lb/TrBtu)		**6.68**		**7.06**
	Hg Oxidation (%)		**22.0%**		**21.1%**
SCR outlet	Hg T (Lb/TrBtu)	**7.65**	**8.30**	**7.37**	**8.29**
	Hg0 (Lb/TrBtu)	**1.62**	**1.68**	**2.44**	**2.42**
	Hg Oxidation (%)	**77.9%**	**79.8%**	**65.8%**	**70.7%**
Stack mercury	Hg T (Lb/TrBtu)	0.42			

Test Summary – All Units

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Parameter	Unit 3 May of 2016	Unit 3 Sep of 2016	Unit 1 Sep of 2016	Unit 2 Dec of 2016
Method	A-C72	E-C144	E-C144	E-C144
Total DeNOx Potential	4.98	4.42	4.7	5.7
Boiler Load (MW)	630	600	623	649
Nox Out (ppm)	70.6	116	44	54
SCR outlet Temp (F)	654	647	635	656
% Oxidzed at SCR inlet	21%	21%	21.0%	21.0%
HCl (ppm)	**32**	**49(1)**	**49**	N/A
SCR Inlet Hgo (#/TBTU)	5.9	5.6	5.9	6.2
SCR Out Hg Total #/TBTU	**7.5**	**7.1**	**7.5**	**7.9**
SCR Outlet Hgo	**2.2**	**1.4**	**1.2**	**1.7**
Stack Hg Total	0.37	0.44	0.53	0.42
% Oxized at SCR Outlet	**71%**	**80%**	**84%**	**79.5%**
% Oxidized at Scrubber Inlet	95%	94%	93%	95%
% Oxidized Across SCR	63%	75%	80%	74%
% Oxidized Across APH/ESP	83%	69%	56%	74%

Harrison SCR Performance Needed to Reach MATS Limit

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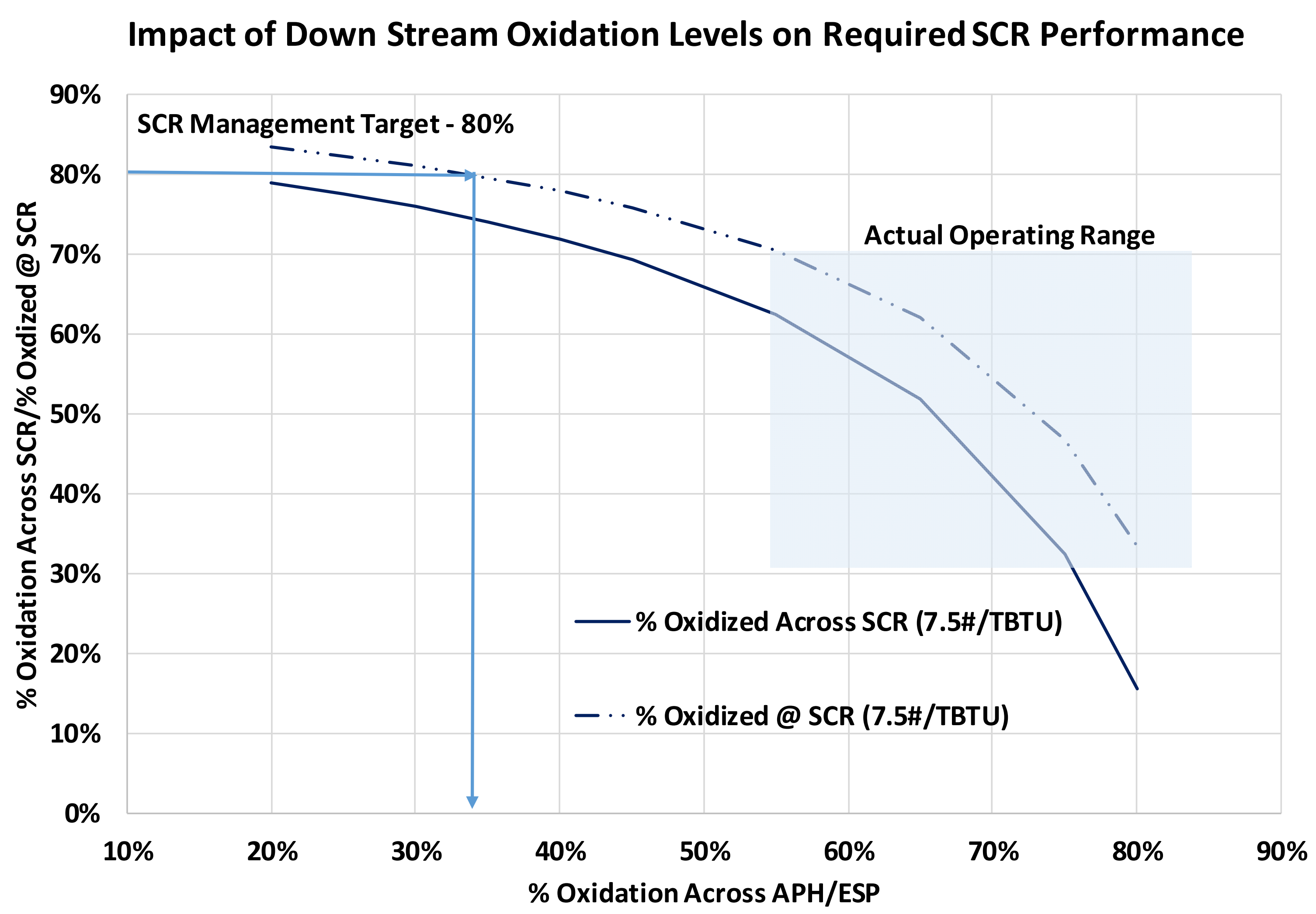

Field Testing Benefits

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Field Performance Analysis is feasible and is a valuable SCR management tool in a MATS world

- Harrison can meet MATS limit with Oxidation levels <<80%

Keys to Meaningful field SCR Hg Oxidation performance analysis.

- Well designed trap filtration system
  - Inert filtration material and interconnecting system
- Well planned test plan
  - Account for operation and method variability
  - Sample locations
- Measurement of critical flue gas constituents
- DCS Data analysis
- Intimate understanding of catalyst/SCR history, condition and forecast
- Expertise in Mercury control/SCR management

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