May 11, 2018

Via e-mail
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RE: Maryland Rulemaking for Limits for Nitrogen Oxides Emissions from Large Municipal Waste Combustors

Dear Mr. Aburn:

The Environmental Integrity Project ("EIP") and the Chesapeake Bay Foundation ("CBF") (collectively "Commenters") respectfully submit these comments on the new regulation limiting emissions of nitrogen oxides ("NOx") from large municipal waste combustors ("MWCs" or "incinerators") that the Maryland Department of the Environment ("MDE") has been considering. MDE started holding public stakeholder meetings in August 2016 on this new regulation and, according to the information presented at the December 11, 2017 meeting of MDE's advisory board on air regulations – the Air Quality Control Advisory Council ("AQCAC") - MDE intends to formally issue a proposed rule for public comment in the Maryland Register in May of 2018.[1]

Introduction

Commenters appreciate the time that MDE's staff has put into this rulemaking and the relatively transparent nature of the public stakeholder process that MDE has held as it considered the rule. During public stakeholder meetings, MDE has provided significant information to interested stakeholders about the legal standards involved, the affected facilities, the emission limits that the agency has considered at different stages of the process, and the basis for those limits. MDE has also made important information, including stakeholder presentations and audio recordings of stakeholder meetings, accessible to the public on its website. In addition, we

[1] MDE PowerPoint, NOx RACT for Municipal Waste Combustors (MWCs), AQCAC Meeting - December 11, 2017, at http://mde.maryland.gov/programs/workwithmde/Documents/AQCACMWCNOxRACT121117.pdf.

appreciate the hourly continuous emissions monitoring system ("CEMS") and operational data that MDE has started to make available on its website[2] pursuant to the formal recommendation made by AQCAC in December that such data was important for public scrutiny of this rule and should be easily accessible.[3] Commenters consider it particularly critical for MDE to continue to make this data available on a quarterly basis going forward. We note, however, that MDE could have been more transparent by sharing key documents with stakeholders without requiring formal records requests. In particular, the report on the 2017 optimization study at the Wheelabrator/BRESCO facility was sent by Wheelabrator to MDE on July 31, 2017, and Mr. Tim Porter of Wheelabrator stated in his email transmitting the report to MDE: "[y]ou can distribute these as you see fit." Commenters did not receive this critical document until December 13, 2017,[4] when we received it in response to a Public Information Act ("PIA") request submitted on November 1, 2017.[5]

Commenters have significant concerns regarding the high NOx emissions from the Wheelabrator Baltimore/BRESCO incinerator in Baltimore City. As we have expressed to MDE numerous times during this proceeding, Commenters believe that substantially more can be done to reduce NOx from this facility than is required under the draft revisions to COMAR 26.11.08 dated November 17, 2017 that were shared by MDE with stakeholders in November 2017 as part of the agenda for the December 11, 2017 AQCAC meeting (hereinafter "Nov. 2017 Draft Rule"). We think that Wheelabrator should be required to meet a 24-hour NOx limit that is much lower than 150 parts per million by volume dry @ 7% O2 (hereinafter "ppm").[6] We expressed this position at the December 11, 2017 AQCAC meeting, during which Commenters and other groups repeatedly requested that MDE add a lower presumptive emissions limit for the BRESCO facility to the draft rule. We are writing to share more information regarding these concerns, as further supported by the attached report of Dr. Ranajit Sahu, who has reached several salient conclusions after reviewing information that we obtained following the December 11, 2017 AQCAC meeting, including the 2017 1-hour CEMS data.[7]

In addition, as described in more detail below, we think that further edits are needed to the text of the Nov. 2017 Draft Rule sections that relate to the feasibility study to be completed in 2020. More specificity should be provided in the rule relating to the analyses to be conducted by Wheelabrator, and Commenters have previously shared our views regarding several of the changes that we consider important.[8] Finally, Commenters consider it critical that ammonia slip be measured at the BRESCO incinerator via the use of ammonia CEMS, as expressed in

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[2] MDE, Air & Radiation Administration, Research and Special Studies, Wheelabrator Annual CEM Data Reports, at http://mde.maryland.gov/programs/Air/Pages/ARAResearch.aspx.

[3] *See* MDE AQCAC, December 11, 2017 Final Meeting Minutes (hereinafter "AQCAC 12/11/17 minutes"), at http://mde.maryland.gov/programs/workwithmde/Documents/AQCACMinutes12112017.pdf

[4] Had Commenters received this document and the hourly CEMS data earlier, it would have allowed us to request a lower emissions limit earlier.

[5] PIA request tracking #03049.

[6] CBF has expressed support in the past for a 150 ppm limit as RACT. However, based on the new information and the analysis set forth in Dr. Sahu's report, CBF now believes that a lower limit is warranted.

[7] Expert Report on NOx Emissions from the Wheelabrator Baltimore Municipal Waste Incinerator in Baltimore, owned and operated by Wheelabrator Baltimore, L.P. by Dr. Ranajit (Ron) Sahu, Consultant, dated May 10, 2018 (hereinafter "May 2018 Sahu Report"). Attached hereto as Attachment A.

[8] *See* Commenters' October 6, 2017 comments. Commenters also attempted to share the specific changes that we consider necessary to the feasibility study section of the Nov. 2017 Draft Rule at the December 11, 2017 AQCAC meeting.

comments already submitted by EIP and CBF both jointly and separately.[9] This is of particular importance given information and statements set forth in the optimization study performed in June 2017 by Fuel Tech, Inc.[10]

If MDE disagrees with any of the conclusions set forth in this letter, including our methodology for calculating annual NOx emissions from the Wheelabrator incinerator using different potential short-term limits, we respectfully request that the agency inform us of this as soon as possible. We expect to share these conclusions with others and to include them in our comments during the formal public comment period and hearing on the proposed rule, and we want our comments to be as complete as possible.

I. Further NOx Reductions are Achievable at BRESCO.

For the BRESCO incinerator, MDE has proposed to set a 150 ppm limit on a 24-hour average, which takes effect in 2019, and a 145 ppm limit on a 30-day average, which takes effect in 2020. Commenters recognize that this represents a more aggressive standard when compared with Reasonably Available Control Technology ("RACT") standards currently in effect or proposed in other states. However, we note that New York State has recently announced that it is considering a 150 ppm limit on a 24-hour basis for its incinerators[11] and MDE acknowledged at the December 11, 2017 AQCAC meeting that Virginia is considering a 110 ppm 24-hour limit and a 90 ppm daily limit on an annual average for the two Covanta-operated incinerators located there.[12] In addition, all of these limits allow far greater emissions than the NOx limit required for new incinerators in Maryland, which is 45 ppm on a 24-hour basis.

Commenters believe that Wheelabrator can greatly reduce its NOx emissions and reduce the health burden of its pollution on Baltimoreans. MDE clearly has the legal authority to require additional reductions at this very large source of NOx emissions and it should exercise this authority to reduce the human health and environmental impacts of ozone levels that exceed federal standards. EPA has stated that "a state has discretion to require beyond-RACT reductions from any source, and has an obligation to demonstrate attainment as expeditiously as practicable. Thus, states may require [volatile organic compound ("VOC")] and NOX reductions that are 'beyond RACT' if such reductions are needed . . . to provide for timely attainment of the ozone NAAQS." [13]

[9] *See* Commenters' May 9, 2017 separate comment letters and October 6, 2017 joint comments.
[10] Bisnett, M. "NOx Optimization Project Wheelabrator Baltimore Inc." Fuel Tech Project 459S, June 5-9, 2017 (hereinafter "June 2017 Fuel Tech Study"), at p. 5. Attached hereto as Attachment B. The page numbers of this report, which ends at 22 of 31, would make the version of the report that we obtained appear incomplete. However, we have reviewed emails between MDE and Wheelabrator, received in response to a PIA request, that show that the version ending in page 22 is the complete version.
[11] New York State Department of Environmental Conservation letter to stakeholders, March 26, 2018. Attached hereto as Attachment C.
[12] MDE December 11, 2017 AQCAC meeting audio recording (26:12) at http://mdewin76.mde.state.md.us/MDEMeetings/ARMA_Audio_Files/AQCAC_12_11_17.MP4.
[13] EPA, Implementation of the 2008 National Ambient Air Quality Standards for Ozone: State Implementation Plan Requirements, 80 Fed. Reg. 12264, 12279 (March 6, 2015).

A. *Wheelabrator should be required to install the most effective pollution controls available for NOx.*

Dr. Sahu has concluded that he sees "no technical impediments to the implementation of the [most effective] NOx-reducing technologies, such as SCR (or hybrid SNCR/SCR), in the appropriate locations along the gas paths at each of the [Wheelabrator Baltimore] boilers."[14] Dr. Sahu has reviewed numerous materials relating to the Wheelabrator Baltimore incinerator,[15] including the reports for both optimization studies performed at the facility (one in 2016 and one in 2017), the 1-hour averaged NOx CEMS data collected at the three boilers during 2017,[16] and the Wheelabrator NOx RACT PowerPoint presentation made at the January 2017 stakeholder meeting.

Thus, any objection to using the most effective NOx pollution controls available at BRESCO appears to be solely financial. This is a particularly troubling position when taken by a company that, according to the Baltimore Sun, has been rewarded approximately $10 million over the past six years for being a renewable, and ostensibly green and environmentally friendly, source of energy in Maryland.[17] In the case of hybrid SNCR/SCR, the financial concerns are reduced as this technology is typically much less expensive than SCR. Commenters note that we have no record of Wheelabrator ever addressing our recommendation that it analyze the feasibility of using hybrid SNCR/SCR or Regenerative Selective Catalytic Reduction ("RSCR"), the technology that would have been installed on the proposed Energy Answers incinerator in Baltimore City and was touted in project materials as more cost-effective than SCR while achieving an 80% reduction efficiency.

As Dr. Sahu notes in his report, installation of SCR would likely allow Wheelabrator to achieve levels around 50 ppm on a 24-hour average at BRESCO, assuming roughly 75% NOx reduction efficiency, which he notes is a lenient target for this technology.[18] This would cut approximately 803 tons of NOx per year from the incinerator's 2016 annual emissions, reducing the annual number from 1141 tons to 338 tons.[19]

Commenters understand that it is possible that SCR or a similar technology (hybrid SCR/SNCR or RSCR) will be required because of the feasibility study required under the Nov. 2017 Draft Rule. However, we continue to feel strongly that a presumptive limit should be included in the rule requiring that BRESCO achieve SCR-level reductions of NOx and requiring a demonstration by Wheelabrator that it cannot meet this limit if the company wishes to avoid it.

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[14] May 2018 Sahu Report, p. 10.

[15] Expert Report on NOx Emissions from the Wheelabrator Baltimore Municipal Waste Incinerator in Baltimore City, owned and operated by Wheelabrator Baltimore, L.P. ("Wheelabrator") By Dr. Ranajit (Ron) Sahu, Consultant, May 5, 2017 (hereinafter "May 2017 Sahu Report"), p. 1., Attachment B to May 9, 2017 comments of CBF.

[16] May 2018 Sahu Report, p. 1.

[17] Dance, Scott, *Power struggle: How a trash incinerator – Baltimore's biggest polluter – became 'green' energy*, Baltimore Sun, Dec. 15, 2017, at http://www.baltimoresun.com/news/maryland/environment/bs-md-trash-incineration-20171107-story.html

[18] May 2018 Sahu Report, p. 10.

[19] Potential NOx emission reductions were calculated by applying the proportion of average 24-hour concentrations (50 ppm to 169 ppm in 2016) to the 2016 annual NOx emissions of 1141 tons, effectively calculating the emission rate assuming effluent stack flow and oxygen percentage remain constant.

B. *Wheelabrator can achieve NOx limits lower than those proposed simply by using its current pollution controls.*

In addition, Dr. Sahu concludes, based on his review of 2017 1-hour CEMS data and the 2017 Fuel Tech Report, that Wheelabrator can meet NOx limits lower than the 150 ppm and 145 ppm limits proposed using its existing control technology, solely through further optimization of those controls.[20] Specifically, Dr. Sahu states in his report that Wheelabrator can achieve a 24-hour limit of 135 ppm on a 24-hour basis and 130 ppm on a 30-day basis as demonstrated by the hourly CEMS data during the optimization tests and the failure to use more effective testing approaches during the optimization runs.[21] Adoption of a 135 ppm limit on a 24-hour basis would reduce 230 tons of NOx per year from the incinerator, using 2016 annual emissions as a baseline, reducing annual emissions to 911 tons.[22]

We understand that MDE is planning to formally publish a rule for public comment relatively soon. However, given Maryland's action against the U.S. EPA under Clean Air Act Section 126 seeking an order that requires coal plants in other states to run their controls more effectively, we do not understand why MDE is not requiring Wheelabrator to run its existing controls in the most effective way possible.[23] Requiring the most reduced emissions rate for this source category would be consistent with Maryland's statements in its Clean Air Act 126 and 176a Petitions.

C. *Wheelabrator has not maintained the same emissions reductions that it achieved during optimization testing in the following months.*

Even given Wheelabrator's failure to use approaches during optimization that would likely have reduced its NOx levels even further during those tests, CEMS data shows that Wheelabrator did not maintain the NOx reductions achieved during optimization in the following months.[24] This is likely because it had no legal incentive to do so as the limits in MDE's draft rule have not yet taken effect. Commenters find it troubling that Wheelabrator has not elected to voluntarily maintain the lower levels of NOx that it has shown it can achieve at the BRESCO incinerator, especially, as stated above, since it is treated as a source of environmentally friendly energy under the state's Renewable Portfolio Standard.

As described in Dr. Sahu's report and shown in the tables below - reproduced, using a slightly altered form, from Dr. Sahu's report - NOx emissions increased again at each unit following the optimization tests. For unit 2, Wheelabrator achieved an hourly average of 148.1 ppm during optimization testing and its NOx levels increased to an hourly average of 165.1 ppm after the optimization tests (though this was lower than pre-optimization average of 168.6 ppm). For unit 3, NOx levels of 144.9 ppm were achieved during testing but increased to 165.1 ppm in the following months. Again, however, this was lower than pre-optimization levels, which measured at 167.6 ppm. Finally, at unit 1, optimization testing achieved levels of 147.1 ppm and

[20] May 2018 Sahu Report, pp. 3-8

[21] *Id.* at 8.

[22] Potential NOx emissions reductions were calculated using the same methodology as described in note 19, *supra.*

[23] As stated above, Commenters could have raised this earlier in the stakeholder process had we received the 2017 Fuel Tech Report earlier and hourly CEMS data earlier.

[24] May 2018 Sahu Report, p. 9.

levels increased in the following months to 164.8 ppm, which was actually higher than pre-optimization levels of 158.1 ppm.

Unit 1

Time Period Relative to Optimization Test	Dates	NOx emissions in ppm (average hourly)
Before Optimization	January 1 - June 6, 2017	158.1
During Optimization	June 7, June 12-14, June 20-29, 2017	147.1
After Optimization	June 30 - December 31, 2017	164.8

Unit 2

Time Period Relative to Optimization Test	Dates	NOx emissions in ppm (average hourly)
Before Optimization	January 1 - June 7, 2017	168.6
During Optimization	June 8, June 12-14, June 20-29, 2017	148.1
After Optimization	June 30 - December 31, 2017	165.1

Unit 3

Time Period Relative to Optimization Test	Dates	NOx emissions in ppm (average hourly)
Before Optimization	January 1 - June 5, 2017	167.6
During Optimization	June 6, June 12-14, June 20-29, 2017	144.9
After Optimization	June 30 - December 31, 2017	165.1

II. MDE Should Revise the Feasibility Study Requirements of the Nov. 2017 Draft Rule.

Commenters also have concerns regarding the lack of specificity included within the feasibility study section of the Nov. 2017 Draft Rule (proposed COMAR 26.11.08.10E). As the future NOx limit will be contingent upon the required feasibility analysis, it is essential to include as much specificity as possible to ensure that a full range of alternatives and process parameters are explored within the study. This includes both specifying which technologies should be included within state of the art NOx control technologies at the minimum, as well as specifying details on existing facility operations that will serve as the basis of the study.

Below are the changes to Nov. 2017 Draft Rule that Commenters consider necessary regarding the feasibility study.[25] Commenters' edits show insertions in bold and deletions in strike-out.

[25] Commenters' edits also incorporate the revision that was formally recommended by AQCAC at its December 11, 2017 meeting. According to the final meeting minutes, that edit is as follows:

> Mr. Schoen read the proposed text that could be inserted into the regulation feasibility study requirements: "The feasibility analysis described in paragraph E included analysis of multiple controls and construction measures to achieve various levels of NOx emissions including levels comparable to those of a new source."

(a) *A written narrative and schematics detailing existing facility operations, boiler design, NO_x control technologies,* ***baseline NOx emission*** *performance,* ***temperature profiling and flow modeling, and gas sampling of the exhaust stream****;*

(b) *A written narrative and schematics detailing state of the art NO_x control technologies for achieving additional NO_x emission reductions from existing MWCs ~~in consideration of the current boiler configuration at Wheelabrator Baltimore, Inc.~~* ***including analysis of multiple controls and construction measures to achieve various levels of NOx emissions including levels comparable to those [required of][26] a new source. This analysis must include, at the minimum, selective catalytic reduction (SCR), hybrid selective non-catalytic reduction (SNCR/SCR), and combustion and injection optimization functionally equivalent to the Covanta Low-NO_x system.;***

(c) *A~~n~~* ***technical feasibility*** *analysis of whether each state of the art control technology identified under §E(1)(b) could be implemented at the Wheelabrator Baltimore Inc. facility;*

III. Commenters Consider It Critical that MDE Require Installation of Ammonia CEMS at BRESCO.

Lastly, Commenters have ongoing concerns regarding the apparent failure to monitor ammonia slip at the facility. As stated within the June 2017 Fuel Tech Study, "ammonia slip needs to be determined given its importance in determining the effectiveness of the SNCR process."[27] Ammonia slip is a key parameter to measure as an indicator of whether the urea is being released into the ideal temperature range and is given adequate residence time to react for SNCR systems. Although the facility does not currently have a concentration-based ammonia slip limit within its Title V/Part 70 permit, Wheelabrator has acknowledged that ammonia slip is a key design parameter for the facility to determine its ability to meet NOx emission limits without resulting in visible emissions.[28]

Commenters have seen no evidence that the facility has been routinely and continuously monitoring ammonia with CEMS or that MDE has received annual ammonia slip CEMS data from the facility. The 2017 hourly CEMS data made available by MDE pursuant to AQCAC's recommendation does not include ammonia slip, which strongly indicates that hourly ammonia slip data is not currently monitored and reported. Additionally, during the 2017 optimization study, Fuel Tech measured ammonia slip using a modified EPA wet extraction method taking samples prior to the spray dryer absorbers, indicating that existing data from process monitors or ammonia CEMS were not available as an option.[29] Commenters are also concerned about the

AQCAC 12/11/17 minutes, p. 5.

[26] The bracketed text is not included in the text edit as described in the AQCAC meeting minutes, but Commenters believe this addition it is critical and is consistent with the discussion among the AQCAC members, which included reference to a NOx limit that has been required for new large MWCs in Maryland under the Lowest Achievable Emissions Reduction (LAER) standard.

[27] June 2017 Fuel Tech Study, p. 5.

[28] Wheelabrator Technologies PowerPoint, Wheelabrator Baltimore NOx RACT Review January 17, 2017, pp. 5-7, at http://mde.maryland.gov/programs/Regulations/air/Documents/SHMeetings/MunicipalWasteCombustors/MWCWheelabratorNOxRACTPresentation.pdf

[29] June 2017 Fuel Tech Study, p. 5.

absence of a limit for ammonia slip in the Nov. 2017 Draft Rule, especially as Connecticut includes such a limit in its incinerator NOx RACT regulations. EIP also provided examples in its May 9, 2017 comments of similar Wheelabrator incinerators in other states that are subject to a NOx limit of 150 ppm on a 24-hour basis and an ammonia slip limit of 20 ppm.

Ammonia slip measurement is critical for ongoing optimization, for the feasibility study of alternatives, and is an essential part of maintaining efficient operations in the future if any combination of SNCR or SCR is chosen as the control technology. Given its importance in monitoring the success of control technology, there appears to be no reason for MDE not to require use of ammonia CEMS at the incinerator and no reason for not requiring an ammonia slip limit. MDE should revise the Nov. 2017 Draft Rule to include an ammonia slip limit of no higher than 20 ppm and should require that ammonia CEMS be installed to monitor ammonia slip, as also discussed in EIP and CBF's October 6, 2017 comments, EIP's May 9, 2017 comments, and the May 2017 Sahu Report.

Thank you for considering our comments.

Sincerely,

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ATTACHMENT A

EXPERT REPORT

On

NOx Emissions from the Wheelabrator Baltimore Municipal Waste Incinerator in Baltimore City, owned and operated by Wheelabrator Baltimore, L.P. ("Wheelabrator")

by

Dr. Ranajit (Ron) Sahu, Consultant[1]

May 10, 2018

Introduction

In November of 2017, the Maryland Department of the Environment (MDE) shared with public stakeholders a draft regulation, dated November 17, 2017, that would revise Maryland's standards limiting emissions of nitrogen oxides (NOx) from large municipal waste combustors. The proposed revisions are to Title 26 Department of the Environment, Subtitle 11 Air Quality, Chapter 08 Control of Incinerators of COMAR. There are two large municipal waste combustors in Maryland, the larger being the Wheelabrator facility in Baltimore City.

I was asked to review certain materials relating to the Wheelabrator Baltimore municipal waste combustor and to give my opinion on what is achievable in terms of NOx reduction at this facility. Specifically, I reviewed the following materials in the preparation of this report: (1) the 2017 Fuel Tech Report on optimization of the existing controls at the facility; (2) the 2016 Quinapoxet Report; on optimization of the existing controls at the facility; (3) 1-hour averaged NOx CEMS data collected at the three boilers at the Wheelabrator facility for the calendar year 2017; [2] and (4) the November 2017 draft regulation circulated by MDE. As discussed in more detail below, I have previously commented on an optimization study performed in 2016 (the Quinapoxet Study).

My observations and conclusions based on this review are set forth below.

[1] Resume provided in Attachment A.

[2] In early 2018, MDE began making hourly CEMS data from the Wheelabrator facility available to the public online. The data that I reviewed is available under Special Studies, Wheelabrator Annual CEM Data Reports, Data, at the following link: http://mde.maryland.gov/programs/Air/Pages/ARAResearch.aspx.

<u>NOx Reasonably Achievable Control Technology (RACT) for the Wheelabrator Baltimore Facility</u>

Wheelabrator operates a municipal waste combustion facility in Baltimore. As noted in its application for its Title V permit application, submitted in 2006:

> "The facility is a municipal solid waste resource recovery facility (SIC Code 4953). It consists of three municipal waste combustors that generate steam…."

Each of these three combustors (hereafter "boilers" or "Units") and noted as Boiler 1 (Unit 1), Boiler 2 (Unit 2), and Boiler 3 (Unit 3), respectively – are identical as described by Wheelabrator in its 2006 application:

> "…750 ton per day Wheelabrator-Frye mass burn waterwall municipal waste combustor equipped with SNCR, SDA, ESP and activated carbon injection systems. Combustion gases are exhausted through a stack…that contains three flues (one for each of the three combustors)…."

In its November 2017 proposed regulation for the Wheelabrator facility, MDE effectively proposed a NOx RACT level with specified numerical limits (as noted below) followed by a potential future lower NOx limit– the latter to be developed based on the results of a feasibility study to be submitted by Wheelabrator to MDE in 2020. The November 2017 proposed regulation requires that the analysis will be prepared by an independent third party.

The proposed NOx RACT for Wheelabrator set forth in the November 2017 rule is:

A. a 24-hour block average emission rate[3] of 150 parts per million (ppmv);

   and

B. a 145 ppmv rate over a 30-day period – both corrected to 7% oxygen.[4]

Per the proposed RACT, the 150 ppmv level is to be achieved by 2019 and the 145 ppmv level is to be achieved by 2020. The November 17, 2017 draft regulation also includes section E, "Additional NOx Emission Control Requirements," which states that "(1) Not

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[3] The use of the term, "emission rate" to describe the proposed RACT level, is, in my opinion, inaccurate. Typically emission rate denotes the mass emissions of a pollutant (i.e., in pounds, grams, tons, etc.) either per unit time (i.e., gram/second, pound/hour, ton/year, etc.) or per unit of process input (i.e., lb/million Btu of heat input, lb/ton of waste burned), or per unit of process output (i.e., lb/pound of steam generated), etc. The proposed NOx RACT levels – i.e., parts per million in the exhast gases, corrected to 7% oxygen, are, more properly, concentrations, not emission rates.

[4] In all instances in this Declarations, it should be assumed that NOx levels discussed are always corrected to the 7% oxygen basis, whether explicitly stated or otherwise.

later than January 1, 2020, the owner or operator of Wheelabrator Baltimore, Inc. shall submit a feasibility analysis for additional control of NOx emissions from the Wheelabrator Baltimore Inc. facility to the Department."

Optimizing SNCR at the Wheelabrator, Baltimore Facility

Briefly, in SNCR, a NOx-reducing reagent, such as ammonia or urea is injected into the exhaust gases from a boiler, within a specified gas temperature range (typically when the gas temperature is between 1800-2100 F). At Wheelabrator, urea is injected as liquid droplets using a number of injectors, all located in a single plane at each boiler. Urea converts to ammonia and some ammonia leaves the system. The ammonia that leaves the system is considered unreacted ammonia and is known as the "ammonia slip." The goal of SNCR is to reduce NOx while keeping ammonia slip to a low level. Details of the existing SNCR system at Wheelabrator are provided in the 2017 Fuel Tech Report which is discussed and quoted from extensively later in this document.

I am aware of at least two attempts at "optimizing" the performance of the existing SNCR systems at Wheelabrator since 2016. From February to March of 2016, Wheelabrator conducted an optimization study[5] ("Quinapoxet Study"). I have previously commented on the significant technical shortcomings of this study.[6] Nonetheless, and in spite of these shortcomings, this study showed that certain, modest NOx reductions were possible with additional urea flow and modification of SNCR configuration. More recently, Fuel Tech completed a 4 -day optimization study in early June 2017,[7] which was followed by additional optimization testing of all 3 boilers from June 12-14, 2017 and June 20-29, 2017.[8] I discuss the findings of this work in the next section.

Findings in the 2017 Fuel Tech Report

I note first that Fuel Tech was charged with optimizing the current SNCR controls at each boiler to achieve NOx levels below 150 ppm

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[5] Final Report NOx Control System Optimization at the Wheelabrator Baltimore WTE Facility, Quinapoxet Solutions, (undated, 2016), Quinapoxet Solutions.

[6] My comments on this optimization study are set forth in the Expert Report on NOx Emissions from the Wheelabrator Baltimore Municipal Waste Incinerator in Baltimore City, owned and operated by Wheelabrator Baltimore, L.P. ("Wheelabrator") by Dr. Ranajit (Ron) Sahu, Consultant, May 5, 2017.

[7] Bisnett, Michael, Fuel Tech, NOx Optimization Project Wheelabrator Baltimore Inc., Baltimore, Maryland Units 1,2 & 3, June 5-9. 2017 ("2017 Fuel Tech Report"). I received an incomplete pdf copy of the report with 24 pdf pages. The last page of the report (before two non-numbered pages containing emails) is noted as "Page 22 of 31."

[8] The data for the June 12-14 and 20-29 days was submitted to MDE separately from the Fuel Tech Report.

> "Fuel Tech Inc. (FTI) was contracted by Wheelabrator to conduct SNCR system optimization testing at their Waste to Energy (WTE) facility located in Baltimore, Maryland. The objective was to obtain provide further optimization of the SNCR system to reduce NOx levels below 150 ppmdc (corrected to 7%02) while minimizing ammonia slip…"[9]

Briefly, Fuel Tech described the optimization details as follows:

> "For this optimization program, additional changes were made to the existing SNCR equipment to allow for more flexibility for enhancing NOx removal. These changes primarily included installation of new NOx injector tips with 30 deg up angle cone spray and use of alternate rear furnace wall injector ports. The use of the additional rear wall injector ports and modified injector tips enhanced the coverage of the injectors allowed for more flexibility to optimize the SNCR system to control NOx below the 150 ppmdc (corrected to 7% 02) target while simultaneously maintaining low ammonia slip levels."[10]

Admittedly, the Fuel Tech optimization work was of short duration, mainly indicating (and proving, as I show later) that lower than 150 ppm NOx levels can be achieved, even on a short-term, i.e., hourly basis at each boiler. Thus, it was a proof-of-concept study.

As far as baseline NOx levels during the 2017 Fuel Tech study, Fuel Tech notes the following:

> "Baseline NOx values on all 3 units were close to previous optimization testing levels of around 200+ ppmdc. Overall the during this testing period the baseline varied in the range of 190 to 220 ppmdc It appeared that earlier in the day the baseline was lower and increased during the day. The plant confirmed that the NOx would increase at times and but the mechanism or its consistency was not understood."[11]

The allusion to "previous optimization testing" is not entirely clear. It could be referencing the 2016 Quinapoxet Study, which did observe baseline levels around 200 ppm. I note that after years of experience with its boilers, it is troubling that Wheelabrator still does not have a reasonable understanding of the NOx levels from its boilers, as evidenced by Fuel Tech's comment in the last sentence above.

Fuel Tech reports the results of its optimization work at Unit 3 (the first unit at which the work was done on June 6, 2017), as follows:

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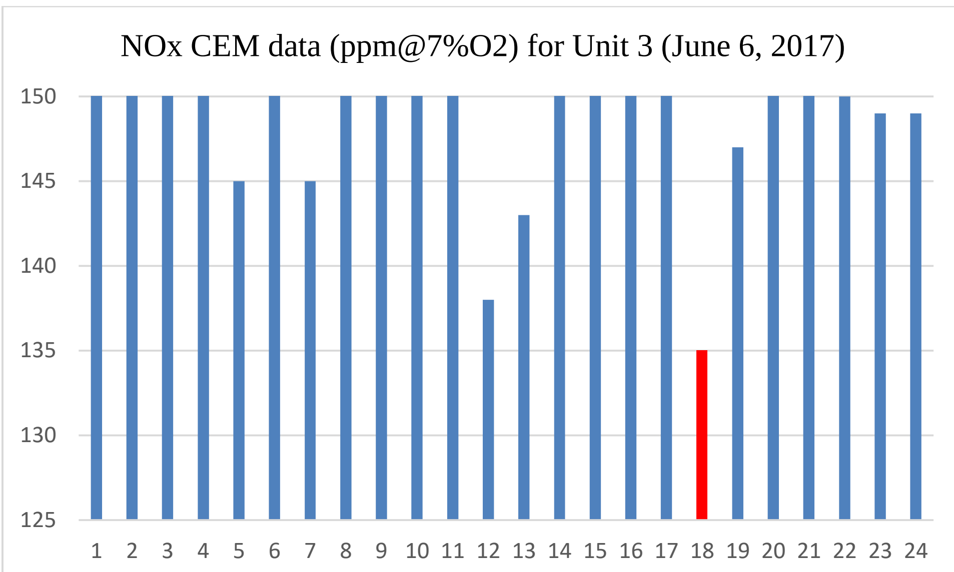
[9] 2017 Fuel Tech Report, p. 3.

[10] 2017 Fuel Tech Report, p. 3.

[11] 2017 Fuel Tech Report, p. 6.

"The results were very good. Using the same urea dosage of 15 gph, with an NSR of 1.14, the NOx reduction increased from 37.5 to 42.7%, utilization increased from 32.9% to 37.4% and the NOx dropped to 130 ppmdc. Individual injector water flow was 1.33 gpm at an air pressure of 40 psig. The measured ammonia slip increased slightly to 3.3 ppm from 1.1 ppm and stack observation indicated there was no visible plume. Making the change to the angled up tips showed that releasing the urea higher in the furnace with the right injector configuration was very beneficial….The initial Unit 3 optimization results were very positive and predictable and, as such, were used as the starting point for further optimization of the other 2 units."[12]

Shown below are the hourly NOx data for Unit 3 from the CEMS for June 6, 2017. It confirms that levels as low as 135 ppm[13] on an hourly basis, were obtained at Unit 3 during the optimization.



At Unit 1, the next Unit subjected to optimization, on June 7, 2017, Fuel Tech describes the results as follows:

"A baseline NOx value was obtained prior to the first test. For the 1st test NOx was kept close to 140 ppmdc with 15 gph of urea and a measured slip of 1.7 ppm (internal citation omitted) and utilization rate of 36.5%. This proved that the final configuration from Unit 3 carried over successfully to Unit 1 as SNCR performance was very good. (internal

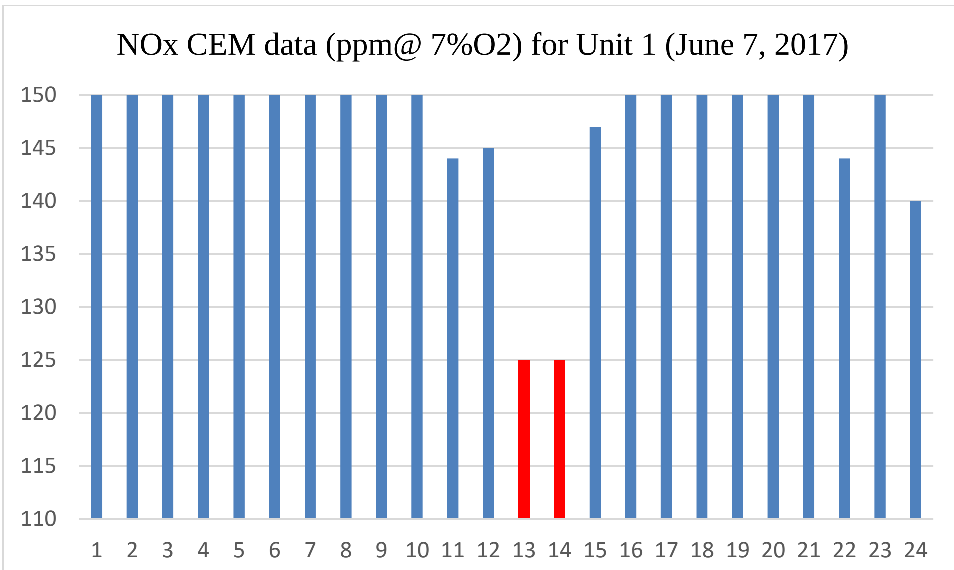
[12] 2017 Fuel Tech Report, p. 11-12.

[13] I do note that, while the Fuel Tech Report shows a NOx level as low as 130 ppm, the CEMS data for that day do not show that level. This discrepancy may simply be due to the different instruments used to measure the NOx levels (i.e., Fuel Tech's instrument and the CEM).

citation omitted). Given the successful duplication of results on Unit 1, further optimization was done to this configuration to evaluate the impact on SNCR performance….

Increasing the urea dosage (internal citation omitted) from 15 to 20 gph was done to determine if there is a point where increasing the urea dosage will not lead to a reasonable increase in the NOx reduction with the 6 injector configuration and essentially determining a point of diminishing returns. Increasing to 20 gph of urea reduced NOx to 130 ppmdc but the utilization dropped from 34.7 to 32.9% while ammonia slip increased slightly from 1.7 to 2.7 ppm evidence that urea rates above 20 gph, ammonia slip would increase very quickly."[14]

Shown below are the hourly NOx levels measured by the CEM on Unit 1. It confirms that levels as low as 125 ppm were obtained during the optimization.[15]



Finally, for Unit 2, the last unit optimized by Fuel Tech on June 8, 2017, Fuel Tech describes the result as follows:

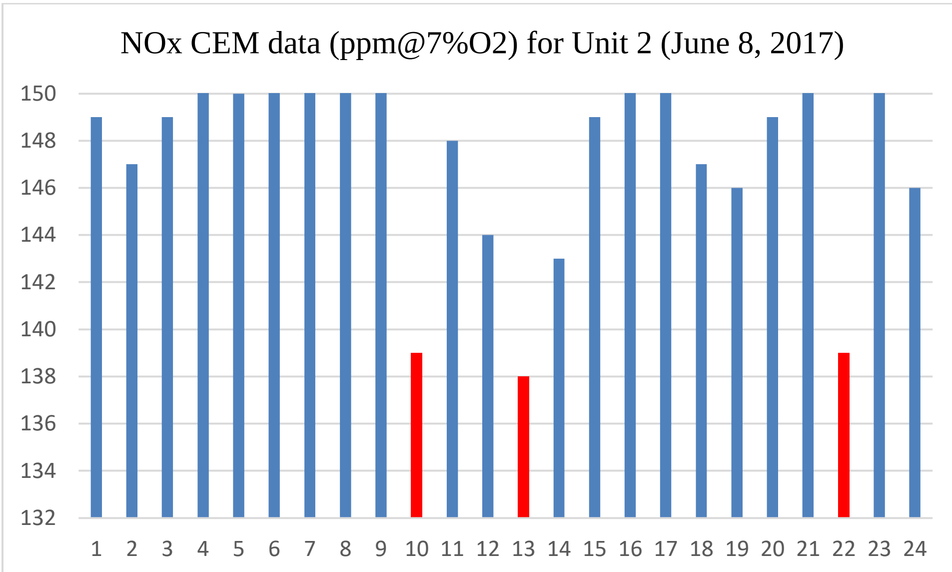
"Starting up the SNCR system for the first set of tests went without incident and the NOx was reduced to 140 ppmdc. (Figure 17) This was achieved with 4 injectors at 1 gpm water flow, 15 gph urea flow, and 40 psig air pressure. NOx levels were about 140 ppmdc and ammonia slip

[14] 2017 Fuel Tech Report, p. 14.

[15] As in the case of Unit 3, there appears to be a slight discrepancy between the NOx levels discussed in the Fuel Tech Report and the NOx CEM. For Unit 2, the CEM showed a value of 125 ppm, while the Fuel Tech Report notes 130 ppm.

> was 2.9 ppm….Increasing the urea from 15 to 20 gph reduced NOx to about 135 ppmdc but the slip increases to 3.9 ppm."[16]

Similar to the data presented above for the other two units, I show below the NOx CEM data for Unit 2 for June 8, 2017. This data shows levels lower than 140 ppm with a low of 138 ppm.



Summarizing its results and relating it to the objective of the study, Fuel Tech stated:

> "The results of FTI's short term SNCR optimization testing indicated that use of 30 deg up angled injector tips and injector total liquid flow of 1 gpm provided additional capability for SNCR systems to achieve and maintain NOx emission level of 150 ppmdc with minimal ammonia slip."[17]

Thus, it is clear that, a level of 150 ppm NOx can be achieved today, at each unit at Wheelabrator. In fact, as shown above, hourly levels in the 125-140 range were achievable at each unit during mid-2017.

The proposed RACT limits for Wheelabrator include averaging times longer than hourly – i.e, 150 ppm using a block average of 24 hours and 145 ppm using a 30 day average. The longer the averaging time, the more the ability to smooth out variations. Given these proposed averaging times, and reviewing the results of the 2017 Fuel Tech optimization work, it is my opinion that the proposed RACT levels can be lowered – likely from 150

[16] 2017 Fuel Tech Report, p. 18.

[17] 2017 Fuel Tech Report, p. 21.

down to a level closer to 135 ppm for the 24 hour block average and from 145 down to a level of 130 ppm for the 30-day averaging period.

As the optimization testing discussed in the 2017 Fuel Tech Report was of limited duration, it is my opinion that longer term testing performed using a more methodical approach would likely have shown the Wheelabrator facility's ability to achieve the 130-135 ppm levels discussed above on a more consistent basis is possible right now. These tests would likely have shown the facility's ability to achieve lower NOx levels on a longer term and more consistent basis if Wheelabrator had continued the adjustments made by Fuel Tech in June 2017 at each of its boilers with the express goal of achieving 130/135 ppm levels.

In addition, Wheelabrator should also have monitored and run all necessary feedback loops involving local NOx concentrations near the SNCR injection points, gas temperature in the SNCR injection plane, and ammonia slip. While Fuel Tech tested and showed the ability for automatic SNCR control to meet the 150 ppm setpoint, lower setpoints were not tested to explore the limits of the system. The use of automatic feedback controls at lower NOx setpoints should allow the SNCR system to consistently meet the lower 130/135 ppm levels on a longer term basis.

Wheelabrator should also have continued to optimize injector configurations and parameters as needed to achieve, maintain, and further reduce NOx at each of the boilers along the lines of the adjustments described in the conclusion of the 2017 Fuel Tech Report. Additional SNCR adjustments mentioned include using additional injectors, increasing total liquid flow to injectors, and changing the atomizing air pressure. The Fuel Tech test results indicate that even further NOx reduction may be possible, as the choice to decrease total liquid flow through each injector led to sub-optimal results in terms of NOx concentration, NOx reduction percentage and utilization percentage. Urea flow was also constrained to 20 gph, limiting the amount of information available on additional reduction and corresponding ammonia slip.

Importantly, it is clear to me that a limit of 135 ppm on a 24-hour basis and 130 ppm on a 30-day basis can be achieved <u>now</u> (and that more methodical optimization testing would have shown this to be the case) as opposed to the future dates in MDE's proposed RACT – i.e., 2020 for the 145 ppm 30-day average and 2019 for the 150 ppm 24-hour block average.

Performance Levels After the 2017 Fuel Tech Study

I reviewed the 2017 hourly CEM NOx data for each unit to ascertain if Wheelabrator had attempted to conduct a long-term assessment of the optimization work, as recommended by Fuel Tech.[18] Emails and data submitted to MDE by Wheelabrator show that Wheelabrator conducted longer-term testing from June 12- 14, 2017 and June 20-29, 2017. However, this is still a relatively brief time period for such testing and my review of the hourly data shows that the reductions achieved during the optimization periods were not sustained afterward. Also, the June 12-14, 2017 and June 20-29, 2017 data did not include additional important parameters such as ammonia slip, etc. which were discussed in the Fuel Tech Report covering the June 6-8, 2017 tests.

Shown below are the NOx levels, for each Unit:

- on the days of the optimization tests for that unit, including the initial testing date for each boiler and the subsequent dates (June 12-14 and 20-29, during which all boilers were tested);
- after the optimization tests (i.e., from June 30, 2017, the date on which all of optimization testing ended, until December 31, 2017, after the last day for which CEM data was available); and
- before the optimization testing (i.e., from January 1, 2017, till the day prior to the first optimization day for the respective unit).

Unit 1 Average Hourly NOx (June 7, June 12-14, June 20-29, 2017), ppm	147.1
Unit 1 Average Hourly NOx (June 30 - December 31, 2017), ppm	164.8
Unit 1 Average Hourly NOx (January 1 - June 6, 2017), ppm	158.1

Unit 2 Average Hourly NOx (June 8, June 12-14, June 20-29, 2017), ppm	148.1
Unit 2 Average Hourly NOx (June 30 - December 31, 2017), ppm	165.1
Unit 2 Average Hourly NOx (January 1 - June 7, 2017), ppm	168.6

Unit 3 Average Hourly NOx (June 6, June 12-14, June 20-29, 2017), ppm	144.9
Unit 3 Average Hourly NOx (June 30 - December 31, 2017), ppm	165.1
Unit 3 Average Hourly NOx (January 1 - June 5, 2017), ppm	167.6

It is clear, from Wheelabrator's own CEM data presented above that the lower NOx levels achieved during the optimization were not sustained after the optimization dates at each unit. Arguably, for Unit 1, post-optimization average NOx (164.8 ppm) was worse than the pre-optimization level (158.1 ppm), which was higher than the 147.1 ppm for the optimization dates. For Unit 2, while the post-optimization level (165.1 ppm) was a little lower than the pre-optimization level (168.6 ppm), it was considerably higher than the 148.1 ppm for the optimization periods. Similarly, for Unit 3, the post-optimization level of 165.1 ppm was slightly lower than the pre-optimization level of 167.6, but much higher than the level for the optimization (144.9 ppm) periods.

It is clear that Wheelabrator did not continue to sustain the lower levels achieved during the 2017 Fuel Tech optimization study.

Conclusions

Based on my review of prior optimization work on its current SNCR systems including the 2017 Fuel Tech study and my analysis of the 2017 hourly NOx CEMS data for each Unit, I reach the following conclusions:

A. that each of the three units at the Wheelabrator facility can reasonably achieve hourly NOx levels of 150 ppm today, if the existing SNCR systems at each Unit, as modified per the suggestions and descriptions in the 2017 Fuel Tech Report, were properly implemented and operated;

B. that, therefore, 24-hour and 30-day averaged NOx levels of less than 150 ppm should also be achievable today. It is my opinion, based on the data that a 24-hour block level of 135 ppm should be achievable today and that a 30-day average level of 130 ppm should be achievable today at each Unit using optimized, existing SNCR;

C. that, based on the observed NOx levels reported by Wheelabrator post-optimization via the NOx CEM at each Unit, it appears that Wheelabrator did not continue with the optimization of the existing SNCR systems as discussed in the 2017 Fuel Tech Report beyond June 29, 2017. This is consistent with there being no regulatory driver or requirement for Wheelabrator to do so;

D. that Wheelabrator should electronically report not just the hourly NOx (and SO2 and CO) hourly CEMS data are it is currently doing, but also the additional parameters that are listed in the Tables on Page 22 of the 2017 Fuel Tech Report; and, finally

E. notwithstanding all of the above pertaining to the interim NOx levels that can be obtained via the proper and optimized operation of the existing SNCR systems to meet the proposed RACT – it is my opinion, based on my understanding of the boilers at the facility, that I see no technical impediments to the implementation of the even-more NOx reducing technologies, such as SCR (or hybrid SNCR/SCR), in the appropriate locations along the gas paths at each of the boilers. SCR would provide significantly better NOx levels (around 50 ppm, assuming roughly 75% SCR NOx reduction efficiency, a lenient target), than compared to optimized SNCR at 130-135 ppm as noted above.

ATTACHMENT A

RANAJIT (RON) SAHU, Ph.D, QEP, CEM (Nevada)

CONSULTANT, ENVIRONMENTAL AND ENERGY ISSUES

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EXPERIENCE SUMMARY

Dr. Sahu has over twenty eight years of experience in the fields of environmental, mechanical, and chemical engineering including: program and project management services; design and specification of pollution control equipment for a wide range of emissions sources including stationary and mobile sources; soils and groundwater remediation including landfills as remedy; combustion engineering evaluations; energy studies; multimedia environmental regulatory compliance (involving statutes and regulations such as the Federal CAA and its Amendments, Clean Water Act, TSCA, RCRA, CERCLA, SARA, OSHA, NEPA as well as various related state statutes); transportation air quality impact analysis; multimedia compliance audits; multimedia permitting (including air quality NSR/PSD permitting, Title V permitting, NPDES permitting for industrial and storm water discharges, RCRA permitting, etc.), multimedia/multi-pathway human health risk assessments for toxics; air dispersion modeling; and regulatory strategy development and support including negotiation of consent agreements and orders.

He has over twenty five years of project management experience and has successfully managed and executed numerous projects in this time period. This includes basic and applied research projects, design projects, regulatory compliance projects, permitting projects, energy studies, risk assessment projects, and projects involving the communication of environmental data and information to the public.

He has provided consulting services to numerous private sector, public sector and public interest group clients. His major clients over the past twenty five years include various trade associations as well as individual companies such as steel mills, petroleum refineries, cement manufacturers, aerospace companies, power generation facilities, lawn and garden equipment manufacturers, spa manufacturers, chemical distribution facilities, and various entities in the public sector including EPA, the US Dept. of Justice, several states, various agencies such as the California DTSC, various municipalities, etc.). Dr. Sahu has performed projects in all 50 states, numerous local jurisdictions and internationally.

In addition to consulting, Dr. Sahu has taught numerous courses in several Southern California universities including UCLA (air pollution), UC Riverside (air pollution, process hazard analysis), and Loyola Marymount University (air pollution, risk assessment, hazardous waste management) for the past seventeen years. In this time period he has also taught at Caltech, his alma mater (various engineering courses), at the University of Southern California (air pollution controls) and at California State University, Fullerton (transportation and air quality).

Dr. Sahu has and continues to provide expert witness services in a number of environmental areas discussed above in both state and Federal courts as well as before administrative bodies (please see Annex A).

EXPERIENCE RECORD

2000-present	**Independent Consultant.** Providing a variety of private sector (industrial companies, land development companies, law firms, etc.) public sector (such as the US Department of Justice) and public interest group clients with project management, air quality consulting, waste remediation and management consulting, as well as regulatory and engineering support consulting services.
1995-2000	Parsons ES, **Associate, Senior Project Manager and Department Manager for** Air Quality/Geosciences/Hazardous Waste Groups, Pasadena. Responsible for the management of a group of approximately 24 air quality and environmental professionals, 15 geoscience, and 10 hazardous waste professionals providing full-service consulting, project management, regulatory compliance and A/E design assistance in all areas.
	Parsons ES, **Manager for Air Source Testing Services**. Responsible for the management of 8 individuals in the area of air source testing and air regulatory permitting projects located in Bakersfield, California.
1992-1995	Engineering-Science, Inc. **Principal Engineer and Senior Project Manager** in the air quality department. Responsibilities included multimedia regulatory compliance and permitting (including hazardous and nuclear materials), air pollution engineering (emissions from stationary and mobile sources, control of criteria and air toxics, dispersion modeling, risk assessment, visibility analysis, odor analysis), supervisory functions and project management.
1990-1992	Engineering-Science, Inc. **Principal Engineer and Project Manager** in the air quality department. Responsibilities included permitting, tracking regulatory issues, technical analysis, and supervisory functions on numerous air, water, and hazardous waste projects. Responsibilities also include client and agency interfacing, project cost and schedule control, and reporting to internal and external upper management regarding project status.
1989-1990	Kinetics Technology International, Corp. **Development Engineer.** Involved in thermal engineering R&D and project work related to low-NOx ceramic radiant burners, fired heater NOx reduction, SCR design, and fired heater retrofitting.
1988-1989	Heat Transfer Research, Inc. **Research Engineer**. Involved in the design of fired heaters, heat exchangers, air coolers, and other non-fired equipment. Also did research in the area of heat exchanger tube vibrations.

EDUCATION

1984-1988	Ph.D., Mechanical Engineering, California Institute of Technology (Caltech), Pasadena, CA.
1984	M. S., Mechanical Engineering, Caltech, Pasadena, CA.
1978-1983	B. Tech (Honors), Mechanical Engineering, Indian Institute of Technology (IIT) Kharagpur, India

TEACHING EXPERIENCE

Caltech

"Thermodynamics," Teaching Assistant, California Institute of Technology, 1983, 1987.

"Air Pollution Control," Teaching Assistant, California Institute of Technology, 1985.

"Caltech Secondary and High School Saturday Program," - taught various mathematics (algebra through calculus) and science (physics and chemistry) courses to high school students, 1983-1989.

"Heat Transfer," - taught this course in the Fall and Winter terms of 1994-1995 in the Division of Engineering and Applied Science.

“Thermodynamics and Heat Transfer,” Fall and Winter Terms of 1996-1997.

U.C. Riverside, Extension

"Toxic and Hazardous Air Contaminants," University of California Extension Program, Riverside, California. Various years since 1992.

"Prevention and Management of Accidental Air Emissions," University of California Extension Program, Riverside, California. Various years since 1992.

"Air Pollution Control Systems and Strategies," University of California Extension Program, Riverside, California, Summer 1992-93, Summer 1993-1994.

"Air Pollution Calculations," University of California Extension Program, Riverside, California, Fall 1993-94, Winter 1993-94, Fall 1994-95.

"Process Safety Management," University of California Extension Program, Riverside, California. Various years since 1992-2010.

"Process Safety Management," University of California Extension Program, Riverside, California, at SCAQMD, Spring 1993-94.

"Advanced Hazard Analysis - A Special Course for LEPCs," University of California Extension Program, Riverside, California, taught at San Diego, California, Spring 1993-1994.

“Advanced Hazardous Waste Management” University of California Extension Program, Riverside, California. 2005.

Loyola Marymount University

"Fundamentals of Air Pollution - Regulations, Controls and Engineering," Loyola Marymount University, Dept. of Civil Engineering. Various years since 1993.

"Air Pollution Control," Loyola Marymount University, Dept. of Civil Engineering, Fall 1994.

“Environmental Risk Assessment,” Loyola Marymount University, Dept. of Civil Engineering. Various years since 1998.

“Hazardous Waste Remediation” Loyola Marymount University, Dept. of Civil Engineering. Various years since 2006.

University of Southern California

"Air Pollution Controls," University of Southern California, Dept. of Civil Engineering, Fall 1993, Fall 1994.

"Air Pollution Fundamentals," University of Southern California, Dept. of Civil Engineering, Winter 1994.

University of California, Los Angeles

"Air Pollution Fundamentals," University of California, Los Angeles, Dept. of Civil and Environmental Engineering, Spring 1994, Spring 1999, Spring 2000, Spring 2003, Spring 2006, Spring 2007, Spring 2008, Spring 2009.

International Programs

“Environmental Planning and Management,” 5 week program for visiting Chinese delegation, 1994.

“Environmental Planning and Management,” 1 day program for visiting Russian delegation, 1995.

“Air Pollution Planning and Management,” IEP, UCR, Spring 1996.

"Environmental Issues and Air Pollution," IEP, UCR, October 1996.

PROFESSIONAL AFFILIATIONS AND HONORS

President of India Gold Medal, IIT Kharagpur, India, 1983.

Member of the Alternatives Assessment Committee of the Grand Canyon Visibility Transport Commission, established by the Clean Air Act Amendments of 1990, 1992-present.

American Society of Mechanical Engineers: Los Angeles Section Executive Committee, Heat Transfer Division, and Fuels and Combustion Technology Division, 1987-present.

Air and Waste Management Association, West Coast Section, 1989-present.

PROFESSIONAL CERTIFICATIONS

EIT, California (#XE088305), 1993.

REA I, California (#07438), 2000.

Certified Permitting Professional, South Coast AQMD (#C8320), since 1993.

QEP, Institute of Professional Environmental Practice, since 2000.

CEM, State of Nevada (#EM-1699). Expiration 10/07/2017.

PUBLICATIONS (PARTIAL LIST)

"Physical Properties and Oxidation Rates of Chars from Bituminous Coals," with Y.A. Levendis, R.C. Flagan and G.R. Gavalas, *Fuel*, **67**, 275-283 (1988).

"Char Combustion: Measurement and Analysis of Particle Temperature Histories," with R.C. Flagan, G.R. Gavalas and P.S. Northrop, *Comb. Sci. Tech.* **60**, 215-230 (1988).

"On the Combustion of Bituminous Coal Chars," PhD Thesis, California Institute of Technology (1988).

"Optical Pyrometry: A Powerful Tool for Coal Combustion Diagnostics," *J. Coal Quality*, **8**, 17-22 (1989).

"Post-Ignition Transients in the Combustion of Single Char Particles," with Y.A. Levendis, R.C. Flagan and G.R. Gavalas, *Fuel*, **68**, 849-855 (1989).

"A Model for Single Particle Combustion of Bituminous Coal Char." Proc. ASME National Heat Transfer Conference, Philadelphia, **HTD-Vol. 106**, 505-513 (1989).

"Discrete Simulation of Cenospheric Coal-Char Combustion," with R.C. Flagan and G.R. Gavalas, *Combust. Flame*, **77**, 337-346 (1989).

"Particle Measurements in Coal Combustion," with R.C. Flagan, in "**Combustion Measurements**" (ed. N. Chigier), Hemisphere Publishing Corp. (1991).

"Cross Linking in Pore Structures and Its Effect on Reactivity," with G.R. Gavalas in preparation.

"Natural Frequencies and Mode Shapes of Straight Tubes," Proprietary Report for Heat Transfer Research Institute, Alhambra, CA (1990).

"Optimal Tube Layouts for Kamui SL-Series Exchangers," with K. Ishihara, Proprietary Report for Kamui Company Limited, Tokyo, Japan (1990).

"HTRI Process Heater Conceptual Design," Proprietary Report for Heat Transfer Research Institute, Alhambra, CA (1990).

"Asymptotic Theory of Transonic Wind Tunnel Wall Interference," with N.D. Malmuth and others, Arnold Engineering Development Center, Air Force Systems Command, USAF (1990).

"Gas Radiation in a Fired Heater Convection Section," Proprietary Report for Heat Transfer Research Institute, College Station, TX (1990).

"Heat Transfer and Pressure Drop in NTIW Heat Exchangers," Proprietary Report for Heat Transfer Research Institute, College Station, TX (1991).

"NOx Control and Thermal Design," Thermal Engineering Tech Briefs, (1994).

"From Purchase of Landmark Environmental Insurance to Remediation: Case Study in Henderson, Nevada," with Robin E. Bain and Jill Quillin, presented at the AQMA Annual Meeting, Florida, 2001.

"The Jones Act Contribution to Global Warming, Acid Rain and Toxic Air Contaminants," with Charles W. Botsford, presented at the AQMA Annual Meeting, Florida, 2001.

PRESENTATIONS (PARTIAL LIST)

"Pore Structure and Combustion Kinetics - Interpretation of Single Particle Temperature-Time Histories," with P.S. Northrop, R.C. Flagan and G.R. Gavalas, presented at the AIChE Annual Meeting, New York (1987).

"Measurement of Temperature-Time Histories of Burning Single Coal Char Particles," with R.C. Flagan, presented at the American Flame Research Committee Fall International Symposium, Pittsburgh, (1988).

"Physical Characterization of a Cenospheric Coal Char Burned at High Temperatures," with R.C. Flagan and G.R. Gavalas, presented at the Fall Meeting of the Western States Section of the Combustion Institute, Laguna Beach, California (1988).

"Control of Nitrogen Oxide Emissions in Gas Fired Heaters - The Retrofit Experience," with G. P. Croce and R. Patel, presented at the International Conference on Environmental Control of Combustion Processes (Jointly sponsored by the American Flame Research Committee and the Japan Flame Research Committee), Honolulu, Hawaii (1991).

"Air Toxics - Past, Present and the Future," presented at the Joint AIChE/AAEE Breakfast Meeting at the AIChE 1991 Annual Meeting, Los Angeles, California, November 17-22 (1991).

"Air Toxics Emissions and Risk Impacts from Automobiles Using Reformulated Gasolines," presented at the Third Annual Current Issues in Air Toxics Conference, Sacramento, California, November 9-10 (1992).

"Air Toxics from Mobile Sources," presented at the Environmental Health Sciences (ESE) Seminar Series, UCLA, Los Angeles, California, November 12, (1992).

"Kilns, Ovens, and Dryers - Present and Future," presented at the Gas Company Air Quality Permit Assistance Seminar, Industry Hills Sheraton, California, November 20, (1992).

"The Design and Implementation of Vehicle Scrapping Programs," presented at the 86th Annual Meeting of the Air and Waste Management Association, Denver, Colorado, June 12, 1993.

"Air Quality Planning and Control in Beijing, China," presented at the 87th Annual Meeting of the Air and Waste Management Association, Cincinnati, Ohio, June 19-24, 1994.

Annex A

Expert Litigation Support

A. Occasions where Dr. Sahu has provided Written or Oral testimony before Congress:

1. In July 2012, provided expert written and oral testimony to the House Subcommittee on Energy and the Environment, Committee on Science, Space, and Technology at a Hearing entitled "Hitting the Ethanol Blend Wall – Examining the Science on E15."

B. Matters for which Dr. Sahu has provided affidavits and expert reports include:

2. Affidavit for Rocky Mountain Steel Mills, Inc. located in Pueblo Colorado – dealing with the technical uncertainties associated with night-time opacity measurements in general and at this steel mini-mill.

3. Expert reports and depositions (2/28/2002 and 3/1/2002; 12/2/2003 and 12/3/2003; 5/24/2004) on behalf of the United States in connection with the Ohio Edison NSR Cases. *United States, et al. v. Ohio Edison Co., et al.*, C2-99-1181 (Southern District of Ohio).

4. Expert reports and depositions (5/23/2002 and 5/24/2002) on behalf of the United States in connection with the Illinois Power NSR Case. *United States v. Illinois Power Co., et al.*, 99-833-MJR (Southern District of Illinois).

5. Expert reports and depositions (11/25/2002 and 11/26/2002) on behalf of the United States in connection with the Duke Power NSR Case. *United States, et al. v. Duke Energy Corp.*, 1:00-CV-1262 (Middle District of North Carolina).

6. Expert reports and depositions (10/6/2004 and 10/7/2004; 7/10/2006) on behalf of the United States in connection with the American Electric Power NSR Cases. *United States, et al. v. American Electric Power Service Corp., et al.*, C2-99-1182, C2-99-1250 (Southern District of Ohio).

7. Affidavit (March 2005) on behalf of the Minnesota Center for Environmental Advocacy and others in the matter of the Application of Heron Lake BioEnergy LLC to construct and operate an ethanol production facility – submitted to the Minnesota Pollution Control Agency.

8. Expert Report and Deposition (10/31/2005 and 11/1/2005) on behalf of the United States in connection with the East Kentucky Power Cooperative NSR Case. *United States v. East Kentucky Power Cooperative, Inc.*, 5:04-cv-00034-KSF (Eastern District of Kentucky).

9. Affidavits and deposition on behalf of Basic Management Inc. (BMI) Companies in connection with the BMI vs. USA remediation cost recovery Case.

10. Expert Report on behalf of Penn Future and others in the Cambria Coke plant permit challenge in Pennsylvania.

11. Expert Report on behalf of the Appalachian Center for the Economy and the Environment and others in the Western Greenbrier permit challenge in West Virginia.

12. Expert Report, deposition (via telephone on January 26, 2007) on behalf of various Montana petitioners (Citizens Awareness Network (CAN), Women's Voices for the Earth (WVE) and the Clark Fork Coalition (CFC)) in the Thompson River Cogeneration LLC Permit No. 3175-04 challenge.

13. Expert Report and deposition (2/2/07) on behalf of the Texas Clean Air Cities Coalition at the Texas State Office of Administrative Hearings (SOAH) in the matter of the permit challenges to TXU Project Apollo's eight new proposed PRB-fired PC boilers located at seven TX sites.

14. Expert Testimony (July 2007) on behalf of the Izaak Walton League of America and others in connection with the acquisition of power by Xcel Energy from the proposed Gascoyne Power Plant – at the State of Minnesota, Office of Administrative Hearings for the Minnesota PUC (MPUC No. E002/CN-06-1518; OAH No. 12-2500-17857-2).

15. Affidavit (July 2007) Comments on the Big Cajun I Draft Permit on behalf of the Sierra Club – submitted to the Louisiana DEQ.

16. Expert Report and Deposition (12/13/2007) on behalf of Commonwealth of Pennsylvania – Dept. of Environmental Protection, State of Connecticut, State of New York, and State of New Jersey (Plaintiffs) in connection with the Allegheny Energy NSR Case. *Plaintiffs v. Allegheny Energy Inc., et al.,* 2:05cv0885 (Western District of Pennsylvania).

17. Expert Reports and Pre-filed Testimony before the Utah Air Quality Board on behalf of Sierra Club in the Sevier Power Plant permit challenge.

18. Expert Report and Deposition (October 2007) on behalf of MTD Products Inc., in connection with *General Power Products, LLC v MTD Products Inc*., 1:06 CVA 0143 (Southern District of Ohio, Western Division) .

19. Expert Report and Deposition (June 2008) on behalf of Sierra Club and others in the matter of permit challenges (Title V: 28.0801-29 and PSD: 28.0803-PSD) for the Big Stone II unit, proposed to be located near Milbank, South Dakota.

20. Expert Reports, Affidavit, and Deposition (August 15, 2008) on behalf of Earthjustice in the matter of air permit challenge (CT-4631) for the Basin Electric Dry Fork station, under construction near Gillette, Wyoming before the Environmental Quality Council of the State of Wyoming.

21. Affidavits (May 2010/June 2010 in the Office of Administrative Hearings))/Declaration and Expert Report (November 2009 in the Office of Administrative Hearings) on behalf of NRDC and the Southern Environmental Law Center in the matter of the air permit challenge for Duke Cliffside Unit 6. Office of Administrative Hearing Matters 08 EHR 0771, 0835 and 0836 and 09 HER 3102, 3174, and 3176 (consolidated).

22. Declaration (August 2008), Expert Report (January 2009), and Declaration (May 2009) on behalf of Southern Alliance for Clean Energy in the matter of the air permit challenge for Duke Cliffside Unit 6. *Southern Alliance for Clean Energy et al., v. Duke Energy Carolinas, LLC*, Case No. 1:08-cv-00318-LHT-DLH (Western District of North Carolina, Asheville Division).

23. Declaration (August 2008) on behalf of the Sierra Club in the matter of Dominion Wise County plant MACT.us

24. Expert Report (June 2008) on behalf of Sierra Club for the Green Energy Resource Recovery Project, MACT Analysis.

25. Expert Report (February 2009) on behalf of Sierra Club and the Environmental Integrity Project in the matter of the air permit challenge for NRG Limestone's proposed Unit 3 in Texas.

26. Expert Report (June 2009) on behalf of MTD Products, Inc., in the matter of *Alice Holmes and Vernon Holmes v. Home Depot USA, Inc., et al.*

27. Expert Report (August 2009) on behalf of Sierra Club and the Southern Environmental Law Center in the matter of the air permit challenge for Santee Cooper's proposed Pee Dee plant in South Carolina).

28. Statements (May 2008 and September 2009) on behalf of the Minnesota Center for Environmental Advocacy to the Minnesota Pollution Control Agency in the matter of the Minnesota Haze State Implementation Plans.

29. Expert Report (August 2009) on behalf of Environmental Defense, in the matter of permit challenges to the proposed Las Brisas coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH).

30. Expert Report and Rebuttal Report (September 2009) on behalf of the Sierra Club, in the matter of challenges to the proposed Medicine Bow Fuel and Power IGL plant in Cheyenne, Wyoming.

31. Expert Report (December 2009) and Rebuttal reports (May 2010 and June 2010) on behalf of the United States in connection with the Alabama Power Company NSR Case. *United States v. Alabama Power Company*, CV-01-HS-152-S (Northern District of Alabama, Southern Division).

32. Pre-filed Testimony (October 2009) on behalf of Environmental Defense and others, in the matter of challenges to the proposed White Stallion Energy Center coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH).

33. Pre-filed Testimony (July 2010) and Written Rebuttal Testimony (August 2010) on behalf of the State of New Mexico Environment Department in the matter of Proposed Regulation 20.2.350 NMAC – *Greenhouse Gas Cap and Trade Provisions*, No. EIB 10-04 (R), to the State of New Mexico, Environmental Improvement Board.

34. Expert Report (August 2010) and Rebuttal Expert Report (October 2010) on behalf of the United States in connection with the Louisiana Generating NSR

Case. *United States v. Louisiana Generating, LLC*, 09-CV100-RET-CN (Middle District of Louisiana) – Liability Phase.

35. Declaration (August 2010), Reply Declaration (November 2010), Expert Report (April 2011), Supplemental and Rebuttal Expert Report (July 2011) on behalf of the United States in the matter of DTE Energy Company and Detroit Edison Company (Monroe Unit 2). *United States of America v. DTE Energy Company and Detroit Edison Company*, Civil Action No. 2:10-cv-13101-BAF-RSW (Eastern District of Michigan).

36. Expert Report and Deposition (August 2010) as well as Affidavit (September 2010) on behalf of Kentucky Waterways Alliance, Sierra Club, and Valley Watch in the matter of challenges to the NPDES permit issued for the Trimble County power plant by the Kentucky Energy and Environment Cabinet to Louisville Gas and Electric, File No. DOW-41106-047.

37. Expert Report (August 2010), Rebuttal Expert Report (September 2010), Supplemental Expert Report (September 2011), and Declaration (November 2011) on behalf of Wild Earth Guardians in the matter of opacity exceedances and monitor downtime at the Public Service Company of Colorado (Xcel)'s Cherokee power plant. No. 09-cv-1862 (District of Colorado).

38. Written Direct Expert Testimony (August 2010) and Affidavit (February 2012) on behalf of Fall-Line Alliance for a Clean Environment and others in the matter of the PSD Air Permit for Plant Washington issued by Georgia DNR at the Office of State Administrative Hearing, State of Georgia (OSAH-BNR-AQ-1031707-98-WALKER).

39. Deposition (August 2010) on behalf of Environmental Defense, in the matter of the remanded permit challenge to the proposed Las Brisas coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH).

40. Expert Report, Supplemental/Rebuttal Expert Report, and Declarations (October 2010, November 2010, September 2012) on behalf of New Mexico Environment Department (Plaintiff-Intervenor), Grand Canyon Trust and Sierra Club (Plaintiffs) in the matter of *Plaintiffs v. Public Service Company of New Mexico* (PNM), Civil No. 1:02-CV-0552 BB/ATC (ACE) (District of New Mexico).

41. Expert Report (October 2010) and Rebuttal Expert Report (November 2010) (BART Determinations for PSCo Hayden and CSU Martin Drake units) to the Colorado Air Quality Commission on behalf of Coalition of Environmental Organizations.

42. Expert Report (November 2010) (BART Determinations for TriState Craig Units, CSU Nixon Unit, and PRPA Rawhide Unit) to the Colorado Air Quality Commission on behalf of Coalition of Environmental Organizations.

43. Declaration (November 2010) on behalf of the Sierra Club in connection with the Martin Lake Station Units 1, 2, and 3. *Sierra Club v. Energy Future Holdings Corporation and Luminant Generation Company LLC*, Case No. 5:10-cv-00156-DF-CMC (Eastern District of Texas, Texarkana Division).

44. Pre-Filed Testimony (January 2011) and Declaration (February 2011) to the Georgia Office of State Administrative Hearings (OSAH) in the matter of Minor Source HAPs status for the proposed Longleaf Energy Associates power plant (OSAH-BNR-AQ-1115157-60-HOWELLS) on behalf of the Friends of the Chattahoochee and the Sierra Club).

45. Declaration (February 2011) in the matter of the Draft Title V Permit for RRI Energy MidAtlantic Power Holdings LLC Shawville Generating Station (Pennsylvania), ID No. 17-00001 on behalf of the Sierra Club.

46. Expert Report (March 2011), Rebuttal Expert Report (June 2011) on behalf of the United States in *United States of America v. Cemex, Inc.*, Civil Action No. 09-cv-00019-MSK-MEH (District of Colorado).

47. Declaration (April 2011) and Expert Report (July 16, 2012) in the matter of the Lower Colorado River Authority (LCRA)'s Fayette (Sam Seymour) Power Plant on behalf of the Texas Campaign for the Environment. *Texas Campaign for the Environment v. Lower Colorado River Authority,* Civil Action No. 4:11-cv-00791 (Southern District of Texas, Houston Division).

48. Declaration (June 2011) on behalf of the Plaintiffs MYTAPN in the matter of Microsoft-Yes, Toxic Air Pollution-No (MYTAPN) v. State of Washington, Department of Ecology and Microsoft Corporation Columbia Data Center to the Pollution Control Hearings Board, State of Washington, Matter No. PCHB No. 10-162.

49. Expert Report (June 2011) on behalf of the New Hampshire Sierra Club at the State of New Hampshire Public Utilities Commission, Docket No. 10-261 – the 2010 Least Cost Integrated Resource Plan (LCIRP) submitted by the Public Service Company of New Hampshire (re. Merrimack Station Units 1 and 2).

50. Declaration (August 2011) in the matter of the Sandy Creek Energy Associates L.P. Sandy Creek Power Plant on behalf of Sierra Club and Public Citizen. *Sierra Club, Inc. and Public Citizen, Inc. v. Sandy Creek Energy Associates, L.P.*, Civil Action No. A-08-CA-648-LY (Western District of Texas, Austin Division).

51. Expert Report (October 2011) on behalf of the Defendants in the matter of *John Quiles and Jeanette Quiles et al. v. Bradford-White Corporation, MTD Products, Inc., Kohler Co., et al.,* Case No. 3:10-cv-747 (TJM/DEP) (Northern District of New York).

52. Declaration (October 2011) on behalf of the Plaintiffs in the matter of *American Nurses Association et. al. (Plaintiffs), v. US EPA (Defendant)*, Case No. 1:08-cv-02198-RMC (US District Court for the District of Columbia).

53. Declaration (February 2012) and Second Declaration (February 2012) in the matter of *Washington Environmental Council and Sierra Club Washington State Chapter v. Washington State Department of Ecology and Western States Petroleum Association,* Case No. 11-417-MJP (Western District of Washington).

54. Expert Report (March 2012) and Supplemental Expert Report (November 2013) in the matter of *Environment Texas Citizen Lobby, Inc and Sierra Club v.*

ExxonMobil Corporation et al., Civil Action No. 4:10-cv-4969 (Southern District of Texas, Houston Division).

55. Declaration (March 2012) in the matter of *Center for Biological Diversity, et al. v. United States Environmental Protection Agency,* Case No. 11-1101 (consolidated with 11-1285, 11-1328 and 11-1336) (US Court of Appeals for the District of Columbia Circuit).

56. Declaration (March 2012) in the matter of *Sierra Club v. The Kansas Department of Health and Environment*, Case No. 11-105,493-AS (Holcomb power plant) (Supreme Court of the State of Kansas).

57. Declaration (March 2012) in the matter of the Las Brisas Energy Center *Environmental Defense Fund et al., v. Texas Commission on Environmental Quality,* Cause No. D-1-GN-11-001364 (District Court of Travis County, Texas, 261st Judicial District).

58. Expert Report (April 2012), Supplemental and Rebuttal Expert Report (July 2012), and Supplemental Rebuttal Expert Report (August 2012) on behalf of the states of New Jersey and Connecticut in the matter of the Portland Power plant *State of New Jersey and State of Connecticut (Intervenor-Plaintiff) v. RRI Energy Mid-Atlantic Power Holdings et al.,* Civil Action No. 07-CV-5298 (JKG) (Eastern District of Pennsylvania).

59. Declaration (April 2012) in the matter of the EPA's EGU MATS Rule, on behalf of the Environmental Integrity Project.

60. Expert Report (August 2012) on behalf of the United States in connection with the Louisiana Generating NSR Case. *United States v. Louisiana Generating, LLC,* 09-CV100-RET-CN (Middle District of Louisiana) – Harm Phase.

61. Declaration (September 2012) in the Matter of the Application of *Energy Answers Incinerator, Inc.* for a Certificate of Public Convenience and Necessity to Construct a 120 MW Generating Facility in Baltimore City, Maryland, before the Public Service Commission of Maryland, Case No. 9199.

62. Expert Report (October 2012) on behalf of the Appellants (Robert Concilus and Leah Humes) in the matter of Robert Concilus and Leah Humes v. Commonwealth of Pennsylvania Department of Environmental Protection and Crawford Renewable Energy, before the Commonwealth of Pennsylvania Environmental Hearing Board, Docket No. 2011-167-R.

63. Expert Report (October 2012), Supplemental Expert Report (January 2013), and Affidavit (June 2013) in the matter of various Environmental Petitioners v. North Carolina DENR/DAQ and Carolinas Cement Company, before the Office of Administrative Hearings, State of North Carolina.

64. Pre-filed Testimony (October 2012) on behalf of No-Sag in the matter of the North Springfield Sustainable Energy Project before the State of Vermont, Public Service Board.

65. Pre-filed Testimony (November 2012) on behalf of Clean Wisconsin in the matter of Application of Wisconsin Public Service Corporation for Authority to

Construct and Place in Operation a New Multi-Pollutant Control Technology System (ReACT) for Unit 3 of the Weston Generating Station, before the Public Service Commission of Wisconsin, Docket No. 6690-CE-197.

66. Expert Report (February 2013) on behalf of Petitioners in the matter of Credence Crematory, Cause No. 12-A-J-4538 before the Indiana Office of Environmental Adjudication.

67. Expert Report (April 2013), Rebuttal report (July 2013), and Declarations (October 2013, November 2013) on behalf of the Sierra Club in connection with the Luminant Big Brown Case. *Sierra Club v. Energy Future Holdings Corporation and Luminant Generation Company LLC*, Civil Action No. 6:12-cv-00108-WSS (Western District of Texas, Waco Division).

68. Declaration (April 2013) on behalf of Petitioners in the matter of *Sierra Club, et al., (Petitioners) v Environmental Protection Agency et al. (Resppondents),* Case No., 13-1112, (Court of Appeals, District of Columbia Circuit).

69. Expert Report (May 2013) and Rebuttal Expert Report (July 2013) on behalf of the Sierra Club in connection with the Luminant Martin Lake Case. *Sierra Club v. Energy Future Holdings Corporation and Luminant Generation Company LLC*, Civil Action No. 5:10-cv-0156-MHS-CMC (Eastern District of Texas, Texarkana Division).

70. Declaration (August 2013) on behalf of A. J. Acosta Company, Inc., in the matter of *A. J. Acosta Company, Inc., v. County of San Bernardino*, Case No. CIVSS803651.

71. Comments (October 2013) on behalf of the Washington Environmental Council and the Sierra Club in the matter of the Washington State Oil Refinery RACT (for Greenhouse Gases), submitted to the Washington State Department of Ecology, the Northwest Clean Air Agency, and the Puget Sound Clean Air Agency.

72. Statement (November 2013) on behalf of various Environmental Organizations in the matter of the Boswell Energy Center (BEC) Unit 4 Environmental Retrofit Project, to the Minnesota Public Utilities Commission, Docket No. E-015/M-12-920.

73. Expert Report (December 2013) on behalf of the United States in *United States of America v. Ameren Missouri*, Civil Action No. 4:11-cv-00077-RWS (Eastern District of Missouri, Eastern Division).

74. Expert Testimony (December 2013) on behalf of the Sierra Club in the matter of Public Service Company of New Hampshire Merrimack Station Scrubber Project and Cost Recovery, Docket No. DE 11-250, to the State of New Hampshire Public Utilities Commission.

75. Expert Report (January 2014) on behalf of Baja, Inc., in *Baja, Inc., v. Automotive Testing and Development Services, Inc. et. al*, Civil Action No. 8:13-CV-02057-GRA (District of South Carolina, Anderson/Greenwood Division).

76. Declaration (March 2014) on behalf of the Center for International Environmental Law, Chesapeake Climate Action Network, Friends of the Earth, Pacific

Environment, and the Sierra Club (Plaintiffs) in the matter of *Plaintiffs v. the Export-Import Bank (Ex-Im Bank) of the United States*, Civil Action No. 13-1820 RC (District Court for the District of Columbia).

77. Declaration (April 2014) on behalf of Respondent-Intervenors in the matter of *Mexichem Specialty Resins Inc., et al., (Petitioners) v Environmental Protection Agency et al.,* Case No., 12-1260 (and Consolidated Case Nos. 12-1263, 12-1265, 12-1266, and 12-1267), (Court of Appeals, District of Columbia Circuit).

78. Direct Prefiled Testimony (June 2014) on behalf of the Michigan Environmental Council and the Sierra Club in the matter of the Application of DTE Electric Company for Authority to Implement a Power Supply Cost Recovery (PSCR) Plan in its Rate Schedules for 2014 Metered Jurisdictional Sales of Electricity, Case No. U-17319 (Michigan Public Service Commission).

79. Expert Report (June 2014) on behalf of ECM Biofilms in the matter of the US Federal Trade Commission (FTC) v. ECM Biofilms (FTC Docket #9358).

80. Direct Prefiled Testimony (August 2014) on behalf of the Michigan Environmental Council and the Sierra Club in the matter of the Application of Consumers Energy Company for Authority to Implement a Power Supply Cost Recovery (PSCR) Plan in its Rate Schedules for 2014 Metered Jurisdictional Sales of Electricity, Case No. U-17317 (Michigan Public Service Commission).

81. Declaration (July 2014) on behalf of Public Health Intervenors in the matter of *EME Homer City Generation v. US EPA* (Case No. 11-1302 and consolidated cases) relating to the lifting of the stay entered by the Court on December 30, 2011 (US Court of Appeals for the District of Columbia).

82. Expert Report (September 2014), Rebuttal Expert Report (December 2014) and Supplemental Expert Report (March 2015) on behalf of Plaintiffs in the matter of *Sierra Club and Montana Environmental Information Center (Plaintiffs) v. PPL Montana LLC, Avista Corporation, Puget Sound Energy, Portland General Electric Company, Northwestern Corporation, and Pacificorp (Defendants)*, Civil Action No. CV 13-32-BLG-DLC-JCL (US District Court for the District of Montana, Billings Division).

83. Expert Report (November 2014) on behalf of Niagara County, the Town of Lewiston, and the Villages of Lewiston and Youngstown in the matter of CWM Chemical Services, LLC New York State Department of Environmental Conservation (NYSDEC) Permit Application Nos.: 9-2934-00022/00225, 9-2934-00022/00231, 9-2934-00022/00232, and 9-2934-00022/00249 (pending).

84. *Declaration (January 2015) relating to Startup/Shutdown in the MATS Rule (EPA Docket ID No. EPA-HQ-OAR-2009-0234) on behalf of the Environmental Integrity Project.*

85. Pre-filed Direct Testimony (March 2015), Supplemental Testimony (May 2015), and Surrebuttal Testimony (December 2015) on behalf of Friends of the Columbia Gorge in the matter of the Application for a Site Certificate for the Troutdale Energy Center before the Oregon Energy Facility Siting Council.

86. Brief of Amici Curiae Experts in Air Pollution Control and Air Quality Regulation in Support of the Respondents, On Writs of Certiorari to the US Court of Appeals for the District of Columbia, No. 14-46, 47, 48. *Michigan et. al., (Petitioners) v. EPA et. al., Utility Air Regulatory Group (Petitioners) v. EPA et. al., National Mining Association et. al., (Petitioner) v. EPA et. al.,* (Supreme Court of the United States).

87. Expert Report (March 2015) and Rebuttal Expert Report (January 2016) on behalf of Plaintiffs in the matter of *Conservation Law Foundation v. Broadrock Gas Services LLC, Rhode Island LFG GENCO LLC, and Rhode Island Resource Recovery Corporation (Defendants)*, Civil Action No. 1:13-cv-00777-M-PAS (US District Court for the District of Rhode Island).

88. Declaration (April 2015) relating to various Technical Corrections for the MATS Rule (EPA Docket ID No. EPA-HQ-OAR-2009-0234) on behalf of the Environmental Integrity Project.

89. Direct Prefiled Testimony (May 2015) on behalf of the Michigan Environmental Council, the Natural Resources Defense Council, and the Sierra Club in the matter of the Application of DTE Electric Company for Authority to Increase its Rates, Amend its Rate Schedules and Rules Governing the Distribution and Supply of Electric Energy and for Miscellaneous Accounting Authority, Case No. U-17767 (Michigan Public Service Commission).

90. Expert Report (July 2015) and Rebuttal Expert Report (July 2015) on behalf of Plaintiffs in the matter of *Northwest Environmental Defense Center et. al., v. Cascade Kelly Holdings LLC, d/b/a Columbia Pacific Bio-Refinery, and Global Partners LP (Defendants),* Civil Action No. 3:14-cv-01059-SI (US District Court for the District of Oregon, Portland Division).

91. Declaration (August 2015, Docket No. 1570376) in support of "Opposition of Respondent-Intervenors American Lung Association, et. al., to Tri-State Generation's Emergency Motion;" Declaration (September 2015, Docket No. 1574820) in support of "Joint Motion of the State, Local Government, and Public Health Respondent-Intervenors for Remand Without Vacatur;" Declaration (October 2015) in support of "Joint Motion of the State, Local Government, and Public Health Respondent-Intervenors to State and Certain Industry Petitioners' Motion to Govern, *White Stallion Energy Center, LLC v. US EPA*, Case No. 12-1100 (US Court of Appeals for the District of Columbia).

92. Declaration (September 2015) in support of the Draft Title V Permit for Dickerson Generating Station (Proposed Permit No 24-031-0019) on behalf of the Environmental Integrity Project.

93. Expert Report (Liability Phase) (December 2015) and Rebuttal Expert Report (February 2016) on behalf of Plaintiffs in the matter of *Natural Resources Defense Council, Inc., Sierra Club, Inc., Environmental Law and Policy Center, and Respiratory Health Association v. Illinois Power Resources LLC, and Illinois Power Resources Generating LLC (Defendants),* Civil Action No. 1:13-cv-01181 (US District Court for the Central District of Illinois, Peoria Division).

94. Declaration (December 2015) in support of the Petition to Object to the Title V Permit for Morgantown Generating Station (Proposed Permit No 24-017-0014) on behalf of the Environmental Integrity Project.

95. Expert Report (November 2015) on behalf of Appellants in the matter of *Sierra Club, et al. v. Craig W. Butler, Director of Ohio Environmental Protection Agency et al.,* ERAC Case No. 14-256814.

96. Affidavit (January 2016) on behalf of Bridgewatch Detroit in the matter of *Bridgewatch Detroit v. Waterfront Petroleum Terminal Co., and Waterfront Terminal Holdings, LLC.*, in the Circuit Court for the County of Wayne, State of Michigan.

97. Expert Report (February 2016) and Rebuttal Expert Report (July 2016) on behalf of the challengers in the matter of the Delaware Riverkeeper Network, Clean Air Council, et. al., vs. Commonwealth of Pennsylvania Department of Environmental Protection and R. E. Gas Development LLC regarding the Geyer well site before the Pennsylvania Environmental Hearing Board.

98. Direct Testimony (May 2016) in the matter of Tesoro Savage LLC Vancouver Energy Distribution Terminal, Case No. 15-001 before the State of Washington Energy Facility Site Evaluation Council.

99. Declaration (June 2016) relating to deficiencies in air quality analysis for the proposed Millenium Bulk Terminal, Port of Longview, Washington.

100. Declaration (December 2016) relating to EPA's refusal to set limits on PM emissions from coal-fired power plants that reflect pollution reductions achievable with fabric filters on behalf of Environmental Integrity Project, Clean Air Council, Chesapeake Climate Action Network, Downwinders at Risk represented by Earthjustice in the matter of *ARIPPA v EPA, Case No. 15-1180.* (D.C. Circuit Court of Appeals).

101. Expert Report (January 2017) on the Environmental Impacts Analysis associated with the Huntley and Huntley Poseidon Well Pad on behalf citizens in the matter of the special exception use Zoning Hearing Board of Penn Township, Westmoreland County, Pennsylvania.

102. Expert Report (January 2017) on the Environmental Impacts Analysis associated with the Apex Energy Backus Well Pad on behalf citizens in the matter of the special exception use Zoning Hearing Board of Penn Township, Westmoreland County, Pennsylvania.

103. Expert Report (January 2017) on the Environmental Impacts Analysis associated with the Apex Energy Drakulic Well Pad on behalf citizens in the matter of the special exception use Zoning Hearing Board of Penn Township, Westmoreland County, Pennsylvania.

104. Expert Report (January 2017) on the Environmental Impacts Analysis associated with the Apex Energy Deutsch Well Pad on behalf citizens in the matter of the special exception use Zoning Hearing Board of Penn Township, Westmoreland County, Pennsylvania.

105. Affidavit (February 2017) pertaining to deficiencies water discharge compliance issues at the Wood River Refinery in the matter of *People of the State of Illinois (Plaintiff) v. Phillips 66 Company, ConocoPhillips Company, WRB Refining LP (Defendants)*, Case No. 16-CH-656, (Circuit Court for the Third Judicial Circuit, Madison County, Illinois).

106. Expert Report (March 2017) on behalf of the Plaintiff pertaining to non-degradation analysis for waste water discharges from a power plant in the matter of *Sierra Club (Plaintiff) v. Pennsylvania Department of Environmental Protection (PADEP) and Lackawanna Energy Center*, Docket No. 2016-047-L (consolidated), (Pennsylvania Environmental Hearing Board).

107. Expert Report (March 2017) on behalf of the Plaintiff pertaining to air emissions from the Heritage incinerator in East Liverpool, Ohio in the matter of *Save our County (Plaintiff) v. Heritage Thermal Services, Inc. (Defendant), Case No. 4:16-CV-1544-BYP*, (US District Court for the Northern District of Ohio, Eastern Division).

108. Rebuttal Expert Report (June 2017) on behalf of Plaintiffs in the matter of *Casey Voight and Julie Voight (Plaintiffs) v Coyote Creek Mining Company LLC (Defendant),* Civil Action No. 1:15-CV-00109 (US District Court for the District of North Dakota, Western Division).

109. Expert Affidavit (August 2017) and Penalty/Remedy Expert Affidavit (October 2017) on behalf of Plaintiff in the matter of *Wildearth Guardians (Plaintiff) v Colorado Springs Utility Board (Defendant,)* Civil Action No. 1:15-cv-00357-CMA-CBS (US District Court for the District of Colorado).

110. Expert Report (August 2017) on behalf of Appellant in the matter of *Patricia Ann Troiano (Appellant) v. Upper Burrell Township Zoning Hearing Board (Appellee)*, Court of Common Pleas of Westmoreland County, Pennsylvania, Civil Division.

111. Expert Report (October 2017), Supplemental Expert Report (October 2017), and and Rebuttal Expert Report (November 2017) on behalf of Defendant in the matter of *Oakland Bulk and Oversized Terminal (Plaintiff) v City of Oakland (Defendant,)* Civil Action No. 3:16-cv-07014-VC (US District Court for the Northern District of California, San Francisco Division).

112. Declaration (December 2017) on behalf of the Environmental Integrity Project in the matter of permit issuance for ATI Flat Rolled Products Holdings, Breckenridge, PA to the Allegheny County Health Department.

113. Expert Report (Harm Phase) (January 2018) on behalf of Plaintiffs in the matter of *Natural Resources Defense Council, Inc., Sierra Club, Inc., and Respiratory Health Association v. Illinois Power Resources LLC, and Illinois Power Resources Generating LLC (Defendants),* Civil Action No. 1:13-cv-01181 (US District Court for the Central District of Illinois, Peoria Division).

C. Occasions where Dr. Sahu has provided oral testimony in depositions, at trial or in similar proceedings include the following:

114. Deposition on behalf of Rocky Mountain Steel Mills, Inc. located in Pueblo, Colorado – dealing with the manufacture of steel in mini-mills including methods of air pollution control and BACT in steel mini-mills and opacity issues at this steel mini-mill.

115. Trial Testimony (February 2002) on behalf of Rocky Mountain Steel Mills, Inc. in Denver District Court.

116. Trial Testimony (February 2003) on behalf of the United States in the Ohio Edison NSR Cases, *United States, et al. v. Ohio Edison Co., et al.*, C2-99-1181 (Southern District of Ohio).

117. Trial Testimony (June 2003) on behalf of the United States in the Illinois Power NSR Case, *United States v. Illinois Power Co., et al.*, 99-833-MJR (Southern District of Illinois).

118. Deposition (10/20/2005) on behalf of the United States in connection with the Cinergy NSR Case. *United States, et* al. *v. Cinergy Corp., et al.*, IP 99-1693-C-M/S (Southern District of Indiana).

119. Oral Testimony (August 2006) on behalf of the Appalachian Center for the Economy and the Environment re. the Western Greenbrier plant, WV before the West Virginia DEP.

120. Oral Testimony (May 2007) on behalf of various Montana petitioners (Citizens Awareness Network (CAN), Women's Voices for the Earth (WVE) and the Clark Fork Coalition (CFC)) re. the Thompson River Cogeneration plant before the Montana Board of Environmental Review.

121. Oral Testimony (October 2007) on behalf of the Sierra Club re. the Sevier Power Plant before the Utah Air Quality Board.

122. Oral Testimony (August 2008) on behalf of the Sierra Club and Clean Water re. Big Stone Unit II before the South Dakota Board of Minerals and the Environment.

123. Oral Testimony (February 2009) on behalf of the Sierra Club and the Southern Environmental Law Center re. Santee Cooper Pee Dee units before the South Carolina Board of Health and Environmental Control.

124. Oral Testimony (February 2009) on behalf of the Sierra Club and the Environmental Integrity Project re. NRG Limestone Unit 3 before the Texas State Office of Administrative Hearings (SOAH) Administrative Law Judges.

125. Deposition (July 2009) on behalf of MTD Products, Inc., in the matter of *Alice Holmes and Vernon Holmes v. Home Depot USA, Inc., et al*.

126. Deposition (October 2009) on behalf of Environmental Defense and others, in the matter of challenges to the proposed Coleto Creek coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH).

127. Deposition (October 2009) on behalf of Environmental Defense, in the matter of permit challenges to the proposed Las Brisas coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH).

128. Deposition (October 2009) on behalf of the Sierra Club, in the matter of challenges to the proposed Medicine Bow Fuel and Power IGL plant in Cheyenne, Wyoming.

129. Deposition (October 2009) on behalf of Environmental Defense and others, in the matter of challenges to the proposed Tenaska coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH). (April 2010).

130. Oral Testimony (November 2009) on behalf of the Environmental Defense Fund re. the Las Brisas Energy Center before the Texas State Office of Administrative Hearings (SOAH) Administrative Law Judges.

131. Deposition (December 2009) on behalf of Environmental Defense and others, in the matter of challenges to the proposed White Stallion Energy Center coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH).

132. Oral Testimony (February 2010) on behalf of the Environmental Defense Fund re. the White Stallion Energy Center before the Texas State Office of Administrative Hearings (SOAH) Administrative Law Judges.

133. Deposition (June 2010) on behalf of the United States in connection with the Alabama Power Company NSR Case. *United States v. Alabama Power Company*, CV-01-HS-152-S (Northern District of Alabama, Southern Division).

134. Trial Testimony (September 2010) on behalf of Commonwealth of Pennsylvania – Dept. of Environmental Protection, State of Connecticut, State of New York, State of Maryland, and State of New Jersey (Plaintiffs) in connection with the Allegheny Energy NSR Case in US District Court in the Western District of Pennsylvania. *Plaintiffs v. Allegheny Energy Inc., et al.*, 2:05cv0885 (Western District of Pennsylvania).

135. Oral Direct and Rebuttal Testimony (September 2010) on behalf of Fall-Line Alliance for a Clean Environment and others in the matter of the PSD Air Permit for Plant Washington issued by Georgia DNR at the Office of State Administrative Hearing, State of Georgia (OSAH-BNR-AQ-1031707-98-WALKER).

136. Oral Testimony (September 2010) on behalf of the State of New Mexico Environment Department in the matter of Proposed Regulation 20.2.350 NMAC – *Greenhouse Gas Cap and Trade Provisions*, No. EIB 10-04 (R), to the State of New Mexico, Environmental Improvement Board.

137. Oral Testimony (October 2010) on behalf of the Environmental Defense Fund re. the Las Brisas Energy Center before the Texas State Office of Administrative Hearings (SOAH) Administrative Law Judges.

138. Oral Testimony (November 2010) regarding BART for PSCo Hayden, CSU Martin Drake units before the Colorado Air Quality Commission on behalf of the Coalition of Environmental Organizations.

139. Oral Testimony (December 2010) regarding BART for TriState Craig Units, CSU Nixon Unit, and PRPA Rawhide Unit) before the Colorado Air Quality Commission on behalf of the Coalition of Environmental Organizations.

140. Deposition (December 2010) on behalf of the United States in connection with the Louisiana Generating NSR Case. *United States v. Louisiana Generating, LLC,* 09-CV100-RET-CN (Middle District of Louisiana).

141. Deposition (February 2011 and January 2012) on behalf of Wild Earth Guardians in the matter of opacity exceedances and monitor downtime at the Public Service Company of Colorado (Xcel)'s Cherokee power plant. No. 09-cv-1862 (D. Colo.).

142. Oral Testimony (February 2011) to the Georgia Office of State Administrative Hearings (OSAH) in the matter of Minor Source HAPs status for the proposed Longleaf Energy Associates power plant (OSAH-BNR-AQ-1115157-60-HOWELLS) on behalf of the Friends of the Chattahoochee and the Sierra Club).

143. Deposition (August 2011) on behalf of the United States in *United States of America v. Cemex, Inc.*, Civil Action No. 09-cv-00019-MSK-MEH (District of Colorado).

144. Deposition (July 2011) and Oral Testimony at Hearing (February 2012) on behalf of the Plaintiffs MYTAPN in the matter of Microsoft-Yes, Toxic Air Pollution-No (MYTAPN) v. State of Washington, Department of Ecology and Microsoft Corporation Columbia Data Center to the Pollution Control Hearings Board, State of Washington, Matter No. PCHB No. 10-162.

145. Oral Testimony at Hearing (March 2012) on behalf of the United States in connection with the Louisiana Generating NSR Case. *United States v. Louisiana Generating, LLC*, 09-CV100-RET-CN (Middle District of Louisiana).

146. Oral Testimony at Hearing (April 2012) on behalf of the New Hampshire Sierra Club at the State of New Hampshire Public Utilities Commission, Docket No. 10-261 – the 2010 Least Cost Integrated Resource Plan (LCIRP) submitted by the Public Service Company of New Hampshire (re. Merrimack Station Units 1 and 2).

147. Oral Testimony at Hearing (November 2012) on behalf of Clean Wisconsin in the matter of Application of Wisconsin Public Service Corporation for Authority to Construct and Place in Operation a New Multi-Pollutant Control Technology System (ReACT) for Unit 3 of the Weston Generating Station, before the Public Service Commission of Wisconsin, Docket No. 6690-CE-197.

148. Deposition (March 2013) in the matter of various Environmental Petitioners v. North Carolina DENR/DAQ and Carolinas Cement Company, before the Office of Administrative Hearings, State of North Carolina.

149. Deposition (August 2013) on behalf of the Sierra Club in connection with the Luminant Big Brown Case. *Sierra Club v. Energy Future Holdings Corporation and Luminant Generation Company LLC*, Civil Action No. 6:12-cv-00108-WSS (Western District of Texas, Waco Division).

150. Deposition (August 2013) on behalf of the Sierra Club in connection with the Luminant Martin Lake Case. *Sierra Club v. Energy Future Holdings Corporation and Luminant Generation Company LLC*, Civil Action No. 5:10-cv-0156-MHS-CMC (Eastern District of Texas, Texarkana Division).

151. Deposition (February 2014) on behalf of the United States in *United States of America v. Ameren Missouri*, Civil Action No. 4:11-cv-00077-RWS (Eastern District of Missouri, Eastern Division).

152. Trial Testimony (February 2014) in the matter of *Environment Texas Citizen Lobby, Inc and Sierra Club v. ExxonMobil Corporation et al.,* Civil Action No. 4:10-cv-4969 (Southern District of Texas, Houston Division).

153. Trial Testimony (February 2014) on behalf of the Sierra Club in connection with the Luminant Big Brown Case. *Sierra Club v. Energy Future Holdings Corporation and Luminant Generation Company LLC*, Civil Action No. 6:12-cv-00108-WSS (Western District of Texas, Waco Division).

154. Deposition (June 2014) and Trial (August 2014) on behalf of ECM Biofilms in the matter of the *US Federal Trade Commission (FTC) v. ECM Biofilms* (FTC Docket #9358).

155. Deposition (February 2015) on behalf of Plaintiffs in the matter of *Sierra Club and Montana Environmental Information Center (Plaintiffs) v. PPL Montana LLC, Avista Corporation, Puget Sound Energy, Portland General Electric Company, Northwestern Corporation, and Pacificorp (Defendants)*, Civil Action No. CV 13-32-BLG-DLC-JCL (US District Court for the District of Montana, Billings Division).

156. Oral Testimony at Hearing (April 2015) on behalf of Niagara County, the Town of Lewiston, and the Villages of Lewiston and Youngstown in the matter of CWM Chemical Services, LLC New York State Department of Environmental Conservation (NYSDEC) Permit Application Nos.: 9-2934-00022/00225, 9-2934-00022/00231, 9-2934-00022/00232, and 9-2934-00022/00249 (pending).

157. Deposition (August 2015) on behalf of Plaintiff in the matter of *Conservation Law Foundation (Plaintiff) v. Broadrock Gas Services LLC, Rhode Island LFG GENCO LLC, and Rhode Island Resource Recovery Corporation (Defendants)*, Civil Action No. 1:13-cv-00777-M-PAS (US District Court for the District of Rhode Island).

158. Testimony at Hearing (August 2015) on behalf of the Sierra Club in the matter of *Amendments to 35 Illinois Administrative Code Parts 214, 217, and 225* before the Illinois Pollution Control Board, R15-21.

159. Deposition (May 2015) on behalf of Plaintiffs in the matter of *Northwest Environmental Defense Center et. al., (Plaintiffs) v. Cascade Kelly Holdings LLC, d/b/a Columbia Pacific Bio-Refinery, and Global Partners LP (Defendants)*, Civil Action No. 3:14-cv-01059-SI (US District Court for the District of Oregon, Portland Division).

160. Trial Testimony (October 2015) on behalf of Plaintiffs in the matter of *Northwest Environmental Defense Center et. al., (Plaintiffs) v. Cascade Kelly Holdings LLC, d/b/a Columbia Pacific Bio-Refinery, and Global Partners LP (Defendants)*, Civil Action No. 3:14-cv-01059-SI (US District Court for the District of Oregon, Portland Division).

161. Deposition (April 2016) on behalf of the Plaintiffs in *UNatural Resources Defense Council, Respiratory Health Association, and Sierra Club (Plaintiffs) v. Illinois Power Resources LLC and Illinois Power Resources Generation LLC (Defendants)*, Civil Action No. 1:13-cv-01181 (Central District of Illinois, Peoria Division).

162. Trial Testimony at Hearing (July 2016) in the matter of Tesoro Savage LLC Vancouver Energy Distribution Terminal, Case No. 15-001 before the State of Washington Energy Facility Site Evaluation Council.

163. Trial Testimony (December 2016) on behalf of the challengers in the matter of the Delaware Riverkeeper Network, Clean Air Council, et. al., vs. Commonwealth of Pennsylvania Department of Environmental Protection and R. E. Gas Development LLC regarding the Geyer well site before the Pennsylvania Environmental Hearing Board.

164. Trial Testimony (July-August 2016) on behalf of the United States in *United States of America v. Ameren Missouri*, Civil Action No. 4:11-cv-00077-RWS (Eastern District of Missouri, Eastern Division).

165. Trial Testimony (January 2017) on the Environmental Impacts Analysis associated with the Huntley and Huntley Poseidon Well Pad Hearing on behalf citizens in the matter of the special exception use Zoning Hearing Board of Penn Township, Westmoreland County, Pennsylvania.

166. Trial Testimony (January 2017) on the Environmental Impacts Analysis associated with the Apex energy Backus Well Pad Hearing on behalf citizens in the matter of the special exception use Zoning Hearing Board of Penn Township, Westmoreland County, Pennsylvania.

167. Trial Testimony (January 2017) on the Environmental Impacts Analysis associated with the Apex energy Drakulic Well Pad Hearing on behalf citizens in the matter of the special exception use Zoning Hearing Board of Penn Township, Westmoreland County, Pennsylvania.

168. Trial Testimony (January 2017) on the Environmental Impacts Analysis associated with the Apex energy Deutsch Well Pad Hearing on behalf citizens in the matter of the special exception use Zoning Hearing Board of Penn Township, Westmoreland County, Pennsylvania.

169. Deposition Testimony (July 2017) on behalf of Plaintiffs in the matter of *Casey Voight and Julie Voight v Coyote Creek Mining Company LLC (Defendant)* Civil Action No. 1:15-CV-00109 (US District Court for the District of North Dakota, Western Division).

170. Deposition Testimony (November 2017) on behalf of Defendant in the matter of *Oakland Bulk and Oversized Terminal (Plaintiff) v City of Oakland (Defendant,)* Civil Action No. 3:16-cv-07014-VC (US District Court for the Northern District of California, San Francisco Division).

171. Deposition Testimony (December 2017) on behalf of Plaintiff in the matter of *Wildearth Guardians (Plaintiff) v Colorado Springs Utility Board (Defendant)* Civil Action No. 1:15-cv-00357-CMA-CBS (US District Court for the District of Colorado).

172. Deposition Testimony (January 2018) in the matter of National Parks Conservation Association (NPCA) v. State of Washington Department of Ecology and British Petroleum (BP) before the Washington Pollution Control Hearing Board, Case No. 17-055.

173. Trial Testimony (January 2018) on behalf of Defendant in the matter of *Oakland Bulk and Oversized Terminal (Plaintiff) v City of Oakland (Defendant,)* Civil Action No. 3:16-cv-07014-VC (US District Court for the Northern District of California, San Francisco Division).

ATTACHMENT B

FUEL TECH

Technologies to enable clean efficient energy

NOx Optimization Project
Wheelabrator Baltimore Inc.
Baltimore, Maryland
Units 1, 2 & 3

Project: 459S

Author: Michael Bisnett

June 5-9. 2017

Table of Contents:

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1. Executive Summary

Fuel Tech Inc. (FTI) was contracted by Wheelabrator to conduct SNCR system optimization testing at their Waste to Energy (WTE) facility located in Baltimore, Maryland. The objective was to obtain provide further optimization of the SNCR system to reduce NOx levels below 150 ppmdc (corrected to 7%O2) while minimizing ammonia slip and the potential for unreacted urea/ammonia to impinge on the furnace waterwall platens given the close proximity of the platens above the SNCR urea injector locations.

For this optimization program, additional changes were made to the existing SNCR equipment to allow for more flexibility for enhancing NOx removal. These changes primarily included installation of new NOx injector tips with 30 deg up angle cone spray and use of alternate rear furnace wall injector ports. The use of the additional rear wall injector ports and modified injector tips enhanced the coverage of the injectors allowed for more flexibility to optimize the SNCR system to control NOx below the 150 ppmdc (corrected to 7% O2) target while simultaneously maintaining low ammonia slip levels. Longer term testing needs to be conducted to ensure that the 150 ppmdc target can be sustained while WTE units are operating throughout the normal range of fuel variations and boiler maintenance cycles.

2. Introduction

Wheelabrator operates 3 mass burn municipal solid waste-to-energy (WTE) units in Baltimore, Maryland. This NOx reduction/SNCR system optimization project was to determine if the existing SNCR system can be further optimized to improve NOx reduction and achieve a target limit of 150 ppmdc. Because this project was focused on all 3 WTE units within a three-day testing period, the short term results are only a small sample of the performance of the modified SNCR system. Longer term data collection using the new injector tips, injector locations and operating parameters (dilution water flow, air pressure) under the normal variations in fuel and unit operation should be done to confirm the target level can be achieved without producing a visible plume or impacting boiler reliability via impingement of urea/ammonia on platen waterwall surfaces.

FTI's optimization test objective was to achieve NOx levels consistently below 150 ppmdc with low ammonia slip, without producing a visible plume at the stack and to minimize impact of SNCR operation on waterwall platens.

3. Methodology

3.1 Single Level SNCR

The SNCR systems on all 3 units use multiple injectors located at a single level in furnace. The number of injectors varies but up to 8 injectors can be used at any one time. All of the injectors were located on the 4th floor at Approx. Elevation 97': 2 rear corner, 2 side wall, 2 front corner, and 2 rear wall.

FTI standard flow injectors have been used the past several years. These injectors have a larger diameter and allow for more liquid flow than earlier version of injectors used when the SNCR system was first installed. In addition, the FTI injectors allow for the installation of various new injectors tips that can help direct the urea droplets to an optimum release area within the furnace.

This set of optimization tests was done using the same existing injection ports but included the installation of new injector tips that provided a 30 degree upward angle cone spray to increase urea dispersion in optimum furnace temperature range. The rear wall injectors had been recently installed based on prior optimization testing that indicated the rear furnace wall could be a more optimum location. Prior optimization testing also indicated that the two front corner injectors may not contribute much to SNCR performance and could be removed without impacting performance.

3.2 Ammonia Slip Measurement

Measuring the ammonia slip, a by-product of the SNCR process, is a very important part of evaluating SNCR performance in any application. Excessive ammonia slip can result in the formation of a detached visible ammonium chloride plume above the stack. As such, keeping the slip as low as possible is always a priority but increasing the NOx reduction efficiency is also as important. Finding the optimum balance between minimizing slip and achieving desired NOx reduction or emission levels is the key in getting the most out of the SNCR process.

The ammonia slip measurements that were taken on all 3 units were done using a modified EPA wet extraction method. This method is used exclusively by FTI to get a quick measurement of the slip. On all 3 units the slip samples were taken before the SDA to ensure that the measured slip was representative of the actual slip coming after the SNCR process. The samples were taken using a single glass lined and heated probe. During testing the plant was also monitoring the possible presence of a visible plume and at no time during the 3 days of testing and while running the units at the 150 ppmdc NOx set point was a detached plume visible. Ammonia slip results during the week registered the highest slip at 10 ppm but most of the tests were less than 5 ppm.

3.3 SNCR Process and Ammonia Slip

Ammonia slip needs to be determined given its importance in determining the effectiveness of the SNCR process. Basically, if the urea is being released into a hotter area of the furnace near the maximum SNCR temperature range, the resultant NOx reduction could be good and the ammonia slip would remain low as there is more reaction/mixing time in the optimum SNCR temperature range for the SNCR reaction to occur. In contrast if the urea is released in a cooler area of the furnace near lower optimum temperature range, NOx reduction may also be very good but the ammonia slip would be much higher given the shorter residence time within optimum temperature range. The furnace temperature and other factors including furnace spatial coverage of urea spray are the driving force that dictates the pathway that the NOx/urea interactions take place. Trying to find the optimum release point and dispersion pattern in any operating unit is the goal and that goal can be difficult to reach.

During this project the ammonia slip was measured at the inlet to the SDA. Only one sample taken exceeded 10 ppm, most were below 5 ppm and most were closer to 1-2 ppm.

Overall the previous optimization tests indicated that the urea was being released in an area that was on the hotter side as evidenced in that increasing the urea feed to 20 gph, did not increase ammonia slip significantly. While some of the additional urea was used to increase NOx reduction, the remaining urea was consumed or oxidized in the hotter area of the furnace.

3.4 Temperature Measurement

A SpectraTemp infrared imaging camera was placed at the 4^{th} Floor injection level to provide continuous measurement of furnace gas temperature at the urea injection level. During testing the furnace temperature measured by the Spectra-Temp was recorded throughout the day. The average temperature for Unit 1 was 2051 F degrees, Unit 2 was 2053 F degrees and Unit 3 was 2011 F degrees. The temperature varied from a low of 1992 F on Unit 3 to a high of 2090 F on Unit 2.

In this case it seems that the variations in the furnace temperatures were not significant and overall furnace temperature were toward the higher side of the SNCR optimum temperature range.

3.5 Baseline NOx

Baseline NOx values on all 3 units were close to previous optimization testing levels of around 200+ ppmdc. Overall the during this testing period the baseline varied in the range of 190 to 220 ppmdc It appeared that earlier in the day the baseline was lower and increased during the day. The plant confirmed that the NOx would increase at times and but the mechanism or its consistency was not understood.

The uncontrolled or baseline NOx concentration is used to calculate the NSR (normalized stoichiometric ratio) or molar ratio of ammonia (urea converts to ammonia) to baseline NOx. The NSR is used as a way to compare urea usage based on the actual demand or uncontrolled NOx levels. NSR is also used to calculate the utilization of urea on a percent basis. Utilization is equal to the NSR/ (% NOx reduction). The utilization rate is a measure of how efficiently/effectively the urea is being used.

3.6 As Found SNCR System Configuration

The as found SNCR configuration at start of optimization test was as follows:

- 2 Rear wall FTI injectors with normal tips
- 2 Rear corner FTI injectors with normal tips
- 2 Side wall FTI injectors with normal tips
- 2 Front wall FTI injectors with normal tips
- Approximately 1.33gpm of mixed chemical/water flow to each injector
- 50 psig of atomizing air pressure to each injector
- SNCR system in automatic control

The atomizing air pressures and mixed chemical flow to each injector can be varied within reason. Note that too much mixed chemical flow to the injectors or atomizing air pressures approaching 30 psig could cause droplet impingement on the water wall platen and superheater pendant tubes given the larger diameter of the droplets.

4. Test Program Narrative

4.1 June 5 (Initial Unit 1 testing)

The intent was to start the testing series on Unit 1 and continue onto the other two units during the next 3 days. An understanding of current SNCR operation was picked up by talking with operators, supervisors and managers at the plant. It was clear that the boiler operating conditions were "as normal" as can be expected and probably represented an average day. The uncontrolled NOx (baseline) was recorded at 200 ppmdc and then the SNCR system was placed in automatic control with a NOx set point of 170 ppmdc. Subsequently ammonia slip was measured using the modified EPA wet chemistry method with a result of 1.8 ppm. The average urea injection rate was 15 gph, dilution water flow rate was 1.33 gpm per injector and all 8 injectors were in service. In this initial testing the NSR was found to be 0.91 and the utilization rate was 36.5%.

4.2 June 6 (Unit 3 Testing)

The test equipment was moved from unit 1 to unit 3 and Unit 3 testing began with a verification of the ammonia slip using the current SNCR injector configuration of 8 injectors. While maintaining an average NOx of 173 ppmdc, the urea injection rate was 10 gph, dilution water rate 0.88 gpm/injector, NSR= 0.76. Ammonia slip was measured at 1.8 ppmdc with a urea utilization rate of 19.2%.

The testing on Unit 3 was used to initially test various injector configurations, angled tips, and adjustments to water flow and injector atomizing air pressure that would then be used as the basis for the testing on the other units

An uncontrolled NOx baseline was obtained with a value of 198 ppmdc. This value was lower than expected but considering the variability of the fuel, the NOx baseline is expected to vary to some degree. The 19.2% utilization rate and low ammonia slip result was an indication that the urea release temperature was at the higher end or rate with low ammonia slip was an indication the urea injection of the of the SNCR optimum temperature range as urea/ammonia was oxidized in the hotter areas before it could react with NOx.

For the next test the NSR was increased to 1.14 by increasing the urea feed rate to 15 gph without changing any of the other SNCR parameters. Dilution water remained the same at 0.88 gpm per injector. This test was done to determine if the higher NSR would increase ammonia slip. Increasing the NSR from 0.76 to 1.14 increased the NOx reduction, from 15 to 25% from original baseline of 198 ppmdc while urea utilization increased to 21.9%. With the increased urea dosage it would have been expected that ammonia slip would have increased as well but it remained around 1.4 ppm. At the higher urea dosage NOx dropped from 173 ppmdc in the initial test to 145 ppmdc. While increasing the NSR improved NOx control, the relatively small increase in urea utilization and continued low ammonia slip was indication that urea release point was still in the upper end of the optimum SNCR temperature range.

Changing the physical size of the injected droplets is another way to affect the performance of the SNCR system. The next test reduced the atomizing air pressure from 50 to 40 psig. The reduction in air pressure increased the individual droplet size and decreased the kinetic energy of the droplet. The effective difference is that the droplets will carry higher into the furnace and release urea in a different temperature zone. One important caveat regarding increasing the droplet size is the potential that the droplets could get large enough to impinge on heat transfer surfaces in the furnace. Therefore being conservative with the droplet size is always a consideration.

Decreasing the atomizing air from 50 to 40 psig had a negative impact on NOx reduction, ammonia slip and utilization rate. NOx increased to 155 ppmdc, NOx reduction percentage decreased to 14.6% and the slip increased significantly, from 1.4 to 10.6 ppm. These results indicated that the urea was not being used efficiently and was now being released into an area that is too cool, resulting in poor NOx reduction with higher slip. The lower atomizing air pressure resulted in larger droplets that carried urea into a cooler region of the furnace before it was available to react with NOx.

Figure 1: Unit 3 Initial Injector Locations

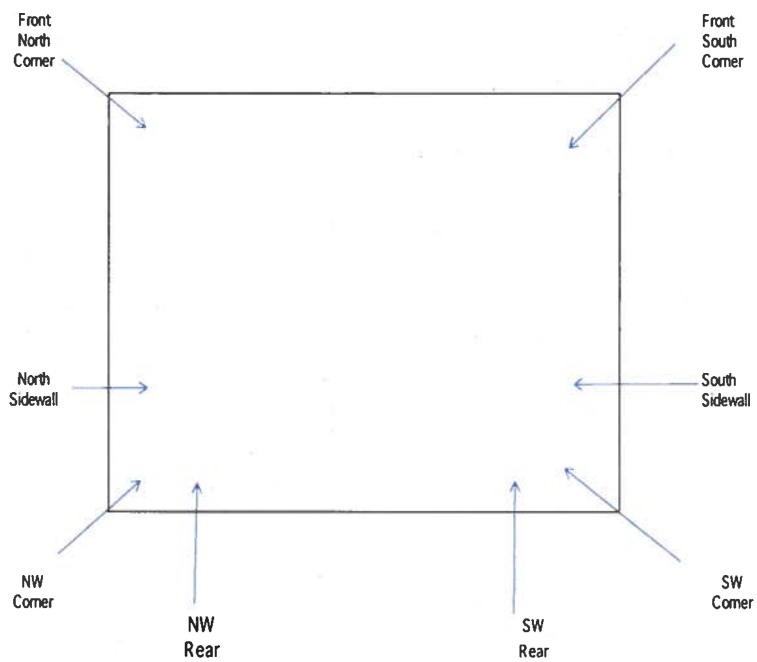
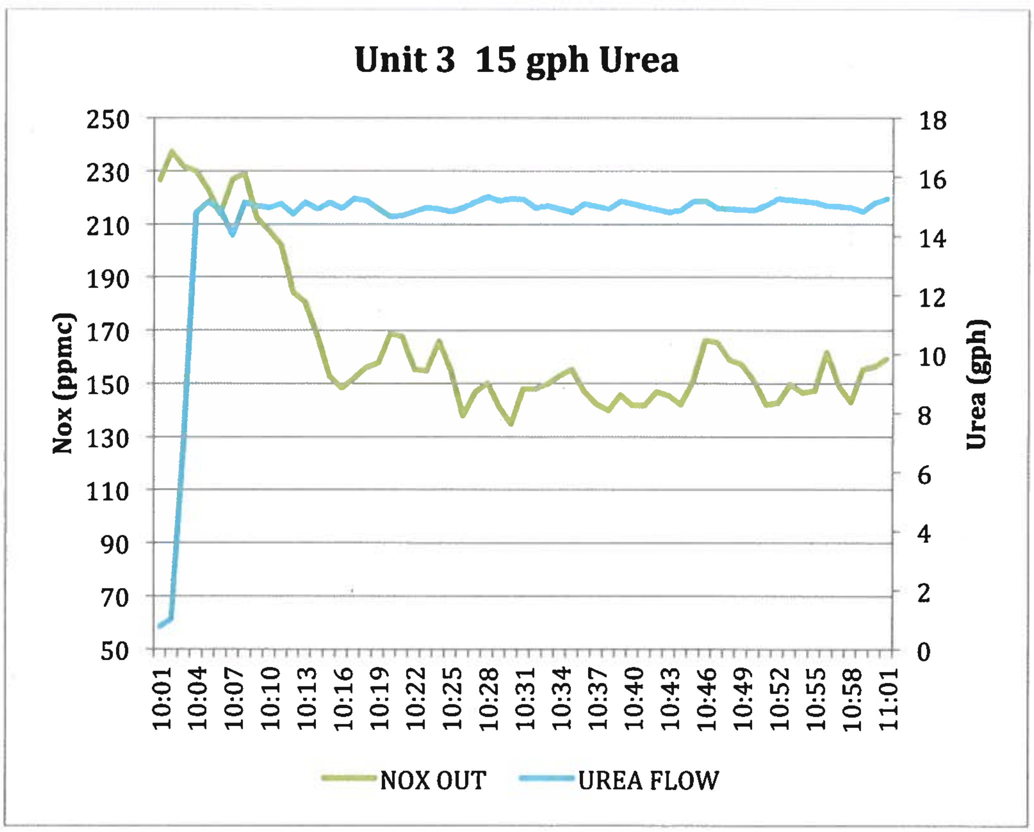


Figure 2: Unit 3 NOx at 15 gph Urea



4.3 Removing the front corner injectors

Based on discussions with plant personnel it was theorized that the front 2 corner injectors were not very effective or contributing much to NOx control.

When the front two corner injectors were removed (Figure 3) and side wall and rear furnace injectors left in place, SNCR system performance improved. The NOx reduction increased from 17 to 37% and the ammonia slip decreased from 10.6 to 1.1 ppm. The comparison was with the test using the same urea dosage, atomizing air pressure and injector water flow. The only difference was the 2 front corner injectors were taken out of service. Making this simple change supported the theory that the front corner port injectors were not contributing to NOx control. After removing the front injectors, the NOx dropped back to 149 ppmdc and slip to 1.1 ppm. NOx reduction and utilization increased to, 37.5% and 32.9% respectively. The reason the controlled NOx value stayed about the same was because the baseline NOx had increased over the testing period from 198 ppmdc to 212 ppmdc.

A baseline NOx value was obtained after this set of tests to ensure it had not changed much and to allow for the installation of the new 30 degree cone tips (angled vertically up) for the next test run.

Figure 3: Unit 3 Injector locations after front wall injectors removed

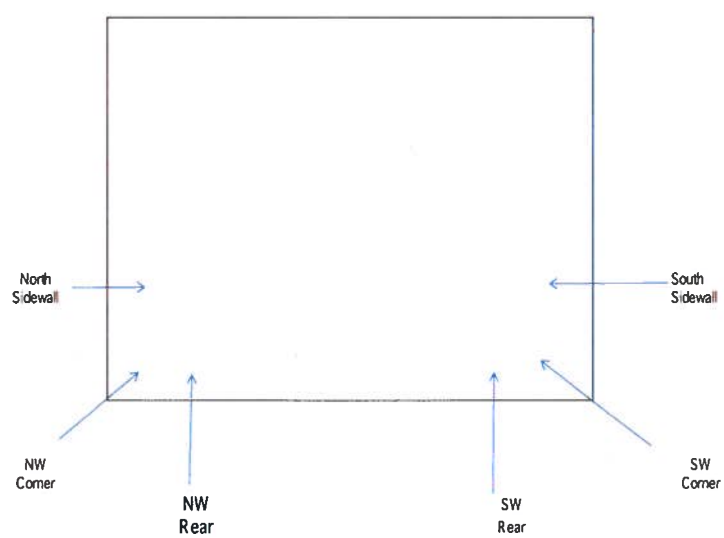
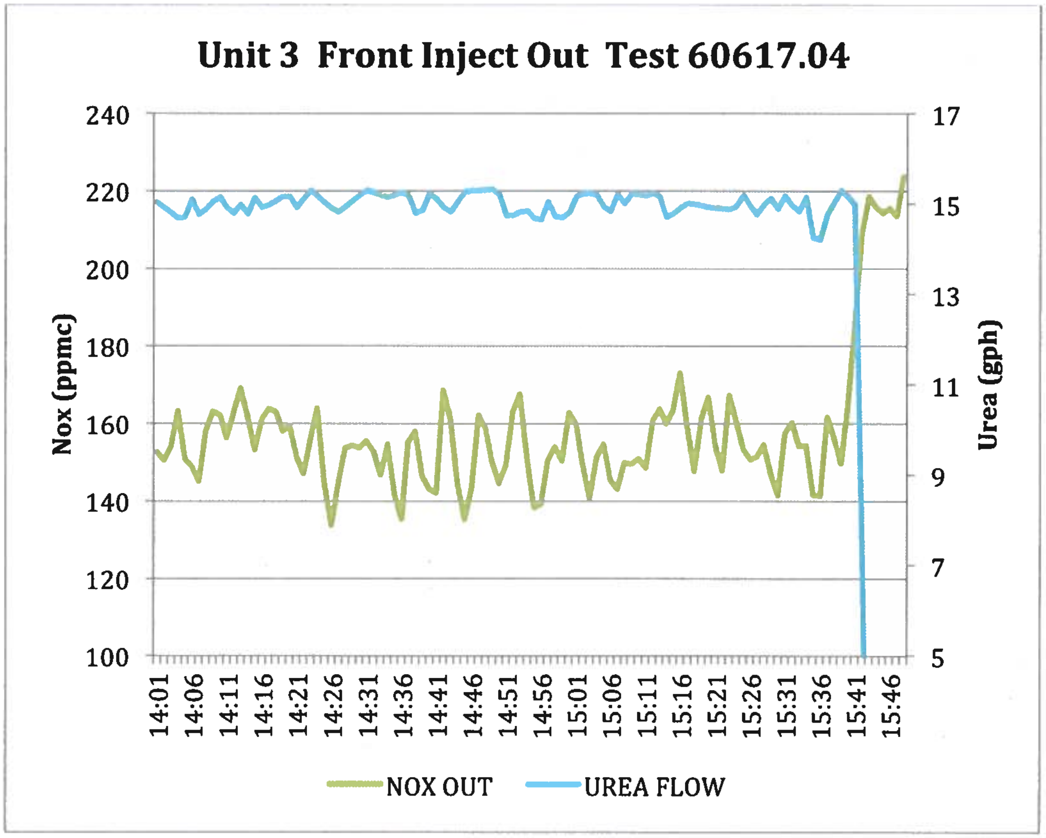


Figure 4: Unit 3 results after front wall injectors removed



4.4 Installing the angled tips

Moving onto the next phase required that the current straight cone spray tips be replaced with cone tips that are angled up at 30 degrees. This purpose of the angled up tips is to give the droplets direction and help to drive the majority of the liquid to a more optimum temperature location in the furnace. Using these tips allows for better placement of the urea without increasing the droplet size too much. The six injectors were fitted with the 30 deg up angled tips: two sidewall, two rear wall and two rear corners.

The results were very good. Using the same urea dosage of 15 gph, with an NSR of 1.14, the NOx reduction increased from 37.5 to 42.7%, utilization increased from 32.9% to 37.4% and the NOx dropped to 130 ppmdc. Individual injector water flow was 1.33 gpm at an air pressure of 40 psig. The measured ammonia slip increased slightly to 3.3 ppm from 1.1 ppm and stack observation indicated there was no visible plume. Making the change to the angled up tips showed that releasing the urea higher in the furnace with the right injector configuration was very beneficial.

The initial Unit 3 optimization results were very positive and predictable and, as such, were used as the starting point for further optimization of the other 2 units.

Figure 5: 30 degree angled tips, angled upwards

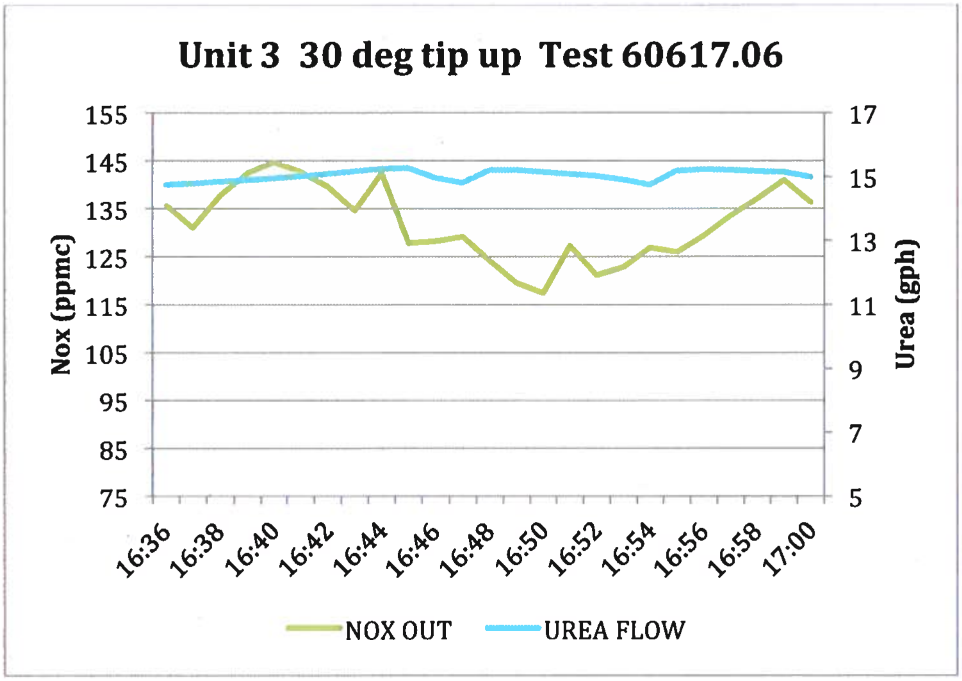


Figure 6: Unit 3 Daily Summary

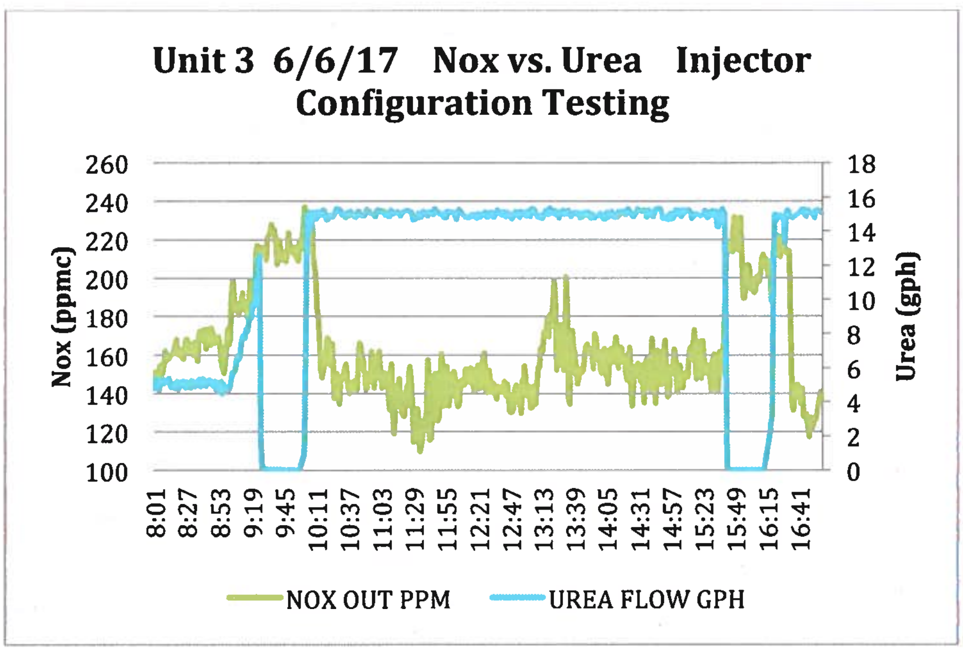


Figure7: Unit 3 Test Results

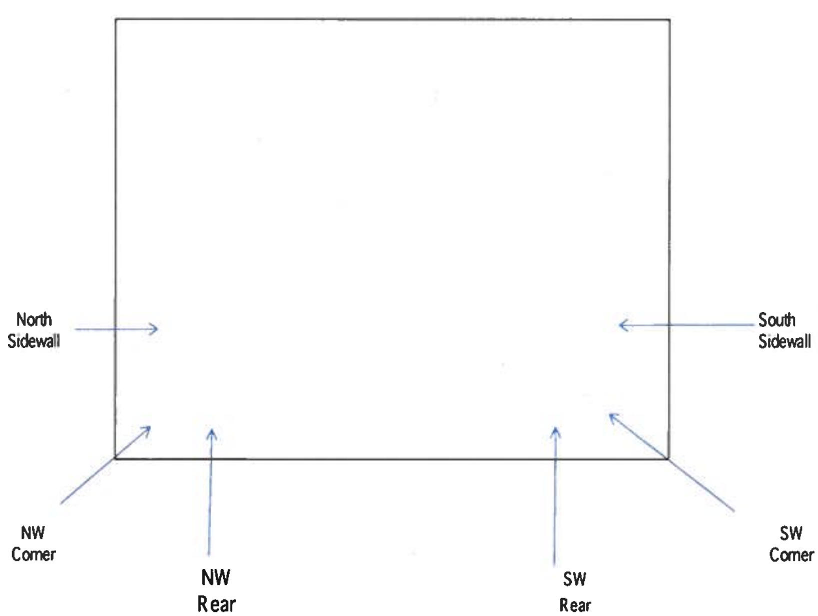
Test No.	Test Type	Test Time	Stm Load KPPH	Load MMBtu per hr	Econ O2	# Inj's	Tip Type	Flow [gpm]	Flow / inj [gpm]	Liquid P [psig]	Air P [psig]	"A" @ Flow [gph]	50% NSR	Nox ppmvc	Spectra Temp deg F	NH3 ppm	BL NOx lbs/hr	NOx lbs/hr	Summary of Results Total NSR	% Red	% Util
60617.00	High load	8:00	190	300	10.5	8	Cone	7.0	0.88	75	50	10.0	0.76	173	1992	1.8	96.000	82.000	0.76	14.6%	19.2%
60617.01	Baseline	9:00	193	300	11.2	8	Cone	7.0	0.88	75	50	0.0	0.00	198	1992		96.000	96.000	0.00	0.0%	0.0%
60617.02	Test 1 Incr NSR	10:00	192	306	11.0	8	Cone	7.0	0.88	75	50	15.0	1.14	145	1992	1.4	96.000	72.000	1.14	25.0%	21.9%
60617.03	Air 40 psig	11:30	190	304	10.5	8	Cone	7.0	0.88	75	40	15.0	1.14	155	1992	10.6	96.000	80.000	1.14	16.7%	14.6%
60617.04	Front N/S inj out	14:00	192	306	9.0	6	Cone	8.0	1.33	80	40	15.0	1.14	149	2050	1.1	96.000	60.000	1.14	37.5%	32.9%
60617.05	Baseline	15:45	192	306	9.3	6	Cone 30 up	8.0	1.33	80	40	0.0	0.00	212	2036		96.000	96.000	0.00	0.0%	0.0%
60617.06	6 inj, 30 deg cone up	16:50	192	304	9.6	6	Cone 30 up	8.0	1.33	80	40	15.0	1.14	130	2021	3.3	96.000	55.000	1.14	42.7%	37.4%

5. June 7 (Unit 1 Testing)

5.1 Duplicated Injector Configuration from Unit 3

On June 7th the injector configuration was changed on Unit 1 to duplicate the final optimized injector configuration used on Unit 3. The new configuration included 2 rear wall, 2 rear corner and 2 side wall injectors with each injector having a 30 degree angled up conical tip (Figure 8).

Figure 8: Unit 1 Injector locations



A baseline NOx value was obtained prior to the first test. For the 1st test NOx was kept close to 140 ppmdc with 15 gph of urea and a measured slip of 1.7 ppm (Figure 10) and utilization rate of 36.5%. This proved that the final configuration from Unit 3 carried over successfully to Unit 1 as SNCR performance was very good. (Figure 9) Given the successful duplication of results on Unit 1, further optimization was done to this configuration to evaluate impact on SNCR performance

Total liquid flow to each injector was reduced from 1.33 to 1.00 gpm to determine if the change would affect the NOx reduction performance. (Figure 11) The smaller droplets that are formed at the lower injector flow could reduce the potential impingement issues on the adjacent water wall platen tubes. While lowering the total water flow reduced NOx removal slightly it was not considered significant and therefore keeping the droplets smaller would result in nearly identical performance but decrease the likelihood of tube impingement.

Increasing the urea dosage (Figure 12) from 15 to 20 gph was done to determine if there is a point where increasing the urea dosage will not lead to a reasonable increase in the NOx reduction with the 6 injector configuration and essentially determining a point of diminishing returns. Increasing to 20 gph of urea reduced NOx to 130 ppmdc but the utilization dropped from 34.7 to 32.9% while ammonia slip increased slightly from 1.7 to 2.7 ppm evidence that a urea rates above 20 gph, ammonia slip would increase very quickly. The results indicate that there is some inherent SNCR operational flexibility or “buffering” potential to maintain NOx below 150 ppmdc to accommodate combustion and process variability associated with MSW combustion.

Since the front corner injectors were found to be ineffective and not providing much NOx reduction the next test removed the two side injectors to see how if they were effective or not. Removing the side injectors did not impact SNCR performance negatively or positively compared to 6 injector operation at 15 gph urea feed rate and therefore may not be needed to achieve 150 ppmdc. (Figure 13) The advantage of using 4 injectors instead of 6 is a lower potential for impingement on the pendant tubes.

Figure 9: Unit 1 Front and side wall injectors removed

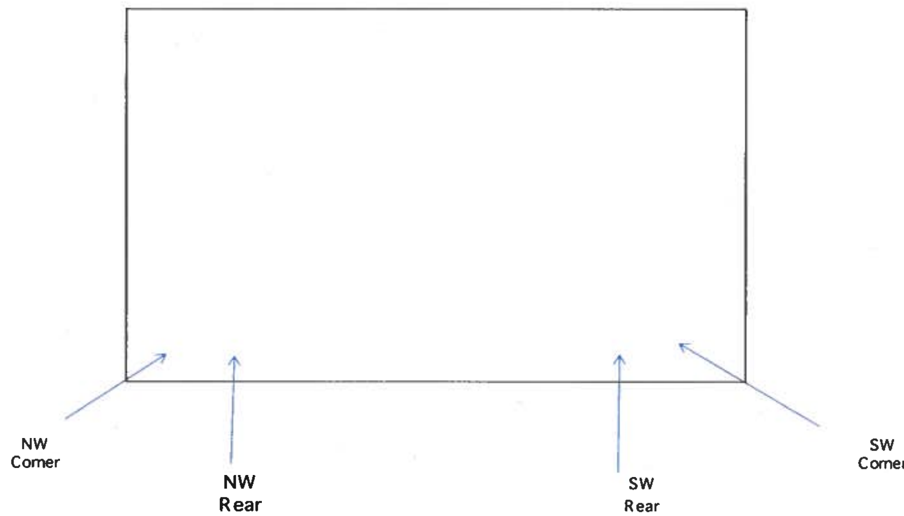


Figure 10: Unit 1 Initial Test

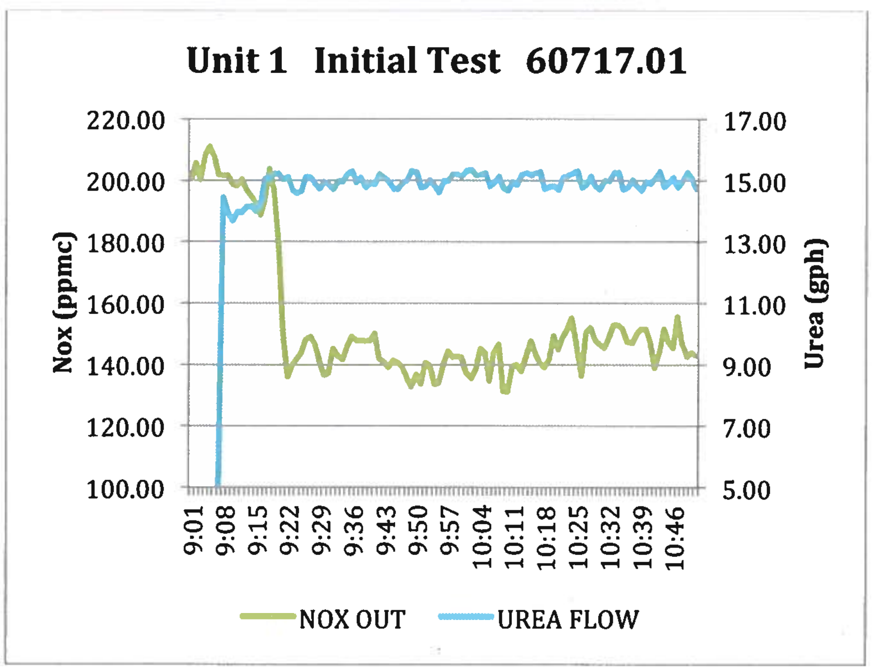


Figure 11: Mixed Chemical Flow Reduced

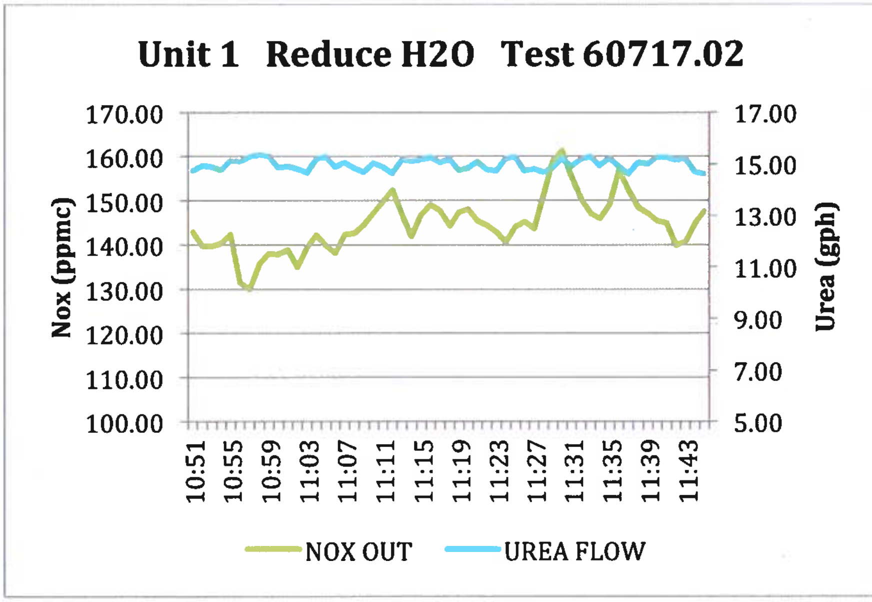


Figure 12: Increased Urea Flow

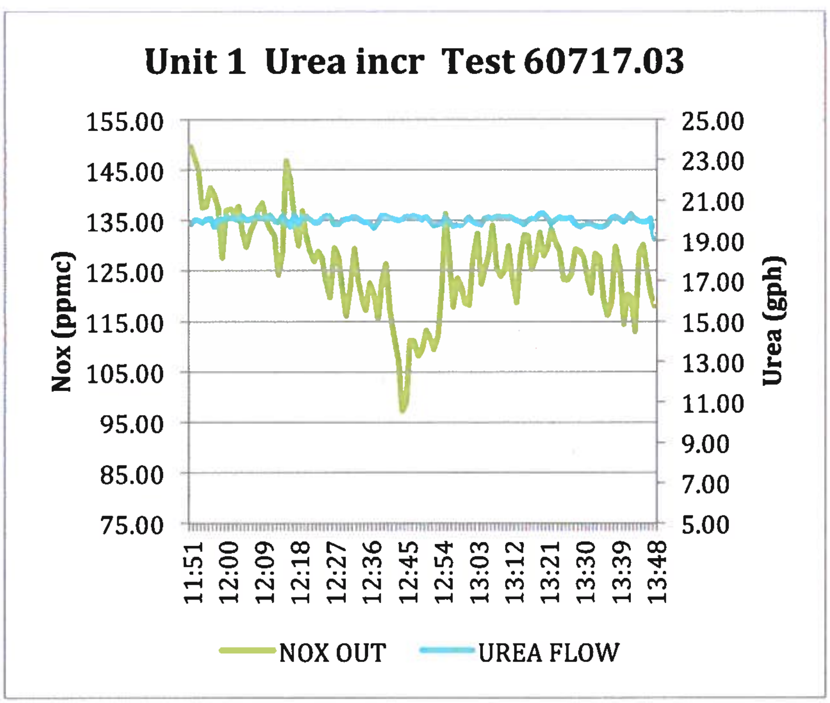


Figure 13: Side Wall Injectors removed

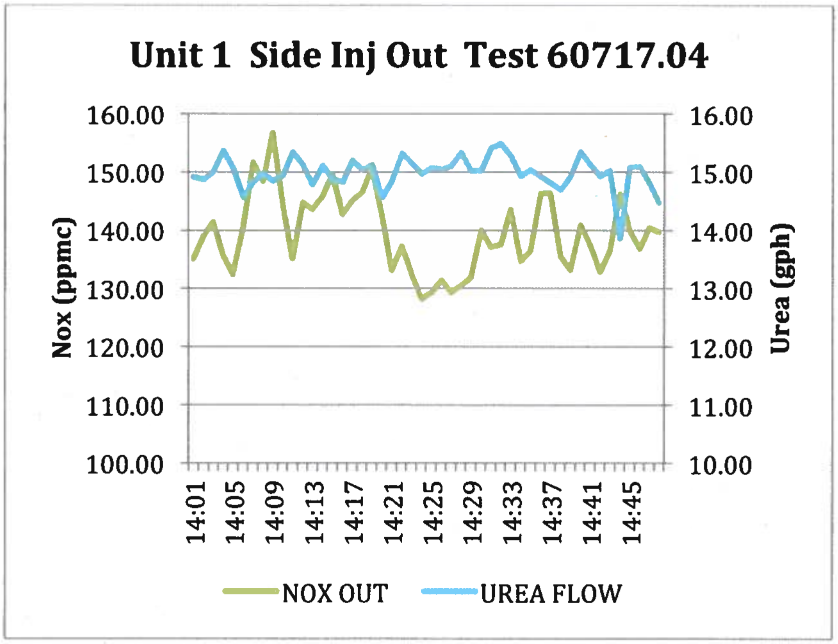


Figure 14: Unit 1 Testing Summary

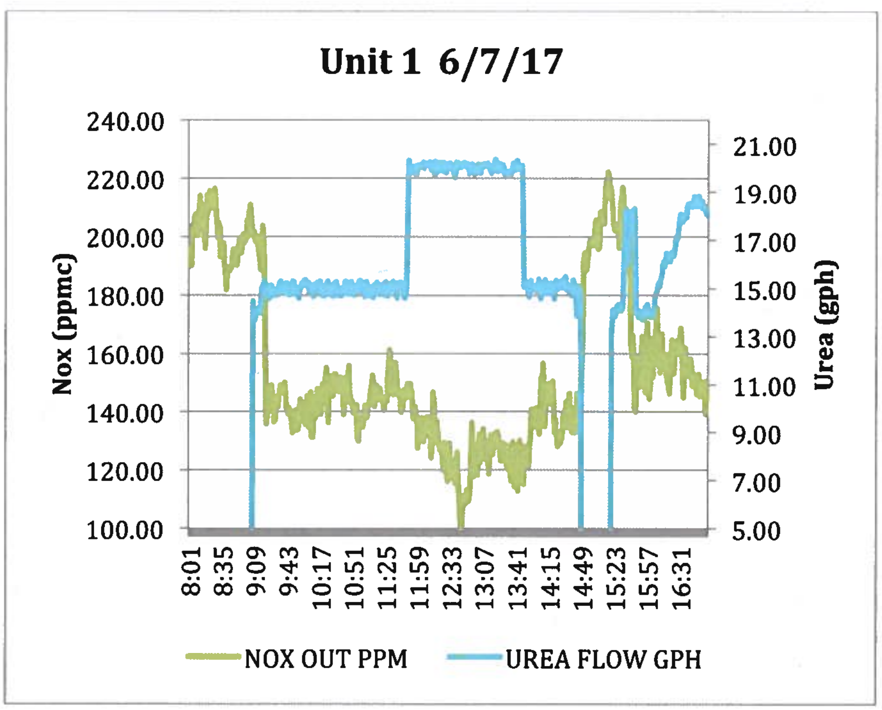


Figure 15: Unit 1 Testing Summary

Unit 1 Test No.	Test Type	Test Time	Stm Load KPPH	# of Inj's	Tip Type	Flow / inj [gpm]	Liquid P [psig]	Air P [psig]	"A" @ Flow [gph]	50% NSR	O2 % dry	NOx ppmvc	Spectra Temp deg F	NH3 ppm	BL NOx lbs/hr	NOx lbs/hr	Total NSR	% Red	% Util
60717.00	Baseline	8:00	192	6	Conc 30 up	1.33	80	40	0.0	0.00	10.4	200	2050		120.000	120.000	0.00	0.0%	0.0%
60717.01	Duplicate Unit 3	9:00	194	6	Conc 30 up	1.33	80	40	15.0	0.91	9.4	140	2060	1.7	120.000	80.000	0.91	33.3%	36.5%
60717.02	Reduce liq 1gpm/inj	10:50	192	6	Conc 30 up	1.00	80	40	15.0	0.91	9.2	147	2040		120.000	82.000	0.91	31.7%	34.7%
60717.03	Incr NSR 20 gph	11:50	191	6	Conc 30 up	1.00	80	40	20.0	1.22	9.5	130	2035	2.7	120.000	72.000	1.22	40.0%	32.9%
60717.04	Decr urea, side inj out	14:00	193	4	Conc 30 up	1.00	80	40	15.0	0.91	9.4	144	2055	2.0	120.000	80.000	0.91	33.3%	36.5%
60717.05	Baseline	2:50	190	4	Conc 30 up	1.00	80	40	0.0	0.00	10.3	200	2067		120.000	120.000	0.00	0.0%	0.0%

5.2 Automatic Control on Unit 1 and 3

Overnight the controls for the Unit 1 and 3 SNCR systems were set to automatic and a NOx set point was set at 150 ppmdc. Reviewing the NOx and urea usage data for overnight operation confirmed that the SNCR system was able to control the NOx below 150 ppmdc most of the time with the urea flow around 5-10 gph. However, there were times the urea feed increased to as high as 20 gph to meet the NOx to 150 ppmdc setpoint.

The cause for the high periods of urea consumption is more than likely due to an increase in the baseline NOx from combustion variability or a change in the combustion/furnace temperature profile that affects SNCR performance. Increasing combustion temperatures could contribute to increased thermal NOx production and/or increase in conversion of fuel bound nitrogen to NOx as both are impacted by combustion temperature and the amount of O2 present in the active combustion zone. Changing combustion could also contribute to a variation in the furnace temperature profile and also impact the SNCR performance.

6. June 8 (Unit 2 Testing)

Unit 2 was the last unit to be tested. The Unit 2 SNCR system was configured to the same as Units 1 and 3 based on the positive results using the 2 rear corner and 2 rear wall injectors with 30 degree angled up tips with atomizing air pressure at 40 psig, 1 gpm of total dilution water flow per injector and urea flows between 5 and 20 gph. A baseline NOx value of 195 ppmdc was obtained in the morning. Again as on Units 1 and 3, Unit 2 baseline NOx tended was lower at the beginning of the day and increased as the day progressed.

Starting up the SNCR system for the first set of tests went without incident and the NOx was reduced to 140 ppmdc. (Figure 17) This was achieved with 4 injectors at 1 gpm water flow, 15 gph urea flow and 40 psig air pressure. NOx levels were about 140 ppmdc and ammonia slip was 2.9 ppm.

Increasing the urea from 15 to 20 gph reduced NOx to about 135 ppmdc but the slip increases to 3.9 ppm. (Figure 18) After testing was completed the system was left in full automatic control with a NOx set point of 150 ppmdc.

Figure 16: Unit 2 Injector locations

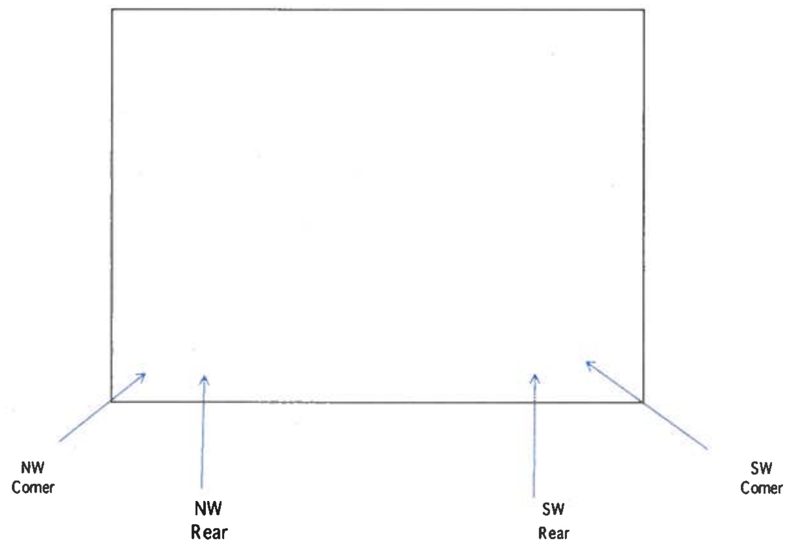


Figure 17: Unit 2 Initial Test

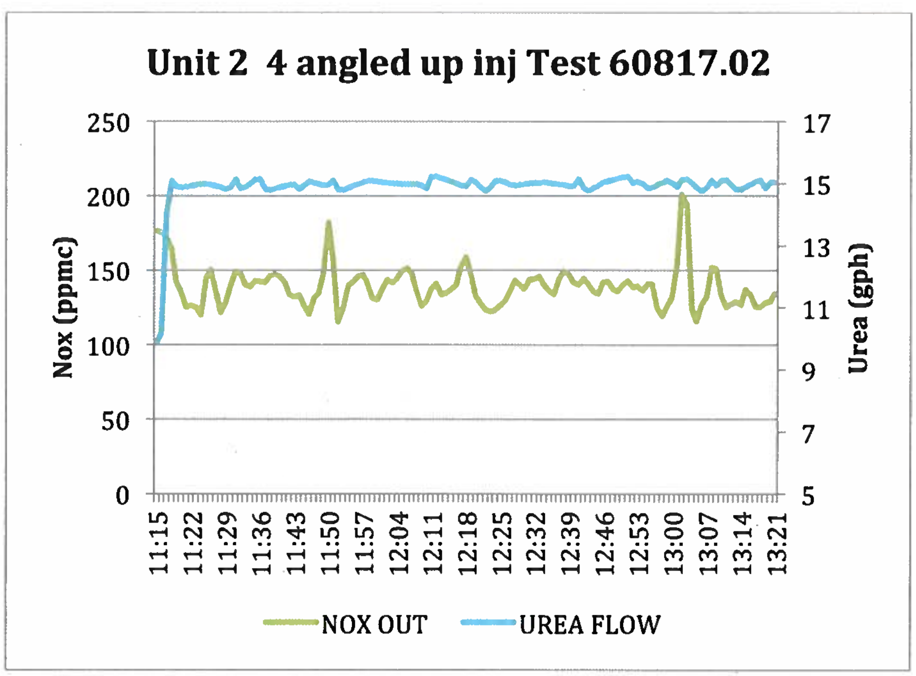


Figure 18: Urea Flow Increased to 20 gph

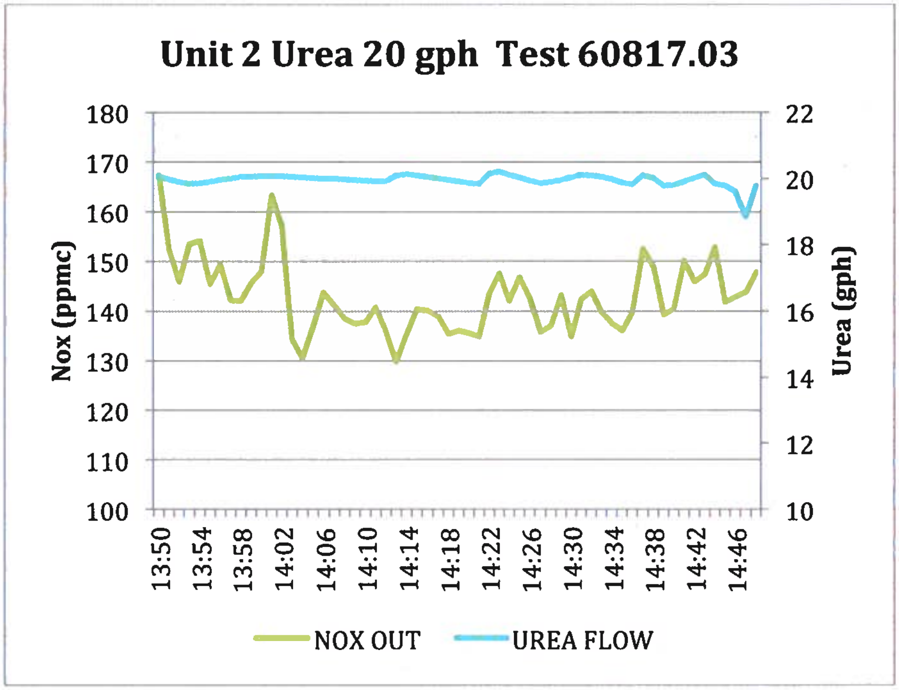


Figure 19: Baseline NOx Changes during day

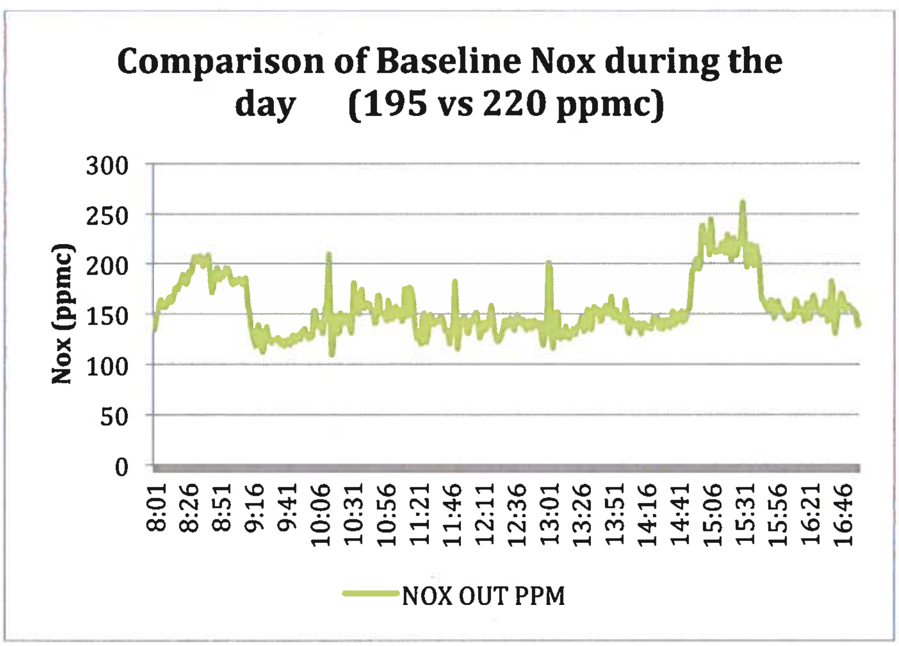


Figure 20: Unit 2 Daily Summary

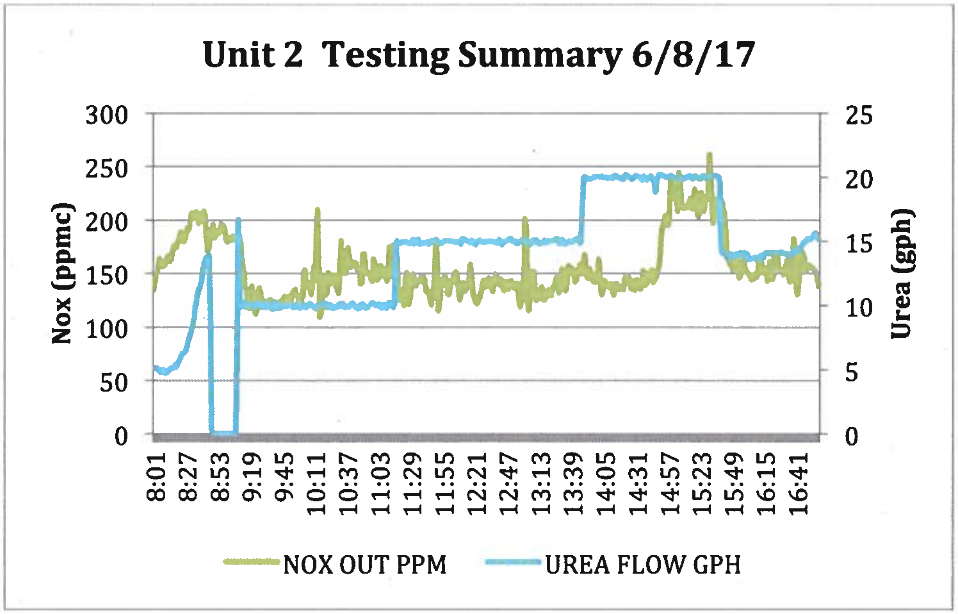


Figure 17: Unit 2 Testing Summary

Unit 2 Test No.	Test Type	Test Time	Stm Load KPPH	# of Inj's	Tip Type	Flow / inj [gpm]	Liquid P [psig]	Air P [psig]	"A" @ Flow [gph]	50% NSR	O2 % dry	NOx ppmvc	Spectra Temp deg F	Red %	NH3 ppm	BL NOx lbs/hr	NOx lbs/hr	Total NSR	% Red	% Util
60817.00	Baseline	8:00	192	4	Cone 30 up	1.00	80	40	0.0	0.00	10.4	195	2090	100.0%		110.000	110.000	0.00	0.0%	0.0%
60817.01	Test stopped	9:15	193	4	Cone 30 up	1.00	80	40	10.0	0.66	10.0	160	2065	80.0%	1.6	110.000	88.000	0.66	20.0%	30.1%
60817.02	4 inj, angled up	11:15	189	4	Cone 30 up	1.00	80	40	15.0	1.00	9.9	140	2078	68.2%	2.9	110.000	75.000	1.00	31.8%	32.0%
60817.03	Urea up 20gph	13:50	190	4	Cone 30 up	1.00	80	40	20.0	1.22	9.9	136	2035	59.2%	3.9	120.000	71.000	1.22	40.8%	33.6%
60817.04	Baseline	14:50	192	4	Cone 30 up	1.00	80	40	0.0	0.00	9.2	220	1995	100.0%		120.000	120.000	0.00	0.0%	0.0%

7. Conclusions

The results of FTI's short term SNCR optimization testing indicated that use of 30 deg up angled injector tips and injector total liquid flow of 1 gpm provided additional capability for SNCR systems to achieve and maintain NOx emission level of 150 ppmdc with minimal ammonia slip. The target NOx could be maintained with urea flow rates of approximately 15 gph and ammonia slip of less than 5ppm. Assuming an average baseline NOx of 210ppm, this equates to an NSR of approximately 1 with 28.6% utilization.

The optimized SNCR system configuration for the all three units based on the test results are as follows:

- 2 Rear Wall FTI Standard Injectors with 30° up angled tips
- 2 Rear Corner Wall FTI Standard injectors with 30° up angled tips
- 1 gpm total liquid flow per injector
- 40 psig atomizing air pressure per injector

Longer term testing for 2-3 week period needs to be performed with SNCR systems in automatic control at setpoint of 145 ppmdc to maintain the targeted NOx level of 150 ppmdc on 24 hour average. Daily and hourly NOx and urea variability should be evaluated at the completion of this longer testing period to provide additional insight on the ability of the SNCR system to achieve 150 ppmdc. This longer term testing, may require some further SNCR system adjustments as needed including using more injectors, increasing total liquid flow to injectors or changing atomizing air pressure to maintain NOx below 150 ppmdc.

A summary of the testing program for all three units is provided below:

All Unit Testing Summary

Unit 1 Test No.	Test Type	Test Time	Steam Load (kpph)	Econ O2 (%)	No. of Inj.	Tip Type	Flow per Inj (gpm)	Liquid Press (psig)	Air Press (psig)	"A" @ Flow (gph)	50% NSR	NOx (ppmvc)	Spectra Temp (°F)	Reduction (%)	NH3 Slip (ppm)	BL NOx (lb/hr)	Controlled NOx (lb/hr)	Total NSR	NOx Reduction (%)	Utilization (%)
60717.00	Baseline	8:00	192	9.9	6	Cone 30 up	1.33	80	40	0.0	0.00	205	2050	100.0%		120.000	120.000	0.00	0.0%	0.0%
60717.01	Duplicate Unit 3	9:00	194	9.9	6	Cone 30 up	1.33	80	40	15.0	0.91	140	2060	66.7%	1.7	120.000	80.000	0.91	33.3%	36.5%
60717.02	Reduce liq 1gpm/inj	10:50	192	9.2	6	Cone 30 up	1.00	80	40	15.0	0.91	147	2040	68.3%		120.000	82.000	0.91	31.7%	34.7%
60717.03	Incr NSR 20 gph	11:50	191	9.5	6	Cone 30 up	1.00	80	40	20.0	1.22	132	2035	60.0%	2.7	120.000	72.000	1.22	40.0%	32.9%
60717.04	Decr urea, side inj out	14:00	193	10.3	4	Cone 30 up	1.00	80	40	15.0	0.91	144	2055	66.7%	2.0	120.000	80.000	0.91	33.3%	36.5%
60717.05	Baseline	2:50	190	10.3	4	Cone 30 up	1.00	80	40	0.0	0.00		2067	100.0%		120.000	120.000	0.00	0.0%	0.0%

Unit 2 Test No.	Test Type	Test Time	Steam Load (kpph)	Econ O2 (%)	No. of Inj.	Tip Type	Flow per Inj (gpm)	Liquid Press (psig)	Air Press (psig)	"A" @ Flow (gph)	50% NSR	NOx (ppmvc)	Spectra Temp (°F)	Reduction (%)	NH3 Slip (ppm)	BL NOx (lb/hr)	Controlled NOx (lb/hr)	Total NSR	NOx Reduction (%)	Utilization (%)
60817.00	Baseline	8:00	192	9.9	4	Cone 30 up	1.00	80	40	0.0	0.00	205	2090	100.0%		110.000	110.000	0.00	0.0%	0.0%
60817.01	Test stopped	9:15	193	9.9	4	Cone 30 up	1.00	80	40	10.0	0.66	140	2065	80.0%	1.6	110.000	88.000	0.66	20.0%	30.1%
60817.02	4 inj, angled up	11:15	189	9.2	4	Cone 30 up	1.00	80	40	15.0	1.00	147	2078	68.2%	2.9	110.000	75.000	1.00	31.8%	32.0%
60817.03	Urea up 20gph	13:50	190	9.5	4	Cone 30 up	1.00	80	40	20.0	1.22	132	2035	59.2%	3.9	120.000	71.000	1.22	40.8%	33.6%
60817.04	Baseline	14:50	192	10.3	4	Cone 30 up	1.00	80	40	0.0	0.00	144	1995	100.0%		120.000	120.000	0.00	0.0%	0.0%

Unit 3 Test No.	Test Type	Test Time	Steam Load (kpph)	Econ O2 (%)	No. of Inj.	Tip Type	Flow per Inj (gpm)	Liquid Press (psig)	Air Press (psig)	"A" @ Flow (gph)	50% NSR	NOx (ppmvc)	Spectra Temp (°F)	Reduction (%)	NH3 Slip (ppm)	BL NOx (lb/hr)	Controlled NOx (lb/hr)	Total NSR	NOx Reduction (%)	Utilization (%)
60617.00	High load	8:00	190	10.5	8	Cone	0.88	75	50	10.0	0.76	173	1992	85.4%	1.8	96.000	82.000	0.76	14.6%	19.2%
60617.01	Baseline	9:00	193	11.2	8	Cone	0.88	75	50	0.0	0.00	198	1992	100.0%		96.000	96.000	0.00	0.0%	0.0%
60617.02	Test 1 Incr NSR	10:00	192	11.0	8	Cone	0.88	75	50	15.0	1.14	145	1992	75.0%	1.4	96.000	72.000	1.14	25.0%	21.9%
60617.03	Air 40 psig	11:30	190	10.5	8	Cone	0.88	75	40	15.0	1.14	155	1992	83.3%	10.6	96.000	80.000	1.14	16.7%	14.6%
60617.04	Front N/S inj out	14:00	192	9.0	6	Cone	1.33	80	40	15.0	1.14	149	2050	62.5%	1.1	96.000	60.000	1.14	37.5%	32.9%
60617.05	Baseline	15:45	192	9.3	6	30 up	1.33	80	40	0.0	0.00	212	2036	100.0%		96.000	96.000	0.00	0.0%	0.0%
60617.06	6 inj, 30 deg cone up	16:50	192	9.6	6	30 up	1.33	80	40	15.0	1.14	130	2021	57.3%	3.3	96.000	55.000	1.14	42.7%	37.4%

ATTACHMENT C

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Division of Air Resources
625 Broadway, Albany, New York 12233-3250
P: (518) 402-8452 I F: (518) 402-9035
www.dec.ny.gov

March 26, 2018

Dear Stakeholder:

This letter is to inform you of an upcoming stakeholder conference call being held by the Division of Air Resources on April 17, 2018 at 10:00 a.m. to discuss draft revisions to the Department's 6 NYCRR Part 219 incinerator regulations. Connection information for the call can be found below.

The Department is considering adding a new Subpart 219-10 to Part 219 that would limit emissions of oxides of nitrogen from municipal and private solid waste incineration units to less than 150 parts per million by volume, corrected to seven percent oxygen. This limitation is consistent with those promulgated in recent years by neighboring states.

The Department will discuss the draft language of this provision during the webinar. Stakeholder comments will be accepted after the webinar and for a period of 30 days following the meeting. The Department will review these comments as it prepares to formally propose these revisions.

Questions about the webinar or the draft Subpart 219-10 should be addressed to Mark Lanzafame, P.E., who can be reached by phone at 518-402-8403, or by e-mail at air.regs@dec.ny.gov.

Call-in Information:

1-518-549-0500 (local)

1-844-633-8697 (toll free)

Access code: 644 511 956 (without spaces)