**Proceedings of the 17th Annual North American Waste-to-Energy Conference**
**NAWTEC17**
**May 18-20, 2009, Chantilly, Virginia, USA**

# NAWTEC17-2322

## THE DESIGN AND OPERATION OF AN ADVANCED NOx CONTROL SYSTEM ON THE NEW 636TPD MWC AT THE LEE COUNTY WTE FACILITY

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## ABSTRACT

In September of 2007, a new 636TPD Municipal Waste Combustor was brought on line at the Lee County WTE Facility in Fort Myers, FL operated by Covanta Energy. This unit was the first new Waste to Energy unit built in the United States in a number of years and included a lower permitted daily average NOx emissions requirement of 110ppm @ 7%O2 while maintaining ammonia slip to less than 10ppm.

To meet this new stringent NOx emissions requirement, the boiler was designed with advanced combustion controls including Flue Gas Recirculation combined with a urea based Selective Non-Catalytic Reduction Process to provide a combined NOx reduction of approximately 70% while maintaining the required ammonia slip.

The SNCR System provided by Fuel Tech was designed with 3 levels of seven wall injectors installed in the upper furnace. Both boiler load and Furnace Gas Temperature were used as a feed forward control with the CEM NOx signal as a feed back to automatically select the injector levels and reagent feed rates to maintain the targeted NOx while also maintaining ammonia slip control.

This paper will outline the design considerations, the details of the process and the operation of the systems on this unit.

## INTRODUCTION

In September of 2007, a new 636TPD Municipal Waste Combustor was brought on line at the Lee County Waste to Energy Facility in Fort Myers, FL operated by Covanta Energy. This unit was the first new Energy From Waste (EFW) unit built in the United States in a number of years and included a lower permitted average NOx emissions requirement of 110 ppm @ 7% $O_2$ with an ammonia slip limit of less than 30 ppmdv @ 7% $O_2$.

To meet this new stringent NOx emissions requirement, the boiler was designed with advanced combustion controls including Flue Gas Recirculation combined with a urea based Selective Non-Catalytic Reduction (SNCR) system to provide a combined NOx reduction of approximately 70% while maintaining the required ammonia slip.

The SNCR System provided by Fuel Tech was designed with 3 levels of seven wall injectors installed in the upper furnace. Both boiler load and furnace flue gas temperature were used as a feed forward control with the CEM NOx signal as a feed back to automatically control reagent feed rates to maintain the targeted NOx, while also maintaining ammonia slip control. Selection of the injection levels was designed to be either manual or automatic.

This paper will outline the design considerations, the details of the process and the operation of the systems on this unit.

The Lee County WTE Facility originally opened for commercial operation in 1994 with two 600TPD boilers using the Martin Gmbh Reverse Acting Grate stoker. An anhydrous ammonia based SNCR NOx control system was installed on these units to meet the NOx emission permit levels in effect at that time of 180 ppmdv NOx @ 7% $O_2$, while maintaining ammonia slip to less than 50ppmdv @ 7% $O_2$.

The expansion of the facility in 2007 with the addition of a third unit rated at 636TPD represented the first of a new series of large EFW boilers constructed in the industry in more than 10 years. More stringent emissions requirements were imposed by the Florida DEP which included a new NOx emissions standard of 150 ppmdv corrected to 7%$O_2$ on a 24-hour block average as well as 110 ppmvd @ 7% $O_2$ on a 12 month rolling average while maintaining an ammonia slip limit of 30 ppmdv @7% $O_2$ based on quarterly stack tests. The permit also allowed CEMS data to be substituted for quarterly stack testing if the system achieved less than 15 ppmdv ammonia slip @7% $O_2$, on a quarterly average basis.

Based on previous experience on smaller units within the Covanta System as well as Fuel Tech's experience within the industry, The Fuel Tech urea based NOxOUT® SNCR system was selected as the technology with the most operating experience at these more stringent emissions standards. The SNCR system was designed to meet the 110 ppm NOx target while maintaining ammonia slip to less than 10ppm as measured by an FTIR based CEMS ammonia monitor.

## PROCESS DESIGN

The NOxOUT® Process is a post-combustion NOx reduction method that reduces NOx through a controlled injection of 50% urea based reagent into the combustion gas path of fossil-fired and waste-fired boilers, furnaces, incinerators, or heaters. The use of urea for control of oxides of nitrogen was developed between 1976 and 1981. These early investigations provided fundamental thermodynamic and kinetic information of the NOx-urea reaction chemistry and identified some traces of by-products. The predominant overall reaction is described as:

$$CO(NH_2)_2 + 2NO + 1/2\ O_2 \Rightarrow 2N_2 + CO_2 + 2H_2O$$

Urea + Nitrogen Oxide ⇒ Nitrogen + Carbon Dioxide + Water

The application of this technology was expanded with improvements in chemical injection hardware to widen the applicable temperature window, improve the reagent coverage in the furnace and development of process control expertise required for commercial applications.

Two key parameters that affect the process performance are flue gas temperature and the reagent distribution. The NOx reducing reaction is temperature sensitive such that by-product emissions become significant at lower than the optimum temperature range, while chemical utilization and NOx reduction decrease at higher than the optimum. This optimum temperature range is specific to each application. The reagent needs to be distributed within this optimum temperature zone to obtain the best performance. Typically, the distribution is more difficult for large units and for units with high flue gas velocity.

In a urea based system, the urea reagent is diluted with water and injected into the gas stream as discreet droplets with a controlled droplet size distribution and reagent concentration. Utilizing compressed air, injector nozzles are used to atomize and direct the diluted NOxOUT® reagents into the combustion gas path. The urea reagent is released to react with the NOx molecules as the water evaporates. Therefore the concentration of the reagent as well as the mass of the droplet provides better distribution of the reagent in the gas stream. This in turn provides better control of the process providing the required NOx reduction while controlling the ammonia slip.

When compared to the anhydrous ammonia based SNCR systems in use on the other boilers at this facility, the urea based system is better able to meet the lower NOx levels while maintaining tighter ammonia slip control because of the fundamental differences in the reaction kinetics of the two technologies. Both technologies are based on achieving optimum distribution of the reagent in the gas stream, within the proper temperature window for the SNCR NOx reduction reaction to occur.

Anhydrous ammonia, once vaporized, must be injected in the upper furnace with high energy to promote mixing with the furnace gases. This approach has been successful with the less stringent NOx reduction requirements of earlier waste fired units. However to meet the new lower NOx and ammonia slip requirements of current permits, better reagent distribution within the furnace gases is required to assure the ammonia molecules effectively react with the NOx molecules. A gas jet will mix with the main gas flow in a turbulent process that is difficulty to predict and therefore difficult to control. Excess reagent would therefore be required to achieve targeted NOx reduction. This increases the probability of higher ammonia slip rates.

Urea has a lower vapor pressure than water in the upper furnace post-combustion conditions and the majority of the urea is released into the gas phase when the droplet water has substantially evaporated. Since the chemical reactions do not occur until the urea is released, the momentum of the droplet and the required evaporation time allow for significant penetration into the furnace and reaction within the appropriate temperature window, even when injected at higher than optimal temperatures.

## LEE COUNTY APPLICATION

The new 636TPD boiler at Lee County is 32 ft wide with a furnace depth of approximately 16ft just above the grate. The furnace was designed with over fire air and flue gas recirculation added to reduce the projected baseline NOx from 350ppm to 273.4 ppmdv @7% $O_2$ at full load. The combustion system design called for air distribution of approximately 64% under grate air, 12.6% over fire air (OFA) and 23.4% flue gas recirculation (FGR) introduced at the front and rear walls of the furnace. The projected furnace outlet temperature was approximately 1618ºF.

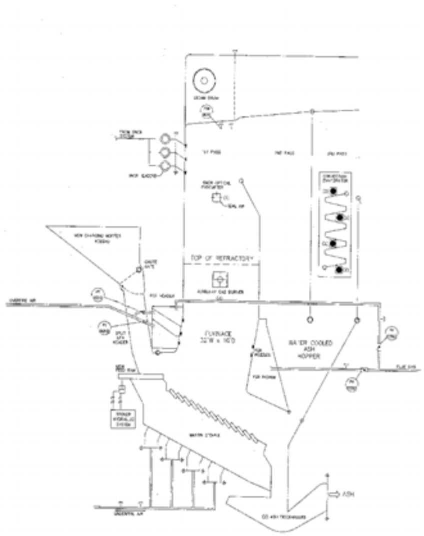

**Figure 1**

The design of the system called for guaranteed NOx levels over the entire operating load range of the unit from approximately 70 to 100% load.

The initial SNCR System Process Design included 3 levels of seven wall injectors. Multiple levels of injectors have been utilized by Fuel Tech to maximize coverage of the reagent in the furnace by following the temperature window as the load and firing conditions change. These were designed to automatically control the flow of diluted reagent to each level based on the load, furnace gas temperatures and reagent required to maintain the targeted NOx emissions level and minimize ammonia slip.

This also provides the capability of adjusting the elevation at which NOxOUT® solution is injected as the furnace becomes fouled and the temperature window moves higher in the furnace.

The final step in the SNCR process design was to determine the optimum injection port locations and injection strategies based on Fuel Tech’s proprietary Chemical Kinetics Model (CKM) and Computational Fluid Dynamic (CFD) model technology. The CFD model was used to predict the expected temperature and flow patterns in the unit. The CKM predicted the NOx reduction potential and by-product emissions from the indicted baselines for each of the load cases as a function of the chemical release temperature and reagent flow rates. The CFD model was used to evaluate injection strategies satisfying the chemical release requirements determined by the CKM to achieve maximum NOx reduction and adjusted to insure that the predictions were in agreement with the expected temperatures provided in the original design. The CKM was then used to estimate the expected NOx reduction and by-product emissions. The injector placement on the unit was guided by the CFD model.

## CFD MODEL FIGURES

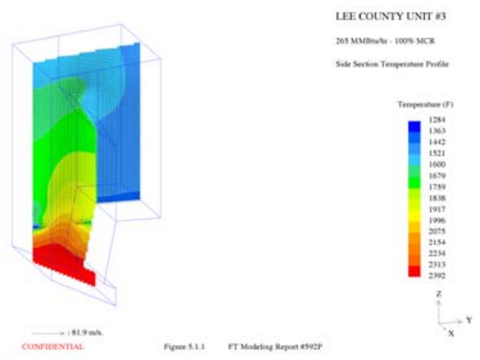


**Figure 2**

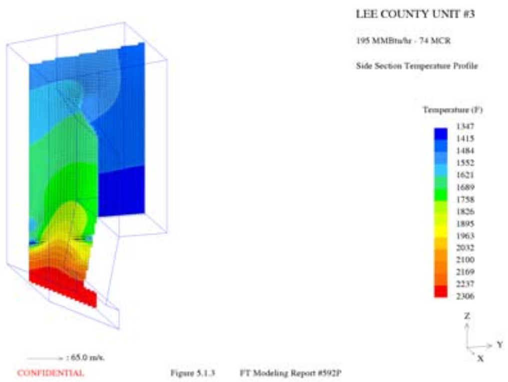


**Figure 3**

Figures 2 and 3 provide the modeled temperature and velocity profile of the unit at both100% load (265 MMBtu/hr) and 74% load (195 MMBtu/hr). Note that the model ends at the outlet of the second pass.

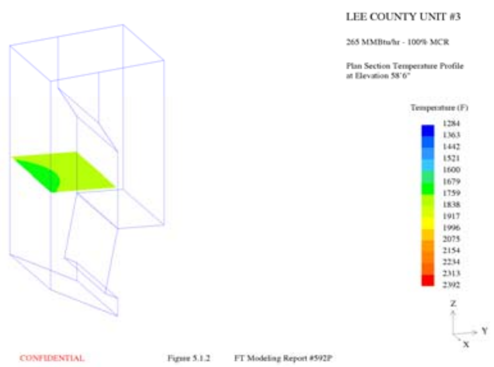


**Figure 4**

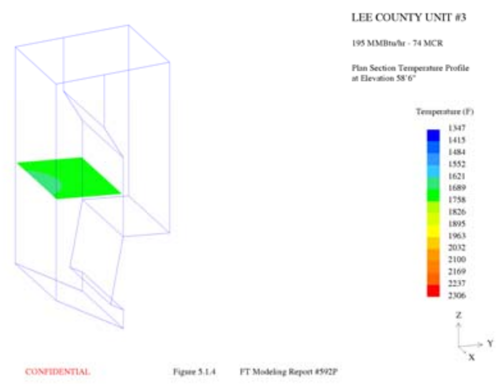


**Figure 5**

Figures 4 and 5 show the plan section temperature profiles for both load conditions at one elevation (El 58'6").

As an example, the following figures (Fig 6, 7, and 8) represent predicted distribution as well as the boundary temperature window for each of the proposed injector levels at full load for the lower baseline design conditions. Similar models runs were made for the higher baseline NOx which requires a slightly different temperature profile at low load conditions.

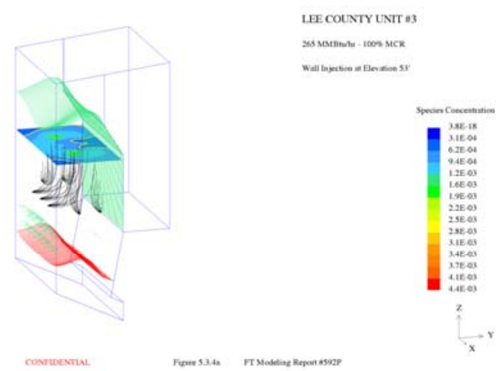


**Figure 6**

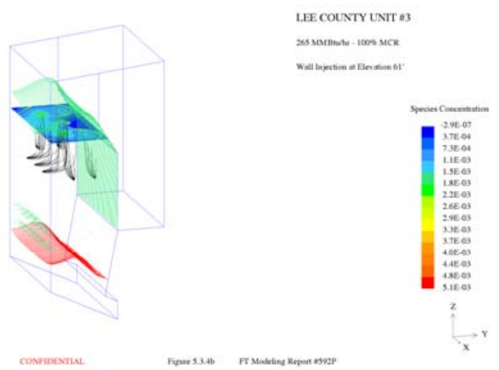


**Figure 7**

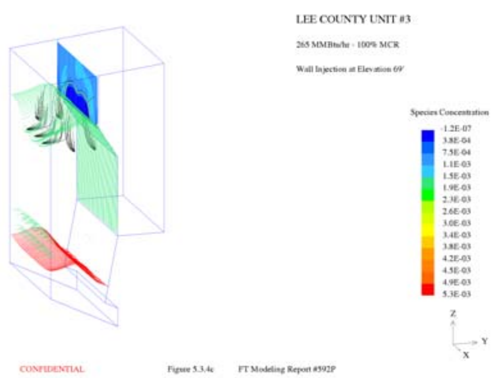


**Figure 8**

## SNCR SYSTEM EQUIPMENT

The SNCR system installed at the Lee County Facility consisted of a 15,000 gallon FRP heated and insulated Reagent Storage Tank designed for tank truck deliveries of 50% urea based reagent. (See Figure 9 Process Flow Diagram) A circulation module enclosed in a weatherproof building was installed next to the storage tank was designed to provide continuous circulation of the urea as well as reagent feed to the metering and dilution module located near the boiler at the injection level.

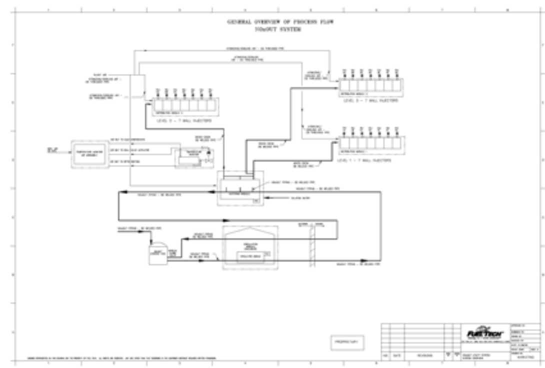

**Figure 9**
**Process Flow Diagram**

The metering and dilution module located at El 61ft consists of a series of chemical metering and water dilution pumps. The module is designed to automatically add urea solution to a dilution water stream, and control the flow to each level of injection based on the requirements of the system. At each injection level, a distribution panel controls the distribution of the reagent and compressed air to each of the seven wall injectors.

A gas temperature monitor installed in the furnace was also provided by Fuel Tech to provide a faster responding signal that would be used along with steam flow as part of the feed forward control of the system.

The system is controlled through an Allen Bradley SLC 5/04 PLC installed on the Metering Module. The feed forward signal is used to determine which injection level is required and how much reagent to feed to each level. The CEM NOx signal is used as a feedback to trim the reagent feed to maintain the targeted NOx emissions level. A “Lookup Table” installed in the PLC was ultimately developed during start-up and optimization of the system, when the reagent feed rates and injection levels were established while measuring ammonia slip rates at each test condition.

The PLC is interconnected by Ethernet to the plant DCS which provides remote monitoring and control of the SNCR system.

In addition to the CEM, the plant installed an FTIR based CEMS ammonia monitor at the ID Fan inlet which was also monitored in the control room. The CEMS ammonia monitor was a requirement of the Air Permit for monitoring purposes only. In addition, as long as the quarterly average ammonia slip levels are less than 15 ppmdv @ 7% $O_2$, then the quarterly stack test for ammonia can be eliminated.

## SYSTEM OPERATION

The SNCR system was started up and optimized by Fuel Tech in August and September of 2007. After the system checkout, the system was optimized by adjusting the reagent flow, dilution rate, air and liquid pressure at each load point.

During the optimization, the system was shut down to record baseline NOx conditions with the FGR and OFA in Service. The baseline NOx at full Load was recorded at 260 to 270ppm. This was followed by the adjustment of the operating parameters including reagent flow, dilution rate, air and liquid pressure at each load point, for each level of injectors. Ammonia testing by wet chemistry, using Method CTM-027 was conducted at each data point to assure maximum NOx reduction with minimum ammonia slip.

The optimization was completed using only reagent injection at levels 1 and 2. The upper level 3 injectors were not placed in service but will be available for future operation based on changes in the operation of the boiler.

Based on the results of the optimization testing, a revised "Look-Up" table was updated in the PLC control system. The system was then capable of full automatic operation to maintain the targeted NOx and ammonia slip levels over the load range of the boiler.

During the first week of November, 2007, a 7 day Environmental Performance Test for NOx and ammonia was conducted by Covanta as part of the system acceptance. The testing was performed on the system to demonstrate the capability to operate at full load over 7 days within the NOx limit of 110 ppmdv @ 7% $O_2$ with an ammonia slip of less than 30 ppmdv @ 7% $O_2$.

The CEMS was used for the NOx emissions data while the FTIR based CEMS ammonia monitor was used for the ammonia slip measurements. The FTIR performance was certified according to the provisions of 40CFR60 Appendix B, Performance Specification Test 2 (RATA) testing with Method CTM-027, Conditional Test Method for Collection and Analysis of Ammonia, as required by the air permit.

The average results over the 7 days of the Environmental Performance Test (excluding downtime) were summarized as follows:

| **Parameter** | **Test Average** | **Allowed** | **Units/Source** |
|---|---|---|---|
| NOx | 102.5 | 110 Maximum | ppm dry corrected at Stack (CEM Reported) |
| $NH_3$ | 4.8 | 30 Maximum | ppm dry corrected at Stack (CEM Reported) |
| Steam Flow | 169.3 | 165 Minimum | Klbs/hr from DCS based on FW minus BD |
| Reagent Consumption | 17.6 | | gph from Metering Module |

Through most of 2008, the SNCR system operated to maintain NOx levels within the interim limits allowed by the permit. In November 2008, the set point was lowered to assure compliance with final permit NOx limits. Although load on the unit has been operating at about 80% of capacity, the SNCR system has continued to automatically track to the targeted set point. The average performance for the month was as follows:

**Lee County Unit #3**
**November 2008 Average Performance Data**

| | |
|---|---|
| Average Steam Flow klbs/hr | 156.1 |
| NOx ppm @ 7% $O_2$ | 109.6 |
| Ammonia slip, ppm @ 7% $O_2$ | 3.7 |
| Reagent consumption, gph | 13.5 |

## OTHER ISSUES

In an effort to reduce overall environmental impact of the facility, filtered municipal waste water treatment reclaim water is used as the dilution water supply for the SNCR system. The 50% urea reagent is added to the dilution water at the metering module. The only impact of this dilution water on the operation of the system was the fouling of downstream filters and the sight glass flow monitors for each of the injectors which clouded over with a green algae/like coating. This was ultimately solved by the plant with the addition of a biocide to the urea reagent storage tank with each load.

## CONCLUSIONS

Based on the experience at the new Lee County Unit #3, a combination of boiler design, combustion controls, Flue Gas Recirculation and a urea based SNCR system provides a reliable approach to meeting permitted NOx emissions limitations as low as 110 ppmdv @7% $O_2$ while limiting ammonia slip to less than 15 ppmdv @ 7% $O_2$.

The NOxOUT® Process, designed by Fuel Tech with the aid of Computational Fluid Dynamics (CFD) and Chemical Kinetic Model (CKM) program data in addition to results from field testing, provides an optimized SNCR system design tailored to the needs of each individual furnace design.

The FTIR based CEMS ammonia monitor designed by Covanta continues to provide a reliable continuous ammonia slip signal and is a considerable improvement over 1 hour wet chemistry tests normally required for contractual acceptance and quarterly tests required for ongoing permit compliance.

## ACKNOWLEDGEMENTS:

We would like to acknowledge the assistance of the following for their assistance in the preparation of this paper; Nick Gorsky, and Jim Schneider at Covanta in Fairfield, NJ and MIke Duff, Chief Engineer at the Lee County Facility

## REFERENCES

1. US Patent 4,208,386 issued to EPRI, June 17, 1980
2. Muzio, L.J., Arand, J.K., Teixeira, D.P., 1977, Sixteenth International Symposium on Combustion: The Combustion Institute; Pittsburg, PA, pp 199-208.
3. Sun, W.H., Hoffman, J.E "Reaction Kinetics of Post Combustion NOx Reduction with Urea." Presented at the AFRC 1991 Spring Members Meeting, March 18-19, 1991, Hartford, CT