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NEW PROCESS FOR ACHIEVING VERY LOW NO_X

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ABSTRACT

Over the last two and a half years, Covanta Energy, working with their technology partner, Martin GmbH of Germany, has developed and commercialized a new technology for reducing NO_x emissions from Energy from Waste (EfW) facilities. NO_x levels below 60 ppm (7% O2) have been reliably achieved, which is a reduction of 70% below the current EPA standard and typical levels of today's EfW facilities in the United States. This technology represents a significant step forward in NO_x control for the EfW industry.

The technology, known as VLN™, employs a unique combustion system design, which in addition to the conventional primary and secondary air streams, also features a new internal stream of "VLN™-gas," which is drawn from the combustor and re-injected into the furnace. The gas flow distribution between the primary and secondary air, as well as the VLN™-gas, is controlled to yield the optimal flue gas composition and furnace temperature profile to minimize NO_x formation and optimize combustion. The VLN™ process is combined with conventional, aqueous ammonia SNCR technology to achieve the superior NO_x performance. The SNCR control system is also integrated with the VLN™ combustion controls to maximize NO_x reduction and minimize ammonia slip.

A simplified version of the process, known as LN™, was also developed and demonstrated for retrofit applications. In the LN™ process, air is used instead of the internal VLN™ gas. The total air flow requirement is higher than in the VLN™ process, but unchanged compared to conventional systems, minimizing the impact on the existing boiler performance and making it ideal for retrofit applications.

Covanta first demonstrated the new VLN™ and LN™ processes at their Bristol, Connecticut facility. One of Bristol's 325 TPD units was retrofitted in April of 2006 to enable commercial scale testing of both the VLN™ and LN™ processes. Since installing and starting up the new system, Bristol has operated in both VLN™ and LN™ modes for extended periods, totaling more than one year of operation at NO_x levels at or below 60 ppm (7% O2). The system is still in place today and being evaluated for permanent operation.

Based on the success of the Bristol program, Covanta installed LN™ NO_x control systems in a number of other existing units in 2007 and 2008 (total MSW capacity of over 5000 TPD), and is planning more installations in 2009. All of these retrofits utilize the Covanta LN™ system to minimize any impacts on existing boiler performance by maintaining existing excess air levels. Going forward, Covanta is making the LN™ technology available to its existing client base and is working with interested facilities to complete the necessary engineering and design modifications for retrofit of this innovative technology.

For new grassroots facilities, Covanta is offering the VLN™ system with SNCR as its standard design for NO_x control. An additional feature, particular to VLN™, is the reduced total combustion air requirement, which results in improved boiler efficiency. This translates into increased energy recovery per ton of waste processed.

In addition to introducing the VLN™ and LN™ processes, this paper will provide an overview of the Bristol development and demonstration project. NO_x and NH_3 slip data from Bristol will be presented, illustrating the extended operating experience that has been established on the system. Other operating advantages

of the new technology will also be discussed, along with lessons learned during the start-up and initial operating periods.

The VLN™ technology has been demonstrated to decrease NO_x emissions to levels well below any yet seen to date with SNCR alone and is comparable to SCR-catalytic systems. The result is a significant improvement in NO_x control for much less upfront capital cost and lower overall operating and maintenance costs. VLN™ also goes hand in hand with higher energy efficiency, whereas SCR systems lower energy efficiency due to an increased pressure drop and the need for flue gas reheat. The commercialization of the VLN™ and LN™ processes represents a significant step forward in the reduction of NO_x emissions from EfW facilities.

INTRODUCTION

Emissions from U.S. Energy from Waste (EfW) facilities have been significantly reduced over the past ten to fifteen years, making them one of the cleanest sources of electrical power in the nation. While very significant reductions have occurred for most of the pollutants, the available technology for reducing NO_X emissions, Selective NonCatalytic Reduction (SNCR), was not able to achieve reductions of the same scale. Mass-burn EfW units typically operate with uncontrolled NO_X emissions in the range of 300 ppmdv corrected to 7% O2. The Federal permit limit for NO_X emissions is currently 205 ppm for large mass-burn units constructed prior to 2005, and 150 ppm for newer units. In some states or regions, more stringent limits of 180 ppm are in place for older units. The limits being imposed on new units have been significantly lower than the current Federal limit. For example, the expansion unit at Lee County, FL, which began commercial operation in 2007, has an annual average NO_X limit of 110 ppmdv @ 7% O2, while the expansion unit currently under construction at Hillsborough County, FL has a permit limit of 90 ppmdv @ 7% O2. These limits are pushing the capabilities of conventional SNCR technologies.

Another option for NO_X control is Selective Catalytic Reduction (SCR). This approach significantly increases both the capital and operating costs for the facility, and reduces energy efficiency due to the need to reheat the flue gas to the temperature required for the reduction reactions after the acid gases and particulate have been removed in the air pollution control system. SCR systems are capable of reducing NO_X to approximately 50 ppmdv, albeit at a significant cost.

Covanta Energy and Martin GmbH have jointly developed a new technology for reducing NO_X emissions from EfW facilities to a range very close to that achieved by SCR technology, but at a significantly lower cost. The process, known as Very Low NO_X, or VLN™, operates by removing a stream of gas from the lower grate area, and reinjecting it into the furnace at an elevation above the conventional overfire air nozzles. U.S. and foreign patents are pending on this process, and a simplified version known as LN™ in which air is used in the new injection nozzles.

Process Description

EfW systems typically employ a moving grate with two major sources of combustion air. Primary air (also called underfire air) is supplied through plenums located under the grate, and is forced through the grate to dry and combust the waste. The quantity of primary air is typically adjusted to minimize excess air during the combustion of the waste on the grate, while maximizing burnout of carbonaceous materials in the waste bed. Secondary air (also called overfire air) is injected through nozzles located in the furnace waterwalls immediately above the grate, and provides turbulent mixing to complete the combustion process. Secondary air provides the majority of the excess air to the combustion process.

With the VLN™ process, the secondary air stream is reduced, and a "VLN™" gas stream is introduced through a new series of nozzles, installed at a higher elevation in the furnace, as shown in Figure 1. The VLN™ gas is taken from the roof of the lower furnace, above the last grate section. This location is beyond the fireline in normal operating conditions, and as a result, the gas is relatively cool, and has little corrosion potential.

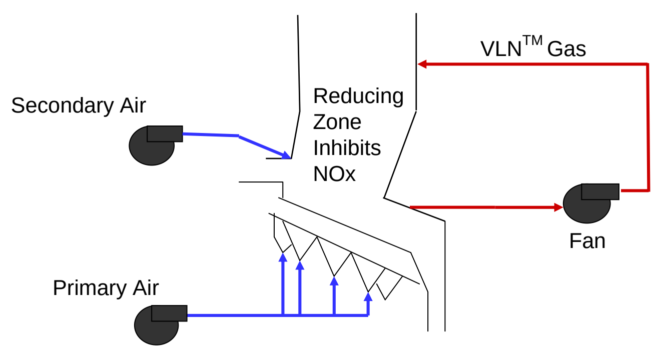

Figure 1
Process flow diagram of the VLN™ process

The relative amounts of primary and secondary air, and the VLN™ gas stream are controlled to yield the optimal gas composition and temperature to minimize NO_X, while simultaneously maintaining high burnout and low CO. The control takes into account the heating value of the waste and the fouling condition of the furnace. The combination of these combustion changes yields an increase in furnace efficiency (more steam per ton of MSW fired).

The design of the VLN™ gas nozzles and their positioning in the furnace is crucial to the process performance. The design must achieve complete coverage of the furnace cross-section to ensure good mixing with the combustion gases. The VLN™ gas injection level acts like a curtain for flames or unburnt material and moderates the furnace temperatures for the SNCR. Furthermore, it yields uniform flue gas temperature and velocity profiles.

For retrofit applications, a simplified version of the process has been developed. This process, known as LN™, uses air in place of the VLN™ gas. LN™ is generally more suitable for existing boilers because the additional fan is not necessary, and because the total air flow through the furnace is maintained at the original level, minimizing the impact on the boiler performance.

Development Program at Bristol

Covanta and Martin selected the Bristol Resource Recovery Facility in Bristol, CT as a test facility during the development of this new process. Bristol is a 650 tpd facility owned and operated by Covanta, under an agreement with the Bristol Resource Recovery Facility Operating Committee (BRRFOC). It consists of two 325 tpd Martin reverse-reciprocating stokers, each producing steam at 865 psi / 830 F, and generates up to 16.3 MW of electrical power. The plant began commercial operation in 1988.

Bristol’s air Pollution Control System (APC) and emissions limits are typical for a modern EfW facility. APC equipment consists of a dry scrubber and baghouse for acid gas and particulate control, carbon injection for mercury and dioxin control, and an SNCR system injecting aqueous ammonia into the furnace for NO_X control. The NO_X limit is 205 ppm.

A complete Computational Fluid Dynamics (CFD) model of the Bristol boiler was developed to evaluate design alternatives and predict performance of the VLN™ test system. The model utilized Covanta’s advanced integrated grate combustion model (Ref. 1) which fully models the primary combustion process on the grate, including drying, devolatization, and burnout. This was essential to get an accurate assessment of the variation in composition and temperature of the gas above the fuel bed along the grate.

The model included the mixing and secondary combustion associated with overfire air injection, with cases run in both the conventional operating mode and the modified mode necessary for the VLN™ process. For the VLN™ mode, the model incorporated the extraction of the VLN™ gas in the lower furnace, and reinjection through new nozzles higher up in the furnace.

Outputs of the model included complete temperature and velocity profiles through the furnace, as well as flue gas composition including CO and NO_X emissions. This was the first time that Covanta used CFD modeling to predict NO_X formation and emissions. The modeling approach used for NO_X is approximate, and results were not expected to be accurate on an absolute basis, but the relative differences resulting from different modeling conditions were expected to correlate with actual differences in operation. The model was validated using test data taken during conventional operating conditions, as well as during a short-term conceptual test, and finally during full operation of the complete system.

Modifications to boiler 1 at Bristol were made during the spring outage in March, 2006. This included installation of the new VLN™ fan, ducting, instrumentation, and tertiary gas nozzles. Testing of the system began in June, when a full test team from Martin and Covanta arrived at the facility. Initial testing focused on measurement of NO_X emissions with and without SNCR, temperature profiles through the furnace, and gas flows and compositions.

To allow an accurate calculation of the mass and energy balance of the boiler, an economizer heat balance approach was used to measure flue gas flow. This method required installation of a grid of thermocouples in the flue gas stream at the economizer inlet to accurately measure the average inlet gas temperature. The resulting temperature was used with existing instrumentation for gas outlet temperature, feedwater flow, and feedwater temperatures, to calculate a real-time flue gas flow rate.

High Velocity Thermocouple (HVT) probes and CO2-wavelength infrared thermometers were used to measure gas temperatures at several elevations in the furnace.

A number of tests were conducted with the SNCR system in operation. Objectives of these tests included not only determining the minimum NO_X emissions achievable, but confirming that excessive ammonia slip did not occur at the stack. For this purpose, a laser-based in-situ ammonia slip analyzer (Servomex Lasergas II model 2920A) was installed at the boiler outlet for certain tests.

Initial Test Results

During the initial test period in June, 2006, a series of short term tests was conducted to evaluate the system’s capabilities. Results confirmed that the modified system was able to achieve substantially lower NO_X emissions without SNCR, and confirmed the CFD predictions as shown in Table 1.

Table 1

	CFD Model Predictions	Test Results
O_2	5.0	4.9
NO_x	149	156
CO	29	12
Temperature (°F)	2230	2084 (Thermocouple)

Comparison of CFD model predictions and test results as measured in the Bristol test unit. Note that the furnace temperature was measured using a thermocouple, which typically reads about 200 °F lower than the actual temperature due to radiation losses and cooling effects near the walls.

Figure 2 illustrates the difference between conventional and VLN™ operation without ammonia injection. This chart shows NO_x emissions over a six-hour period in which the VLN system was running for about two and a half hours, then shut off for about two hours, then returned to service. Average NO_x concentration during the two hours of conventional operation was 280 ppmdv @ 7%O_2. During the four hours of VLN™ operation shown in this chart, the average NOx concentration was 168 ppmdv @ 7%O_2.

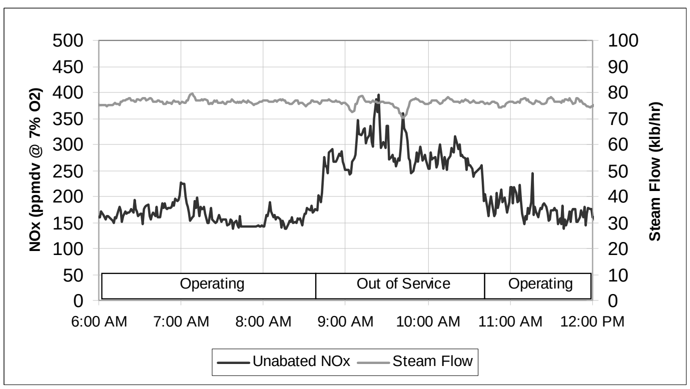

Figure 2

Unabated (i.e. without ammonia flow) NO_x emissions during a six hour period with VLN™ in operation, removed from operation, then returned to operation. Data are collected at 1-minute intervals.

When operated in combination with the existing aqueous-ammonia-based-SNCR system, NO_X emissions were reduced to 50 to 60 ppm with no increase in ammonia slip values. Increasing ammonia feed rate resulted in lower NO_X emissions, but at higher slip levels. Thus 50 to 60 ppm was determined to be the initial NO_X target for long term operation.

Long-Term Test Results

Following the scoping tests, the system has been in operation the majority of the time since installation. Figure 3 illustrates NO_X performance over a five-month period, with the system placed in service about a week into the chart. The effect on NO_X is very clear. During the operating periods, the NO_X setpoint was usually 60 ppm, but many days were operated at 50 ppm.

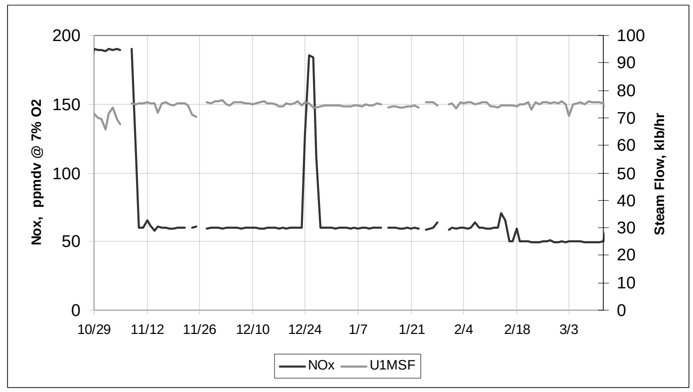

Figure 3

NO_x and steam flow rate during five months of operation between October, 2007 and March, 2008. Values plotted are 24-hour daily averages calculated from values taken at 1-minute intervals. Facility NO_x permit limit is 205 ppm, and typical operating point is 190 ppm as shown at left. During operation of the VLN system, setpoints of 50 and 60 ppm were routinely achieved

The VLN™ system at Bristol has been in operation most of the time since its original installation. During this period, a number of different tests have been conducted operating in various modes, both with and without ammonia injection. Cumulatively, the boiler has operated for over a year with stack NO_X levels at 50 to 60 ppm.

Table 2 summarizes some of the key results of these tests, and illustrates the long-term consistent performance that we have observed with the system in over a year worth of operating days.

Table 2
Key Performance Data Summary
based on over two years of operation

Without ammonia	NO_X reduced ~50% NO_X typically 130 – 180 ppm Meets current MACT standard for existing plants without SNCR
With ammonia	NO_X < 60 ppm No increase in NH_3 slip

Additional Installations

Based on the success of the Bristol test work, Covanta has installed Low NO_X retrofits on ten Covanta-operated mass burn EfW boilers, with several others currently in the planning or engineering stage. Covanta operates three facilities in New Jersey, which has recently issued new regulations that will reduce NO_X limits to 150 ppm beginning in 2009 or 2010, depending on the extent of modifications necessary to achieve the reductions. Because of this requirement, all three New Jersey facilities are being modified with Low NO_X systems during 2009 and 2010.

The expansion unit at Hillsborough was issued a permit with a NO_X limit of 90 ppm – a value which could not be guaranteed using commercially available SNCR NO_X reduction technologies. Based on the success at Bristol, Covanta offered to guarantee the 90 ppm NO_X limit using an LN™ system. Hillsborough County accepted the proposal, and the new boiler is now equipped with LN™ and a conventional aqueous ammonia based SNCR system. Startup of this unit will take place this summer.

The Hennepin Energy Recovery Center is located in downtown Minneapolis, adjacent to the site of the new baseball stadium currently under construction. Hennepin County asked for a less hazardous approach to NO_X control than the anhydrous ammonia system installed during plant construction. Covanta proposed that the LN™ system be installed on the two boilers to reduce the need for an SNCR reagent. The systems were installed in late 2007 and early 2008. Since then, both boilers have been operated without any reagent injection, while continually in compliance with the 205 ppm NO_X emissions limit.

Similarly, Montgomery County, MD requested that the anhydrous ammonia SNCR system be replaced with a less hazardous reagent to eliminate the anydrous ammonia storage tank. In discussions regarding the capabilities of the LN™ technology, they asked that we not only eliminate anhydrous ammonia, but also reduce NO_X emissions from the current 180 ppm permit limit to half that value. Covanta signed an agreement to install LN™ on all three boilers, and to replace the existing anhydrous ammonia system with an aqueous ammonia based SNCR system. While the permit limit remains at 180 ppm, the contract now requires operation at 90 ppm NO_X.

CONCLUSION

Covanta and Martin have cooperatively developed a new, patent-pending technology that allows significant reductions in NO_X emissions from mass-burn EfW facilities. It has been successfully installed in thirteen boilers ranging in design capacity from 200 to 900 tpd. Operating alone, this technology is able to reduce NO_X emissions from approximately 300 ppm normally observed to a range from 130 to 180 ppm. In conjunction with conventional SNCR systems, the LN™ technology can consistently achieve emissions levels of 70 to 90 ppm, while the VLN™ technology can consistently operate below 60 ppm. This technology is now commercially available and can play a significant role in reducing NO_X emissions from both new and existing EfW facilities.

Covanta is continuing to develop this technology with a significant R&D commitment in order to further reduce NO_x emissions from EfW facilities.

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