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DyNOR™ DENOX PERFORMANCE CONFIRMED IN FURTHER MSW PLANTS

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ABSTRACT

Von Roll Inova's innovative new SNCR process is up to the task. This new approach takes the well known Selective non-catalytic reduction process to new heights (lows). By monitoring process conditions very closely and implementing a quick-reacting, highly precise mechanical system for distribution of the reducing agent, emissions can be limited to levels comparable to those demonstrated by SCR.

Von Roll Inova's **DyNOR™ (Dynamic NO_x Reduction)** process takes advantage of fast and precise infrared pyrometer measurements in the exact locations where reagent is needed. Coupled with a patented distribution system, reagent injection is continuously directed to the optimal location in the furnace. The system is capable of responding to changes in a matter of seconds and thus can correct for uneven temperature profiles which are typical in combustion systems with inhomogeneous waste fuel such as MSW.

Good combustion control can limit uncontrolled NO_x emissions to less than 200 ppmv and forms the platform upon which secondary NO_x reduction measures should build. The conventional Von Roll Inova SNCR process limits NO_x emissions to 100 ppmv. **DyNOR™** pushes the envelope further towards 70 ppmv NO_x and less than 10 ppmv ammonia slip and closes the gap towards capital intensive catalytic systems.

Long term trials at a full scale industrial installation have demonstrated emission levels well below 75 ppmv with ammonia slip below 15 ppmv. Now this process has successfully been implemented as a retrofit in a commercial unit. Results confirm that these levels can be safely achieved without compromising furnace air distribution and residence time.

INTRODUCTION

Nitrogen oxides are the one criteria pollutant that has experienced the least relative reduction over the last 20 years (see Figure 1).

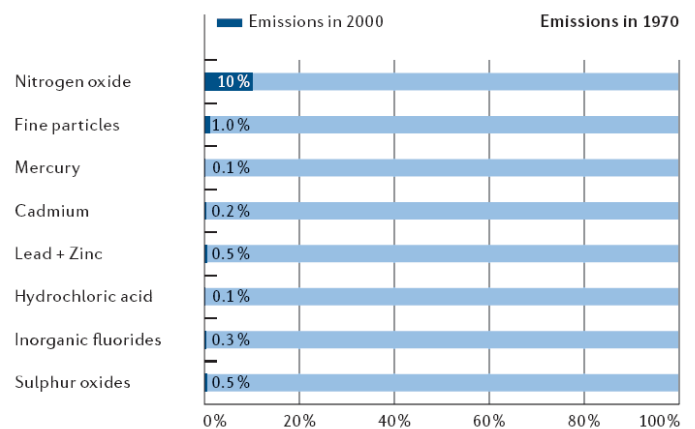


Figure 1: Percent emission reduction of Swiss EfW plants between 1970 and 2000 (1) including primary and secondary measures

Now, European efforts to reduce the emission limit are taking hold: Germany has instituted a new limit of 100 mg/Nm³ (68 ppmv) for new Energy from Waste plants and France has combined a limit for existing plants with a financial incentive to reach 80 mg/Nm³ (55 ppmv). Norway uses a similar taxation approach to minimize NO_x emissions. Switzerland and the Netherlands mandate limits of 80 and 70 mg/Nm³ respectively.

Established SNCR systems in energy from waste plants typically rely on two to three levels to inject the reducing agent (ammonia or urea) through numerous nozzles. Switching from

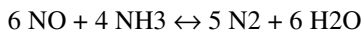
one level to the next is initiated in response to changing temperature in the combustion chamber or is some times done manually after a significant rise of the furnace temperature profile due to increasing boiler fouling. Inaccurate and slow temperature measurements are usually not able to respond to the quickly changing process parameters. This fact is augmented by the rather crude switching scheme implemented by a complicated array of valves and long pipe runs. This technology typically achieves 30..50% NO_x reduction (2,3), which in EfW plants is tailored to the actual NO_x limits 150 ppm or 200 mg/Nm³, but it have to leave the field to the more expensive SCR technology if lower values were required.

NOMENCLATURE

EfW	Energy from Waste
mg/Nm ³	contaminant concentrations indicated the European way based on 11 % oxygen, dry gas
ppmv	contaminant concentrations indicated the US way based on 7 % oxygen, dry gas

SELECTIVE NON-CATALYTIC REDUCTION (SNCR)

Commonly NO_x that has been created in the combustion process can be reduced by reacting it with a strong reducing agent such as NH₃ according to the following reaction:



This reaction can only take place under very controlled conditions, unless it is forced by means of a catalyst. Most importantly the reaction will run best at temperatures in the range of approximately 1600 F to 2100 F. Below this range the reaction will not take place (completely) and un-reacted ammonia will be emitted while at higher temperatures ammonia will oxidize to actually increase NO_x emissions. In order to apply the SNCR process to MSW furnaces the reagent must be introduced at the correct location (temperature) and be distributed evenly within a reasonably short period of time. In case urea is used in place of ammonia an additional dimension is added. Urea must first decompose to form ammonia before it can react as described above. The decomposition time must be considered when designating the best injection location. Best locations for urea based systems are typically at the higher end of the temperature range while for ammonia based systems they are rather at the lower end.

Best practices in MSW combustors in terms of NO_x emissions begin with furnace design and combustion controls. The furnace must allow for positive control of the combustion process:

- Good feed control of waste fuel
- Precise distribution of primary combustion air in response to process needs and minimal uncontrolled air in-leakage
- Post combustion optimized in terms of the 3T's:

- Temperature, e.g. min. 1562°F (850°C), for..
- Time, e.g. 2 sec above the last injection of air
- Turbulence, e.g. by Von Roll Inova's SWIRL injection

Figure 3 shows the results, when all these measures are implemented.

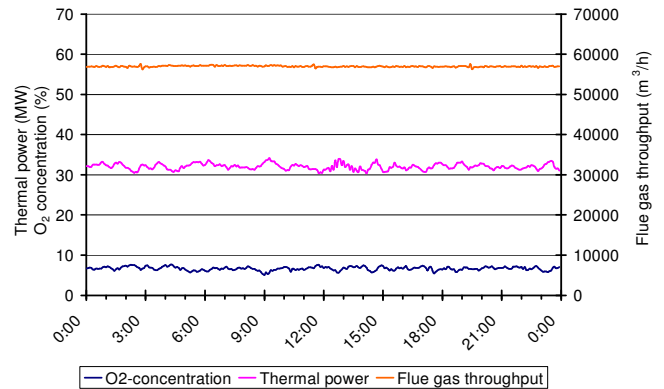


Figure 3: Actual 24h plant operating data using Von Roll Inova combustion control system (hh:mm)

Despite best efforts in combustion control, dealing with an inhomogeneous fuel such as MSW results in a certain variability of temperature regarding place and time. These changes are often not visible, if the measurement occurs by means of single, slow-acting thermocouples (see Figure 3). Good combustion control results in steady oxygen and temperature levels on a 10 minute average basis. However, quick-response measurements, e.g. with infrared pyrometers, show a completely different picture. As shown in Figure 4, flue gas temperatures can routinely vary from left to right by up to 270 F. Variation over time at the same spot can reach 180 F within 60 seconds.

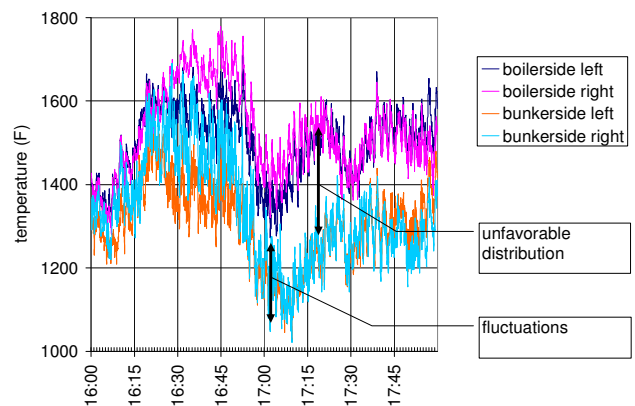


Figure 4: Temperature curves of four IR Pyrometers (hh:mm)

Such dramatic variations have a significant impact on the SNCR process. If left uncontrolled, this could actually mean that in a large percentage of time the reaction agent is injected at the wrong place.

THE DyNOR™ PROCESS

Von Roll Inova's new SNCR process responds in time to these short-term variations and delivers the correct amount of reducing agent to the precise location where it is needed most. The DyNOR™ process (patent applied for) was developed to meet the new EU standards of 80 mg/m³ NO_x (55 ppmv) and 10 mg/m³ NH₃ slip (18 ppmv) or for future US EfW projects which typically request 75-90 ppmv NO_x and 10-15 ppmv NH₃ limits. This objective was reached in full scale demonstration tests at a MSW combustion plant in Trondheim, Norway as well as in a commercial EfW plant at Pithiviers, France. DyNOR™ follows the fundamentals of the well known SNCR process.

Ammonia or urea is used as reagent and reagent injection occurs at different levels in response to measured flue gas temperatures. However, the means of distribution takes into consideration the dynamics shown in figure 4. The process approach is based on:

- Steady control of combustion temperature within the possibilities of a modern MSW combustion plant
- Controlled reagent feed based on stack NO_x emissions
- Precise and quick measurement of flue gas temperatures (see figure 4) in various boiler regions
- Selection of injection location based on individual temperature measurements in the same boiler segment

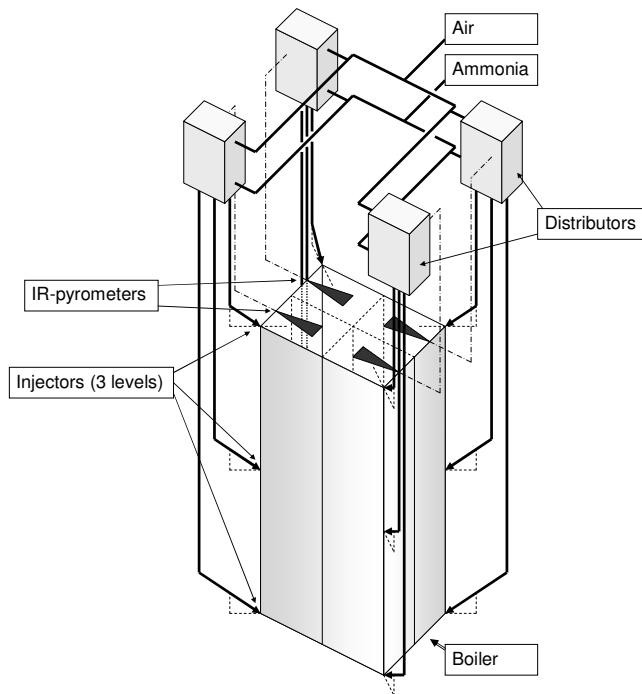


Figure 5: Vertical sectors in the first boiler pass (here 4)

However, to respond to the fast short-term temperature changes in the furnace as shown in figure 4 led to two new key aspects of the DyNOR™ process:

- Reagent injection must be flexible enough to follow the three-dimensional temperature profile
- Injection level changes must be as quick as the temperature changes and occur in a smooth, uninterrupted fashion.

These process needs are addressed by virtually segregating the furnace into several vertical sectors, as indicated in figure 5. In each of the sectors the temperature is individually measured and reagent is injected at the short-term correct location on one of the three to four levels.

For DyNOR™ implementation an EfW plant like Trondheim/ Norway (thermal capacity 46 MW, corresponding to approx 500 tpd MSW) the furnace is divided into four identical sectors (as per figure 5). For smaller boilers like Pithiviers (thermal capacity 10 MW, corresponding to approx 100 tpd MSW) two sectors are indicated while larger plants such as e.g. the plant to be built for the Frederick and Carroll / MD counties (89 MW, 750 tpd MSW) can be divided into any suitable number of sectors.

In order to be able to quickly direct the right amount of reagent to the right location, the total amount of reagent controlled by the NO_x control loop must be distributed to the correct nozzle without delay and without interruption. The DyNOR™ flow distributor (Figure 6; patent applied) is uniquely capable of directing the two phase flow of ammonia and compressed air (or steam) to the nozzle best suited for NO_x reduction. Based on the needs indicated by the quick temperature measurement in the specified sector, the distributor can rapidly change injection elevations and is insensitive to different pipe lengths or nozzle elevations. It does so by continuously redirecting the flow from one nozzle to another in such a manner which may temporarily result in the injection of reagent at two elevations simultaneously. This fast and localized adjustment and the "stepless" level switch result in optimized reaction conditions and minimized ammonia slip.

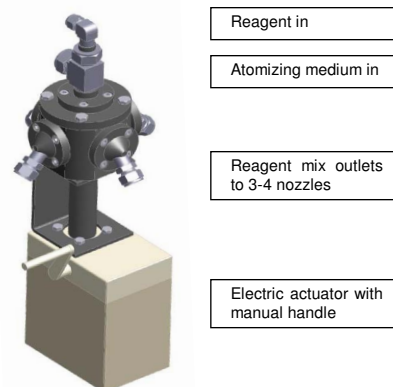


Figure 6: DyNOR™ reagent flow distributor

RESULTS AT TRONDHEIM/ NORWAY

The MSW plant in Trondheim (Line 3) combines the traditional SNCR process with a semi-dry air pollution control system and a tail-end wet scrubber. The plant is typically operated at a NO_x level of 140 mg/Nm³ (96 ppmv). Any ammonia slip resulting from the SNCR process is absorbed in the wet scrubber. This configuration made the plant uniquely suitable for the demonstration of enhanced SNCR systems. DyNOR™ was installed there in late 2008 in parallel with the existing SNCR system. The installation allowed for instantaneous switching from one system to the other. A laser-based ammonia emission monitor was added at the exit of the boiler to watch over ammonia slip.

The impact of DyNOR™ on NO_x emissions at the usual control setpoint of 96 ppmv is shown in Figure 7. Ammonia slip at the boiler exit with traditional SNCR equipment ranged from 2 to 12 ppmv. Upon switching over from traditional SNCR to DyNOR™ the ammonia slip immediately dropped to 2 ppmv and then gradually declined to less than 1 ppmv. Most notable is the stability of the ammonia slip signal during DyNOR™ operation.

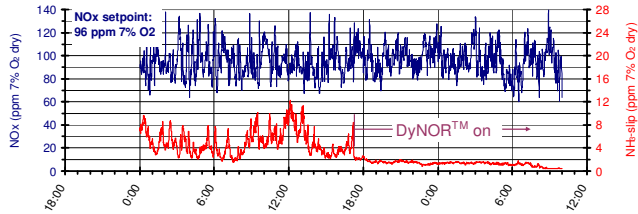


Figure 7: DyNOR™ performance at 96 ppmv NO_x (hh:mm)

Further reducing the NO_x setpoint to 68 ppmv yielded similar results. Obviously ammonia slip increased at these conditions and ultimately leveled off at around 9 ppmv (figure 8).

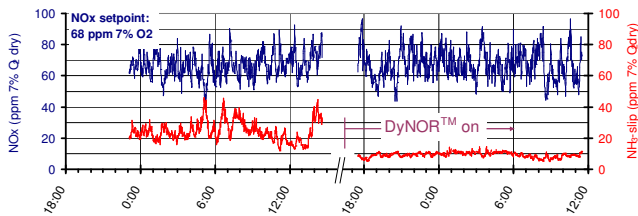


Figure 8: DyNOR™ performance at 68 ppmv NO_x (hh:mm)

RESULTS AT PITHIVIERS/ FRANCE

The MSW plant in Pithiviers (Line 2) combines the traditional SNCR process with a semi-dry air pollution control system. The plant is typically operated at a NO_x level of 180 mg/Nm³ (96 ppmv). The objective was to reach 80 mg/Nm³ (55 ppmv) at an ammonia slip not exceeding 10 mg/Nm³ (18 ppmv) in order to avoid the French NO_x tax without the need for an SCR catalyst. As can be seen in figure 9 the NO_x setpoint was set to 55 ppmv to meet the local objective. With about 13

ppmv NH₃ slip this was confirmed safely below the 18 ppmv newly required in France.

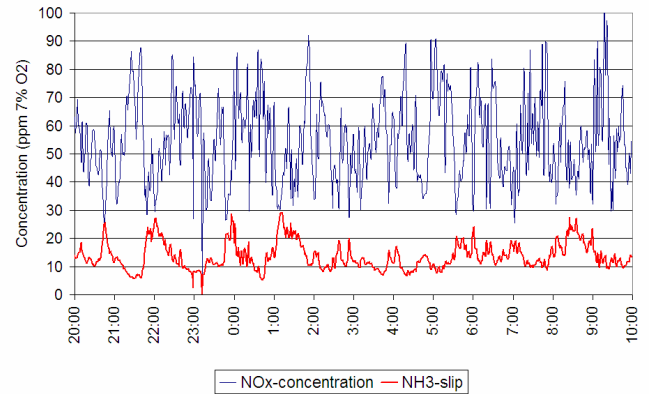


Figure 9: DyNOR™ performance at 55 ppmv NO_x (hh:mm)

CONCLUSIONS

The data from DyNOR™ trials and first operation results have allowed to extend the performance range of SNCR processes to significantly lower NO_x values. This closing the gap between traditional SNCR processes and the more costly SCR systems (figure 10).

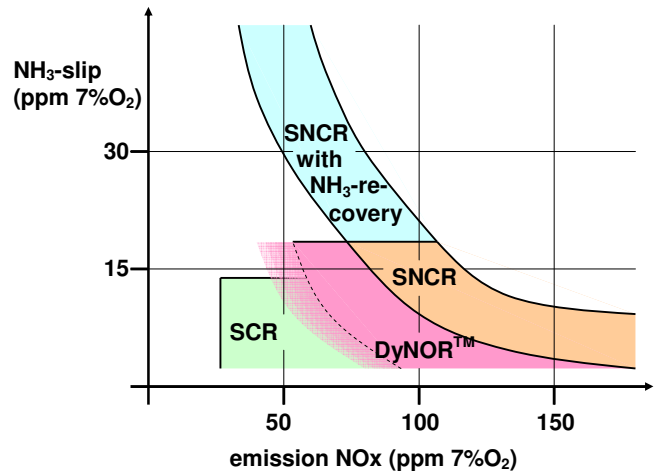


Figure 10: Operating ranges of NO_x-reduction technologies

ACKNOWLEDGMENTS

Trondheim and Pithiviers plant director and personnel for their assistance during the trials and tests.

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