# Advanced Features of SNCR-Technologies for NO<sub>x</sub> Reduction

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#### 1. Introduction

When the SNCR process was introduced first in the eighties of the last century the focus was directed towards applying this low cost technology mainly in combustion plants where only relatively low NO<sub>x</sub> reduction rates were required. These types of boilers like waste-to-energy plants are generally designed in such a way that the first flue gas pass is free of heat exchangers so that the injection and distribution of the reagent into the optimum temperature window can easily be realized. While the demands for low NO<sub>x</sub> emissions increased over the years the SNCR process was continuously improved.

For these applications, NO<sub>x</sub> limits of 100 mg/Nm<sup>3</sup> and lower can be achieved and maintained now at all operating conditions. Therefore, the SNCR process represents the "Best Available Technology" (BAT) today. As a result, more and more owners of waste-to-energy plants take advantage of the low costs at comparable performance and replace their existing SCR system with SNCR.

With this in mind, an increasing number of utility companies have already installed SNCR plants or are seriously investigating to use this technology for their large boilers as well. Besides the  $NO_x$  reduction and overall cost compared to SCR, special attention is also being paid to the formation of ammonia salts caused by the ammonia slip in the flue gas and the effects on fly ash, gypsum and waste water of the FGD downstream the boiler. This requires a comprehensive understanding of the different combustion systems and boiler designs.

This paper describes that the SNCR process is an attractive alternative for various fuels and types of combustion sources, especially if the results and experiences which were gathered to date are assessed, applied and consequently developed further to meet the ambitious demands of the regulators.

#### 2. Influences of Design and Operating Conditions on Performance of SNCR

In theory the SNCR process seems to be very simple. However, the practical realization is sometimes rather complex. In order to comply with the current emission limits for  $NO_x$  and the more stringent limits to be expected in the future, the SNCR technology has to be improved continuously. In order to find solutions a better understanding of the combustion process, the boiler design and the flue gas flow and composition is required.

Especially the following parameters influence the performance of SNCR:

- The boiler design, which in many cases prevents the reagents from being injected and distributed into the flue gas at the right temperatures.
- The design of the combustion chamber

- The design and configuration of the burners
- The operating conditions of the boiler
- The type of fuel
- The flue gas composition, velocity, direction of flow, temperature profile
- The reagent urea solution or ammonia water
- The required NO<sub>x</sub> reduction and ammonia slip
- Ammonia in the fly ash and byproduct of flue gas cleaning

#### 3. Limits of Operating Experiences with Various Boilers

#### 3.1. Operating Experiences with a Waste-to-Energy Plant (WtE)

Grate-fired boilers are most suitable for SNCR since the space above the grate in the first flue gas pass provides sufficient room and residence time at the optimum temperature before the flue gas enters the heat exchangers. Therefore,  $NO_x$  reductions below 100 mg/Nm<sup>3</sup> represent the state-of-the-art for this type of boilers fired with municipal waste, RDF, biomass etc.

In the Netherlands the waste-to-energy plant (WtE) in Wijster had been operating with SCR to reduce  $NO_x$  since 1996. Because of the favorable cost-benefit-ratio of the SNCR technology the operator decided to replace the existing SCR systems with an SNCR plant. Apart from the economical advantages, the precondition for this decision was that the  $NO_x$  emissions approved by the authorities for the SCR will also be maintained for SNCR.



Figure 1: Flow chart - SNCR plant with acoustic temperature measurement (agam) and 3 injection levels

The plant consists of three lines with a capacity of burning 25 t/h of municipal waste per incinerator. The NO<sub>x</sub> baseline is approx. 330 mg/Nm<sup>3</sup>. The guaranteed NO<sub>x</sub> level after SNCR is < 60 mg/Nm<sup>3</sup>. The injectors which are installed on three levels are individually activated

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based on the flue gas temperatures measured with an acoustic gas temperature measurement system (Figure 1).

Compared to the SCR, the savings of natural gas for reheating the flue gas upstream the catalyst are 6.6 million Nm<sup>3</sup>/a and approximately 6,100 MWh/a savings in electricity, since no energy is needed to overcome the pressure drop in the catalyst.



Figure 2: Daily NO<sub>x</sub> averages line 11 – March to September 2012

The first incineration line was put into operation in March 2012, the second one in September 2012 and the third one in April 2013. The plants are operating to the full satisfaction of the operator at extraordinarily low NO<sub>x</sub> emissions of 60 mg/Nm<sup>3</sup> (Figure 2).

# **3.2.** Operating Experience with Liquid Fuel

Boilers fired with liquid fuels usually have smaller combustion chambers than grate-fired boilers with the same capacity. This results in higher temperatures and velocities of the flue gas before entering the heat exchangers.

# **3.2.1. Incineration Plant for Liquid Waste**

Figures 3 and 4 show two incinerators which are burning liquid waste with a wide range of fuel composition. The first boiler (No. 7) was put into operation 2004, the other one (No. 8) at the end of 2014. The profiles of the flue gas flow and the temperature illustrate the difficulties to distribute the reagent properly in the flue gas in order to achieve the NO<sub>x</sub> levels  $< 60 \text{ mg/Nm}^3$ under all operating conditions.



Figure 3: Flue gas flow and temperature profile in a boiler for liquid waste



Figure 4: Operating data and boiler design for liquid waste

In order to avoid the turbulences and back flows of the flue gases, which caused the temperature imbalances in boiler 7, boiler 8 is being built without heat exchangers in the second pass (**Figure 4**). In boiler 7 the injectors were installed close to the boiler wall where the velocity is fastest and the NO<sub>x</sub> freight is heaviest.

#### **3.3.** Coal-Fired Boilers

Common designs of coal-fired utility boilers are boilers with two flue gas passes, a nose and platen heat exchangers at the end of the furnace and further heat exchangers in the second pass. In tower boilers the heat exchangers are installed horizontally above the furnace. The significant differences in the designs which have an impact on the SNCR technology are as follows:



Figure 5: Typical temperature distribution in coal-fired two pass boilers

In two pass boilers (**Figure 5**) the nose at the end of the furnace directs the vertical flue gas flow towards the front wall of the boiler and the heat exchangers depending on the burner configuration. At full load, the optimum temperature is generally in the level of or even within the super heaters. Therefore, a homogeneous distribution within the flue gas at the optimum temperature is not possible, and compromises concerning the performance of the SNCR have to be accepted, especially when the injection between the heat exchangers is not feasible at reasonable technical efforts and costs.

In tower boilers the situation is different. The reagent can be injected in most applications from all four boiler walls. The hot flue gases stream upwards through the heat exchangers while the temperatures decrease from the center towards the boiler walls. The temperature profile in different cross-sections is such that there are three temperature areas of which only one is suitable for  $NO_x$  reduction at the different injection levels. Close to the boiler walls is the coldest temperature which produces higher ammonia slip. In the center the temperature is too hot over the whole load range so that the ammonia is burned to  $NO_x$ .

Only the area marked in green color between those two areas has an optimum temperature range for the reactions (**Figure 6**). Therefore, special measures have to be taken, in order to achieve sufficient distribution of the reagent in the flue gas. One alternative is to inject the reagent into several levels simultaneously with different penetration depths and / or lances with different lengths. An optimum distribution of the reagent is still difficult to realize. The temperatures change considerably downstream the flue gas flow within the heat exchangers, because they are affected by the deposits of fly ash and the operating cycle of the soot blowers.



Figure 6: Typical temperature distribution in coal-fired tower boilers

#### 3.3.1. Pulverized Coal-Fired Boiler (ca. 200 MWel) in Völklingen, Germany

The simplified flow chart (**Figure 7**) shows the function and the scope of supply of the commercial SNCR plant as designed, installed and commissioned in a power plant in Völklingen, Germany. Due to the significant variations in flue gas velocity and flue gas temperatures between low load and full load as well as the extreme temperature imbalances, five levels with 12 injectors per level were installed between 26 and 51.8 m. The injectors are arranged in such a way that the right and the left sides of the boiler can be controlled independently from each other. Each of the 60 injection lances can be individually activated or deactivated in order to assure that the reagent always reaches the flue gas at the optimum temperature.

Because of the number of injection levels and injectors, two distribution modules were installed on each of the five injection levels to distribute the liquids and the atomizing air to the injection lances. All modules contain the necessary armatures as well as measuring and control instruments for flow rates and pressures of reagents, compressed air and process water.

The SNCR plant was put into operation in March 2010. The guaranteed  $NO_x$  and  $NH_3$  clean gas values were instantly reached in most cases with boiler loads ranging from 20 to 100 % and with various coals.



Figure 7: Flow Chart - SNCR with five injection levels and agam

The principle of an SNCR following the temperature profiles and average temperature in the zones established with the acoustic temperature measuring system (agam) is illustrated on the display of the control system (Figure 8).



Figure 8: Display of temperature profile, average temperature in zones, injectors in operation

#### 3.3.2. Commercial Application for a Coal-Fired Boiler (225 MWel) in Jaworzno, Poland

At the location Jaworzno, Poland, six coal fired boilers of the same type (OP 650) are operating (Figure 9).

			No.
Design Data			
Burner Configuration		Front Firing	the state
Capacity	[MW <sub>et</sub> ]	225	0.
Flue Gas Volume	[m <sup>3</sup> /h]	740,000	
Fuel		Coal	
SO <sub>2</sub>	[mg/Nm <sup>3</sup> ]	800 - 2,000	
NO <sub>x</sub> @ 6 % O <sub>2</sub> without SNCR	[mg/Nm <sup>3</sup> ]	250	
NO <sub>x</sub> @ 6 % O <sub>2</sub> with SNCR	[mg/Nm <sup>3</sup> ]	190	
NH <sub>3</sub> with SNCR	[mg/Nm <sup>3</sup> ]	5	
Load Range		60 - 100 %	

Figure 9: Design data of a coal-fired boiler with front firing in Jaworzno, Poland



Figure 10: Display with temperature profiles in 2 levels, injectors in operation, perfomance data

After retrofitting of the combustion had been completed an SNCR system was installed initially for one of these boilers.

In order to follow more closely the load changes of the boiler, three injection levels have been installed. Because of the extreme temperature imbalances which were measured before starting the design of the SNCR, an acoustic temperature measurement system (agam) with

two levels was installed. The second level is used to obtain more precise information on the flue gas temperatures near the injector positions and the temperature gradient between the two measuring levels (Figure 10).



Figure 11: Irregular combustion caused by uneven coal distribution

Temperature imbalances of up to 200 K were measured from the right to the left side of the combustion chamber for following reasons:

- Each coal mill supplies six burners with coal and primary combustion air. Due to different coal deposits in the coal and air ducts, it is practically not possible to evenly distribute the coal and air to the burners and assure a balanced combustion of all burners simultaneously (**Figure 11**). As a result of this, the temperature distribution in the furnace and as a consequence the flue gas velocities vary considerably.
- The burners are installed at the front wall of the boiler so that the horizontal flue gas flow is directed vertical to the entrance of the heat exchangers. Due to the relatively short residence time, temperature imbalances cannot be equalized and flue gases are too hot when they are entering the heat exchangers close to the nose at full load.
- In tangentially fired boilers the flue gas flow is forced into a rotary motion. Because of the longer distance to the exit of the furnace, the flue gas cools down more than in front fired boilers. Furthermore, the flue gas is better mixed so that temperature imbalances are easier to handle.



Figure 12: Flow chart with three NO<sub>x</sub> control valves to limit slip



Figure 13: NO<sub>x</sub> emission and ammonia slip in fly ash

The first SNCR plant was commissioned successfully in March 2012 and handed over to the operator shortly after. The other five were installed one by one until 2016 (Figure 12) All plants are operating commercially now to the satisfaction of the customer.

In combination with the primary measures the required  $NO_x$  level  $< 200 \text{ mg/Nm}^3$  is maintained at all operating conditions. The ammonia content in the ash is below 50 mg/kg

(Figure 13). The injection lances and the mixing and metering modules installed in Jaworzno are shown on Figures 14 and 15.

In many boilers the flue gas temperatures at the exit of the furnace are often too hot for the SNCR process, especially at full load. The injection of the reagent into a location between the heat exchangers where the temperatures are more suitable is sometimes possible, but mostly can only be realized with a lot of technical effort and high costs in existing boilers. In new boilers, sufficient space could be provided with reasonable effort, if it is already considered during the planning stage of a project.



Figure 14: Lances

Figure 15: Mixing and metering modules

# 4. Solutions for a Further Improved SNCR Performance

# 4.1. NO<sub>x</sub> Reduction with Urea and/or Ammonia – The TWIN-NO<sub>x</sub><sup>®</sup> Process

After the general decision has been taken in favor of SNCR, it is as important to select the best reagent for each application. The availability, logistics and cost of urea compared to ammonia water are important arguments. But more often, there are reasons from the process point of view which have a high impact on the performance and should be considered since both reagents have their specific advantages and disadvantages depending on the specific application.

The major difference between ammonia water and urea solution is shown in a strongly simplified diagram in **Figure 16**. Urea dissolved in water can only be decomposed into reactive  $NH_2$  species after the water enclosing the urea particles has been completely evaporated. The place in the flue gas where the reaction is to take place can be defined in advance by the water droplet size and the resulting penetration depth. If the water droplet is big enough, it is possible to inject into a place that is too hot for  $NO_x$  reduction, because the reagents are released at the end of droplet trajectories in a colder place within the flue gas.

The mass of the dilution water, which is additionally used as a carrier medium for urea solution, ensures a high penetration depth at rather low energy consumption, and may in some cases cool down the flue gas to the desired temperature, if necessary. Since urea is very corrosive, impingement of the droplets on the heating surfaces has to be avoided.



Figure 16: NO<sub>x</sub> reduction: urea versus ammonia water

As opposed to urea, ammonia is a highly volatile reagent which is released near the tip of the nozzle, which is immediately after the ammonia water has entered the furnace. The  $NO_x$  reduction will then mainly take place in the cooler area near the boiler walls where it is more likely that ammonia slip is generated. To ensure an optimum penetration depth, more energy is required because of the lower mass of ammonia in gaseous form compared to water droplets. In traditional plants this is accomplished by increasing the volume of steam or compressed air used as a driving medium.

However, a homogeneous distribution is still very difficult to obtain as flue gases are very viscous and it is therefore difficult to mix different gases. This disadvantage, which has often caused a higher ammonia slip in SNCR plants using ammonia water, can be compensated for to a great extent when dilution water is used as a carrier medium also for ammonia water.

The higher mass flow of water decreases the pressure in the jet stream downstream of the nozzle, compared to using compressed air or steam alone (Figure 17). Due to the resulting pressure difference, the surrounding flue gas is mixed with the reagent. This concept produces

similar results with regard to  $NO_x$  reduction and ammonia slip compared to applications where urea is used as reagent.

During commissioning the automatically controlled plant did not provide better results than achieved with the manually controlled trial equipment. The only significant difference between the two systems is that ammonia water is used as reagent for the commercial plant instead of urea solution. The assumption that the performance of urea is better for this application than ammonia water was based on the fact that the reagent (ammonia) reacts too close to the boiler wall and does not reach the area with the optimum temperature.

In order to verify this assumption, additional tests with urea were performed in the commercial plant as well. The realization was easy, since the reactivity and consequently the flow rate of urea solution (45 %) is almost identical to ammonia water (25 %) so that the equipment and settings of the control system and instrumentation do not need to be changed for the application of the other reagent.



Figure 17: Mixing flue gas with free jet

The results showed that immediately after injection of urea the  $NO_x$  reduction increased and the consumption of the reagent decreased (**Figure 18**). This indicated at first glance that for this special boiler design urea is the preferable reagent with regard to the  $NO_x$  emission values at full load and when the effective temperature window lies between the heat exchangers. On the other hand, there was still a concern that there is a higher risk applying urea with regard to impingement and corrosion of the boiler tubes.



Figure 18: Operating results – Injection with NO<sub>x</sub>AMID

The objective of further tests was to verify the expected advantages and disadvantages respectively to confirm the different behavior of ammonia water versus urea solution.



Figure 19: TWIN-NO<sub>x</sub><sup>®</sup> – Mixing of ammonia water and urea extends the temperature window

The tests confirmed that the low volatility reagents (NO<sub>x</sub>AMID) are indeed released at the end of the droplet trajectories while the high volatility reagents (NH<sub>3</sub>) are released near the droplet source close to the boiler walls. Further tests showed that by changing the reagents depending on the operating conditions the performance of the SNCR could be improved considerably.

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It was a logical consequence to mix both reagents together and inject various mixtures into the furnace, in order to combine the respective features (Figure 19).

Following extensive feasibility tests with urea solution two oil-fired boilers in Germany with a steam capacity of 154 t/h each were equipped with SNCR using ammonia water as reagent. During the commissioning of the commercial plant it turned out that in the upper load range the required  $NO_x$  reduction could not be achieved due to the prevailing high flue gas temperatures and velocities before entering the heat exchangers (**Figure 20**). Additional trials confirmed the assumption that the results with urea solution are better, because the high volatile ammonia obviously reacts too early in locations where the flue gas is too hot, while the reaction with urea would take place in the cooler area within the heat exchangers.



Figure 20: Reaction zones of urea and ammonia water in a fire tube boiler

In order to improve the performance at higher loads the plant was modified with the TWIN- $NO_x^{(B)}$  process (**Figure 21**), i. e. at boiler loads up to 80 % only ammonia water is injected as reagent. Above this load urea is increasingly blended into the reagent while the ammonia content is decreased. At 100 % boiler load only urea is injected. As a result of this modification the guaranteed  $NO_x$  emissions < 180 mg/Nm<sup>3</sup> can be maintained at all boiler loads.

Now two commercial plants have been built, one burning coal and the other one oil, which can be operated alternately or simultaneously with urea solution and/or ammonia water in order to combine the advantages and the special features of the two reagents. The results summarize in a more effective and wider temperature and load range, higher efficiency, lower ammonia slip, less consumption of reagent and minimum risk of corrosion. Because of the combination of two reagents the new process is patented and named TWIN-NOx<sup>®</sup> now.



Figure 21: Fire tube boiler with TWIN-NO<sub>x</sub><sup>®</sup> process

# 5. Providing SNCR-Friendly Operating Conditions

When the flue gas temperatures are too high in areas that are free of built-in components, enough space has to be provided in the suitable temperature window for the injection and reaction of the reagent(s). This means that the heat exchangers have to be moved or spread, which is usually a very costly undertaking. For new installations, the specific requirements of the SNCR technology should be considered during the design of the boiler, because then the additional cost can be kept to a minimum.

However, if retrofitting is not possible, and especially when several boilers are operated parallely, it also might be an effective and viable alternative to cool down the flue gases to a level where  $NO_x$  reduction is possible at all operating conditions.

# 5.1. Cooling of the Flue Gases with Additional Water

Since in Waste-to-Energy plants  $NO_x$  levels < 100 mg/Nm<sup>3</sup> are state-of-the-art today, the potential for further developments is highest in larger combustion plants, where the flue gas temperatures are too hot in those areas which are accessible for injecting the reagents. A feasible measure could be to increase the quantity of dilution water. However, this has the following disadvantages and is therefore not recommended in most applications:

- Varying quantities of water change the droplet spectrum and consequently the size of the droplets as well as their penetration depth.
- The concentration of the water/reagent-mixture is also changed so that the area where the reduction takes place is shifted.

A continuous operation of the boiler with an increased amount of water is acceptable only as an exception, because vaporizing the water consumes a lot of energy, as one ton of water is evaporated to one ton of steam and affects the efficiency of the whole combustion plant (Figure 22).

Controlling the quantity of water depending on boiler load respectively temperature is a standard procedure and has been practiced since many years in fire tube boilers. The disadvantages mentioned above do not apply to these boilers, as the reagent is injected against the direction of the flue gas flow, and the penetration depth is adjusted in order to follow the changes of the flue gas temperatures and the velocities.



Figure 22: Flue gas cooling by inreasing the quantity of cooling water

In larger boilers where the reagent is practically always injected from the side walls across the flue gas flow, the installation of an additional injection level which can be operated with cooling water alone, when needed, has proven successful in continuous operation (**Figure 23**).

With this concept cooling water is only applied when temperatures are too high. At lower loads, respectively temperatures, the water is switched off. The droplet spectrum at the injection of reagent is not changed, but the disadvantage is that temperature imbalances can lead to a higher NH<sub>3</sub> slip in areas which are colder. The effect would be an increase of NH<sub>3</sub> slip, a waste of cooling water and a lower efficiency.

Preferably, this method should be applied only in combustion plants that are not constantly operated in temperature ranges which require an additional cooling of the flue gases or in plants with homogenous temperature profiles. By switching on or off the cooling water an additional injection level can be avoided in many cases.



Figure 23: Coal-fired boiler with and without flue gas cooling

# 6. Most Recent Developments of NO<sub>x</sub> Reduction with SNCR

#### 6.1. Selective Cooling of Flue Gases

"Selective Cooling" is a major step ahead. It also requires an additional injection level for cooling water beneath the top injection level, but it improves the efficiency of this additional level. The major difference is that Selective Cooling reacts to temperature imbalances by injecting cooling water only in those areas which are too hot. Individual lances or groups of lances are activated depending on the temperature profile generated by a suitable temperature measurement system (**Figure 24**).



Figure 24: Selective flue gas cooling for coal-fired boilers

Figure 25 shows the results of the Selective Cooling in a coal-fired boiler in the Czech Republic. With additional cooling water alone, the NO<sub>x</sub> reduction of the SNCR could be increased by an additional 120 mg/Nm<sup>3</sup> to a level of < 160 mg/Nm<sup>3</sup>.



Figure 25: Selective Cooling - Retrofitting of an SNCR plant operated with urea solution

# 6.2. Adaptive Flue Gas Cooling

Injecting of water offers the great benefit that extensive and costly modifications of the boiler can be avoided when the flue gases are cooled down before entering the heat exchangers. The major disadvantage, however, is that depending on the operating hours at high boiler loads in which water cooling is necessary, the efficiency of the boiler is affected because of the energy needed to evaporate the water in the flue gas. "Selective Cooling" is already a big step forward to improve the performance of SNCR by cooling down the flue gases.

However, a better solution is to control the amount of water more precisely in order to further decrease the consumption of cooling water. To realize this objective a temperature measurement system which generates a temperature profile has to be installed above the upper injection level across the furnace (**Figure 26**).

The temperatures are constantly being measured online and average flue gas temperatures are calculated in defined sections which are assigned to single injectors or groups of injectors.

- Without injection of reagent
- With injection of reagent only
- With injection of reagent and cooling water simultaneously.



Figure 26: Principle of adaptive flue gas cooling

At the lowest level, injection of cooling water is generally not needed, since the injectors will be switched to higher levels as the flue gas temperatures increase with the load.

With the described concept the temperatures and the influence of the injected liquids, i. e. reagent/water-mixture and cooling water, can be measured. Based on the various temperatures the flow of cooling water can be adapted as needed to maintain the optimum temperatures within the injection level at all injector locations in order to obtain efficient  $NO_x$  reduction and low ammonia slip. Furthermore, the activation of the lances for reagent can be determined more precisely when temperatures are measured in two levels.

To achieve this, another temperature measurement system as described for the top level has to be installed for measuring the flue gas temperatures above the lowest injection level.

# 6.3. Defining Flue Gas Velocity

It is often neglected that apart from the flue gas temperatures, the flue gas velocities at different injection positions, are of equal importance for the efficiency of the SNCR process. Since the  $NO_x$  mass flow to be reduced is the product of

# NO<sub>x</sub> concentration [mg/Nm<sup>3</sup>] \* flue gas flow [Nm<sup>3</sup>/h],

the probability is high, that in some areas where the flue gas velocities are low, too much reagent is injected in areas with similar  $NO_x$  concentration causing higher ammonia slip since the reagents do not find enough partners for the chemical reaction. To avoid this, the flow of reagent should be reduced or completely stopped to decrease the consumption of reagent and minimize ammonia slip.



Figure 27: Adaptive flue gas cooling – Extrapolating flue gas velocities from differences in temperature

With the arrangement of the temperature measurement systems in two levels (**Figure 27**), the temperatures in the levels and sectors can be compared and the temperature gradient between the levels can be defined more correctly than with traditional methods.

Since hot flue gases have a higher natural draught and slower flue gases are cooled down more at the boiler walls and heat exchangers, higher temperature differences indicate a slower flue gas velocity compared to areas with smaller temperature differences.

This information is the basis to control, respectively adjust the flow of reagent to the corresponding injectors or groups of injectors with the objective to optimize the  $NO_x$  reduction and to minimize the ammonia slip.

If measuring equipment is used which provides data of other components like  $NO_x$ , CO,  $O_2$ , etc. in addition to the temperatures, these data could be incorporated into the control of the SNCR as well for a further optimized distribution of the reagent across the furnace for better performance of the SNCR.

#### 7. Summary and Outlook

In smaller combustion plants like those that burn waste or biomass, the SNCR process has been well established and accepted as Best Available Technology (BAT) since many years. In the meantime, the operating experiences in large combustion plants with a capacity of  $> 200 \text{ MW}_{el}$  have shown that the NO<sub>x</sub> levels required under the new EU legislation from 2016 on can reliably be reached.

Recent techniques like the changing of individual lances, the TWIN-NO $_x^{(R)}$  process, the Selective Cooling and Adaptive Cooling of flue gases in combination with primary measures

have produced results which indicate further potential for improvements. Currently, there is an increasing demand for plants that have boilers with an output of 300 to 500  $MW_{el}$  and emission levels of < 150 mg/Nm<sup>3</sup> and NH<sub>3</sub> slip < 5mg/Nm<sup>3</sup>.

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