# SNCR Process for Coal fired Boilers
## Experiences and Potential for the Future


**Bernd J. von der Heide**
**Mehldau & Steinfath**
**Umwelttechnik GmbH**
**Essen, Germany**




## 1. Introduction

The SNCR process has been considerably improved during the last years for small and medium sized boilers, burning municipal and industrial waste, biomass, sludge, etc. These types of boilers 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. Since for these applications $NO_x$ limits of 100 mg/Nm³ and lower can now be achieved and maintained at all operating conditions., the SNCR process represents today the ‘Best Available Technology’ (BAT) with the effect that for instance more and more owners of waste-to-energy plants replace their existing SCR $NO_x$ control system with SNCR because of the low operating costs at comparable performance.

With this in mind, an increasing number of utility companies are seriously investigating if the SNCR process is feasible 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 paper describes that the SNCR process is an attractive alternative for large boilers as well, especially if the results and experiences which are gathered to date are assessed, applied and consequently developed further to meet the ambitious demands of the owners of large utility boilers.

## 2. Basics of SNCR $NO_x$ Control Technology

In most SNCR plants operating today, either urea solution or ammonia water are being used as reagents. Both have their special advantages and disadvantages.

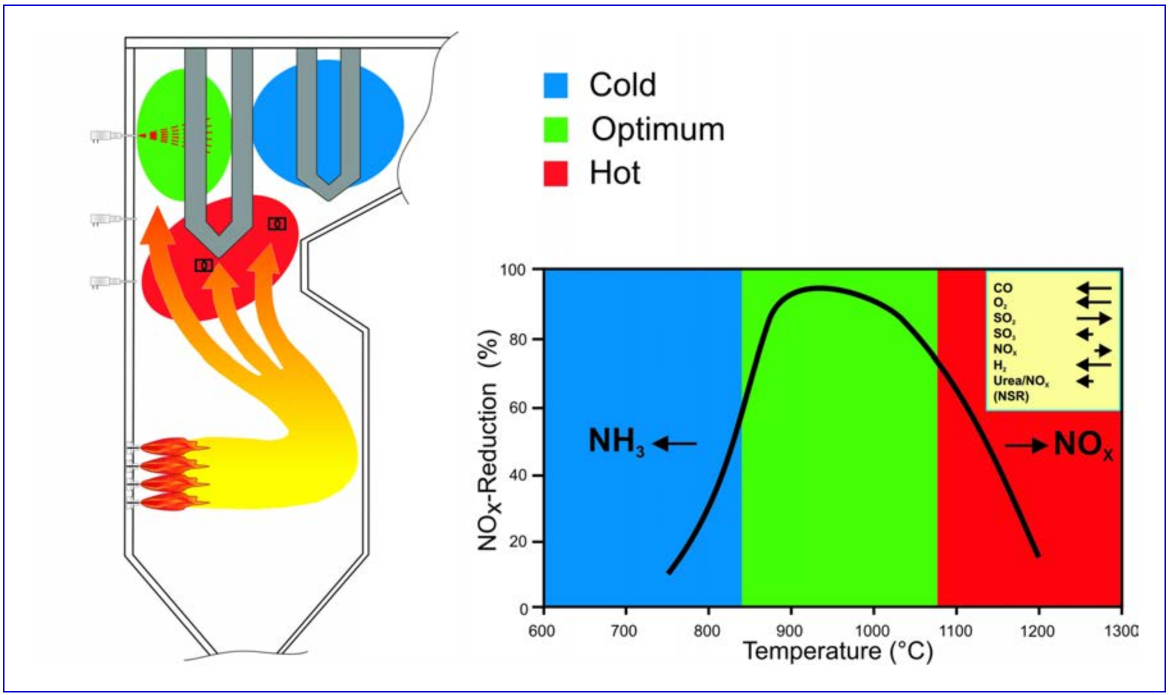


**Fig. 1: $NO_x$ Reduction as a Function of Temperature**

For an optimum $NO_x$ reduction with a minimum $NH_3$ slip it is "only" necessary to evenly distribute and thoroughly mix the reagent in the flue gases within the appropriate temperature window (**figure 1**). The optimum temperature range to achieve a high $NO_x$ reduction combined with a minimum consumption of reagent and a low ammonia slip is rather narrow and depends to a great extent on the flue gas composition.

For coal-fired boilers the optimum temperature lies between about 900 and 1,020 °C. Above this temperature range an increasing amount of ammonia is oxidized, i. e. nitrogen oxides are formed. At lower temperatures, the reaction rate is slowed down causing ammonia slip which may result in the formation of ammonia salts and can lead to secondary problems, downstream the flue gas path. Therefore, ammonia slip should be kept to a minimum.

Since the temperatures over the cross-section in the furnace are rarely uniform and considerable imbalances are often found, it must be ensured that under all prevailing operating conditions the reagent is injected across the overall cross-section from each lance exactly into the $NO_x/NH_3$-optimised temperature window, which is only about 50 K wide. With the traditional concept this cannot be reliably achieved during any given operating condition of incineration plants, power boilers and other applications.

The constantly varying composition of the fuel in waste incineration plants results, for instance, in rapid and major changes of the heating value and the ignition behavior of the fuel. This causes considerable variations in the heat release and as a consequence in the furnace temperatures. Moreover, the temperature window moves further upwards due to the increasing degree of fouling on the heating surfaces in the combustion chamber during operation. In power boilers the temperatures and temperature profiles depend on the load, the burner configurations, the distribution of combustion air, the operating cycles of soot blowers, etc. (**figure 2**).

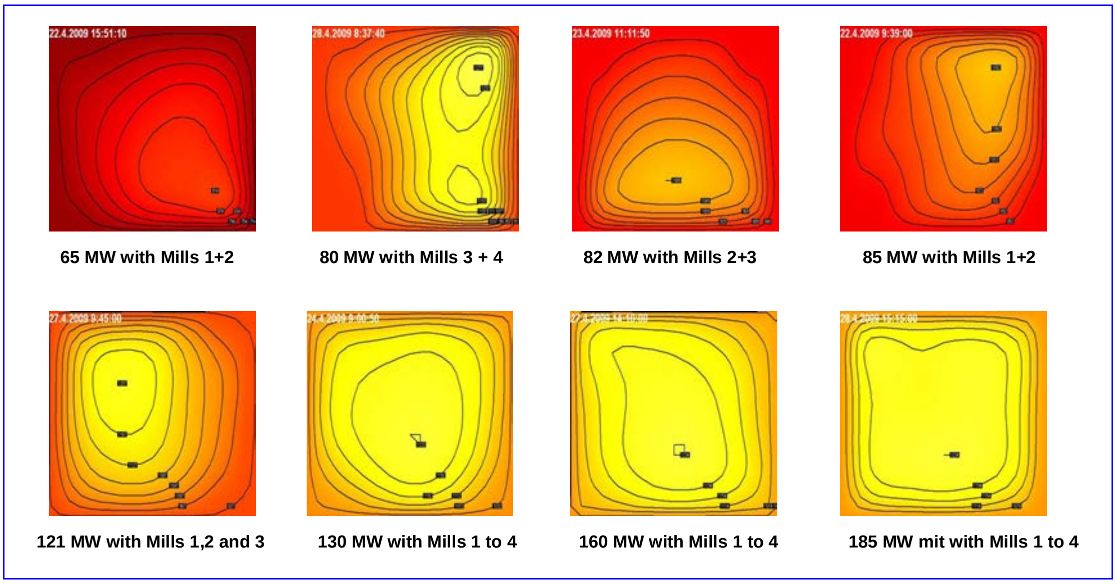


**Fig. 2 Temperature Profiles in agam Measurement Level at Different Boiler Loads and Configuration of Mills**

Depending on the type of fuel, fuel distribution and air supply, temperature imbalances of up to 150 °C - and sometimes even higher - are typical. The furnace temperatures in waste-to-energy plants are generally measured with thermocouples and then averaged. These average temperatures can be used as a reference to a limited extent only, as they do not give any information on the temperature profile or the imbalances within the injection levels.

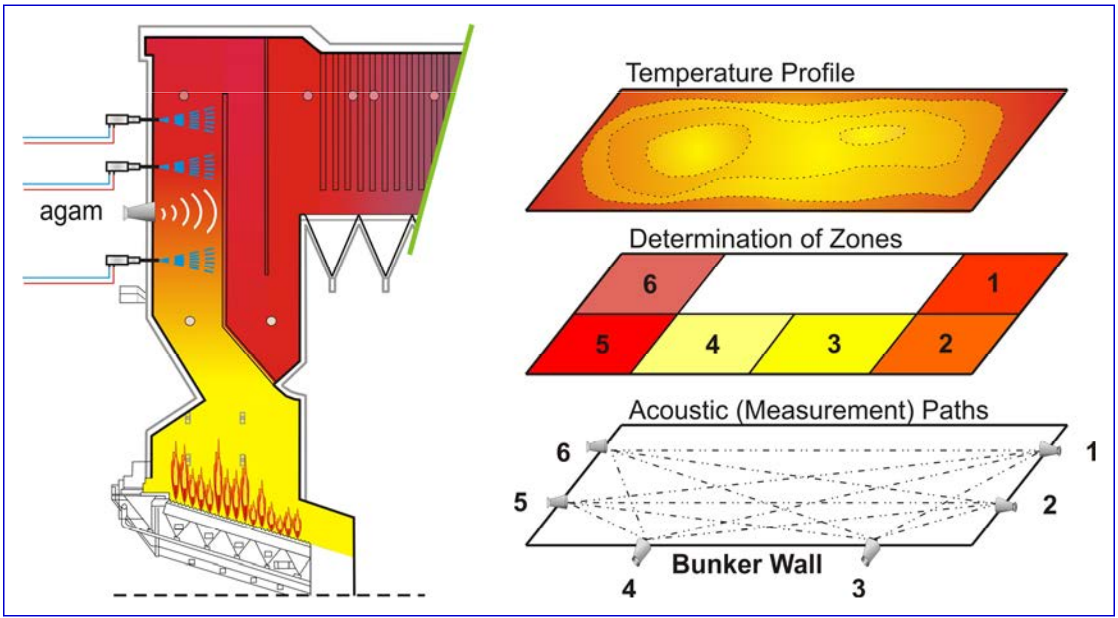


**Fig. 3: Temperature Measurement and Injection Levels for SNCR at WtE Plant**

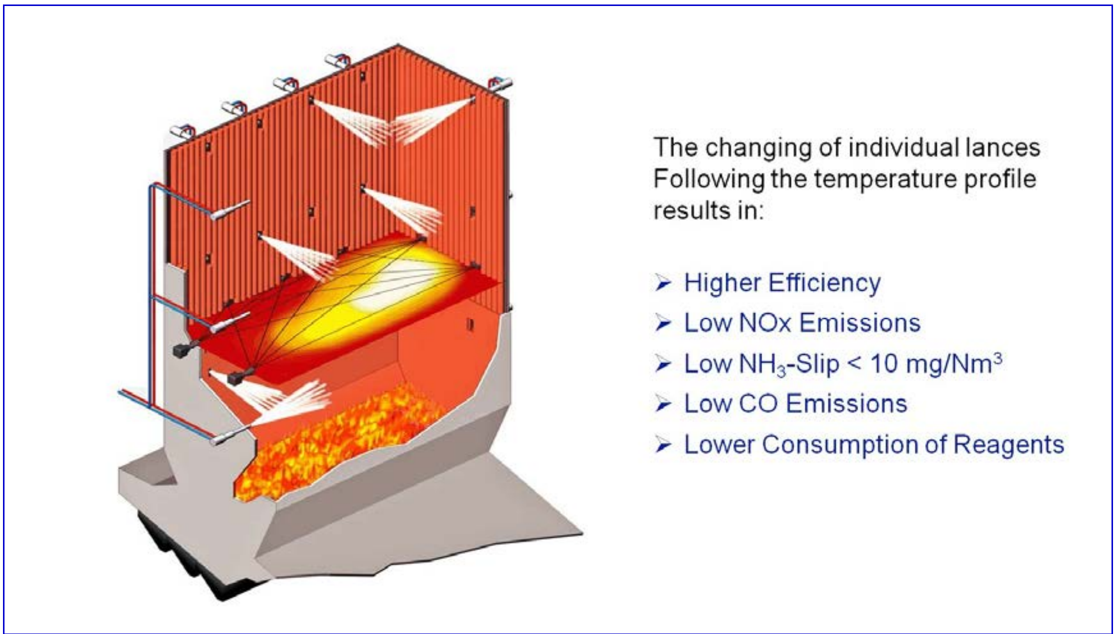


**Fig. 4: Advantages of Temperature Controlled Changing of Individual Lances**

To ensure that in all possible operating scenarios the reagent is always injected into the upper range of the temperature window, where the degree of $NO_x$ reduction is highest and the $NH_3$ slip is lowest, acoustic gas temperature measurement systems (agam) are used where the highest performance is required. Agam measures the real gas temperatures in the cross-section of the combustion chamber near the injection points and determines temperature profiles.

The temperature profile is divided into sections and can be assigned to individual lances or groups of lances which can be changed to another level depending on the flue gas temperature measured (**figures 3 and 4**). This ensures that the reagent gets to the locations which are most effective for the reaction, even at rapidly varying flue gas temperatures. At the same time, the SNCR plant always operates in the optimum range with regard to $NO_x$ reduction, $NH_3$ slip and reagent consumption.

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

Although the SNCR process is theoretically very simple, often the realization is not as easy as it looks in practice. The following factors, for instance, have a great impact on the performance:

- The boiler design, which prevents the reagents from being injected and distributed into the flue gas at the right temperatures.
- The design of the combustion chamber
- The operating conditions of the boiler
- The type of fuel
- The reagent – urea solution or ammonia water
- The required $NO_x$ reduction, ammonia slip and ammonia in the fly ash

### 3.1. Boiler Design

Grate-fired boilers are the major design concept for smaller plants like waste-to-energy plants and - to some extent - fluidized bed boilers.

A typical design of coal-fired utility boilers is the tower boiler with heat exchangers installed horizontally above the furnace as well as 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 path. The significant differences in the designs which have an impact on the SNCR technology are as follows:

Grate-fired boilers are most suitable for SNCR since the space above the grate in the first flue gas path provides sufficient room and residence time at the optimum temperature before the flue gas enters the heat exchangers. Therefore, with this type of boilers the best $NO_x$ reduction achievable lies below 100 mg/Nm³.

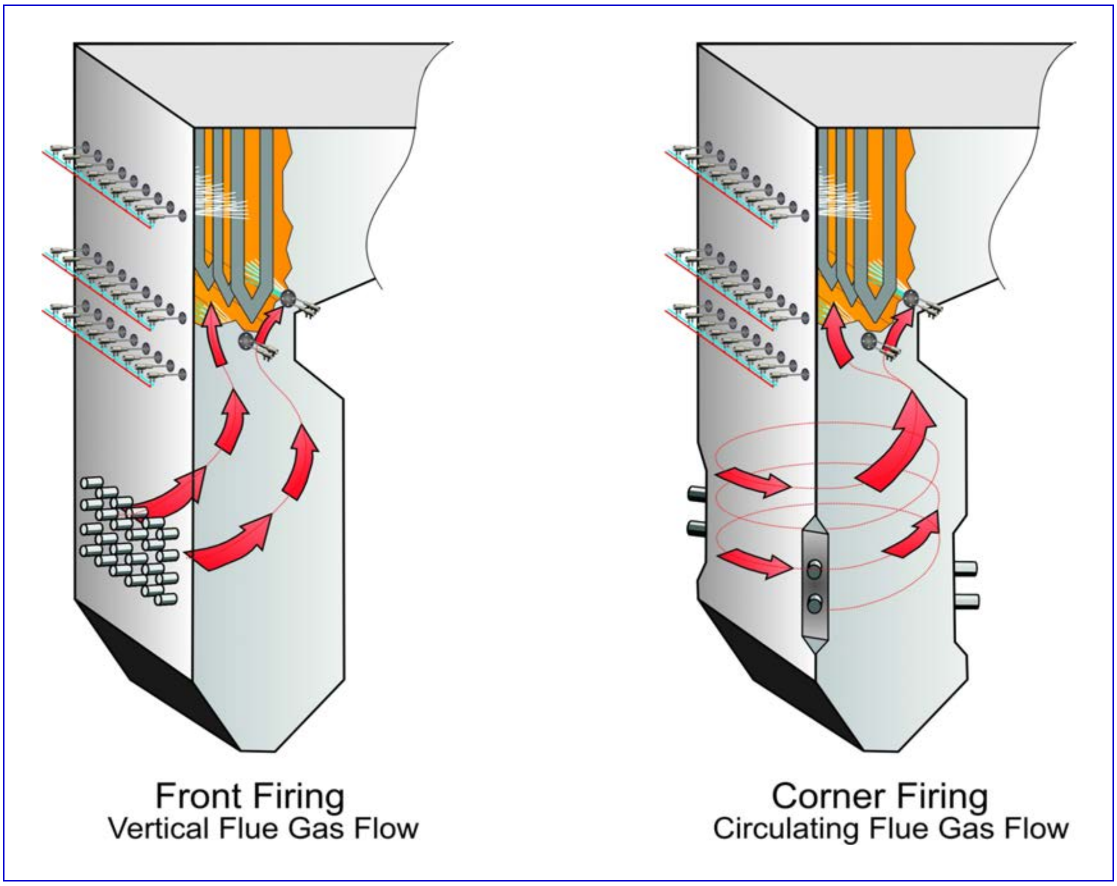


**Fig. 5:** **Effects of Front and Corner Firing on Flue Gas Flow**

In two pass boilers, 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 (**figure 5**). 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 in the performance of the SNCR have to be accepted, especially when the injection between the heat exchangers would not be feasible at reasonable technical effort 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 $NO_x$.

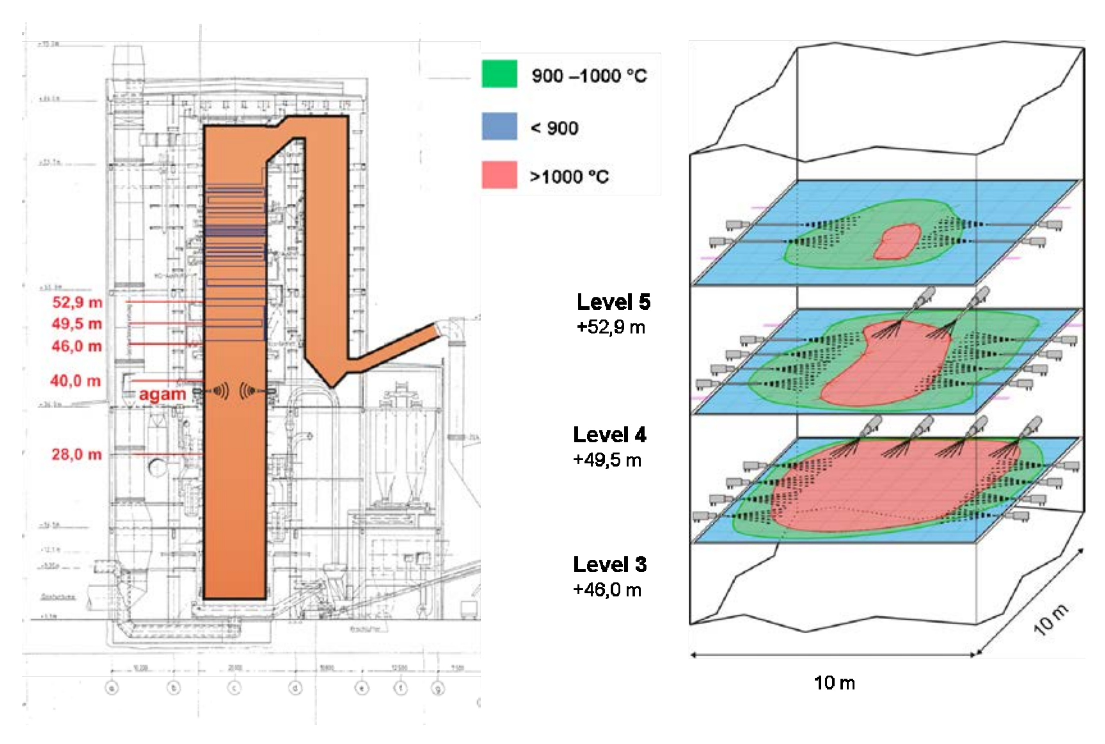


**Fig. 6: SNCR Process for a Coal-Fired Boiler in Germany**

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 agam measuring level, because they are affected by the deposits of fly ash and the operating cycle of the soot blowers.

## 3.2. The Design of the Combustion Chamber and Burners

The design of the burners in combination with the distribution of fuel and the combustion air in the burners and the furnace are the source of the $NO_x$ concentration in the flue gas. Furthermore, the imbalances of temperatures and velocities depend to a great extent on the combination of types and configuration of burners, the fuel and air supply to the burners and size and dimensioning of the furnace.

Before applying secondary $NO_x$ reduction technologies like SNCR or SCR, measures should be taken to minimize the formation of $NO_x$ when the combustion is taking place. This can be achieved by reducing the oxygen and decreasing the temperature in the primary combustion zone. Not completely burnt carbon compounds (CnHm radicals, CO, residual coke) are thus available in enriched form and have a reducing effect on already formed $NO_x$.

In the secondary combustion zone, the combustion will be completed by addition of air. In order to get optimum results, i. e. low $NO_x$ and maximum burn out, a long residence time in the reducing atmosphere of the primary combustion zone and a good mixture with the combustion air in the secondary combustion zone are essential. In order to achieve best results for low $NO_x$ combustion, the following measures are taken alone or in combination with each other:

- Adjustment and optimization of burners and combustion air
- Reduction of excess air
- Air staging in the combustion zone
- Air staging in the burners
- Fuel staging
- Flue gas recirculation

The effectiveness of such primary measures depends very much on the boiler design and the characteristics of the fuel. Each individual case has to be studied carefully with regard to:

- Stability of the flame
- Corrosion of the furnace
- Burn out of the fuel
- Fuel range
- $NO_x$ reduction
- Efficiency of the boilers and cost.

In practical applications, compromises have to be found between the technical possibilities and the effects on cost and operation.

### 3.3. The Reagent – Urea Solution or Ammonia Water

The use of ammonia water as a reagent is often limited by the flue gas temperatures which are too high, so that a lot of the reagent would burn to $NO_x$ already before it could reach the area with appropriate temperatures within the heat exchangers. The overall $NO_x$ reduction would not be satisfying.

Dealing with this problem is easier with urea solution since by the time the water droplet containing the urea particle has evaporated, the $NH_2$ of the decomposed urea will have reached the cooler area. However, there is serious concern that droplets containing urea would impinge on the boiler tubes causing corrosion and damage of the tubes. Therefore, special attention has to be paid to the positioning, maintenance and operation of the injectors.

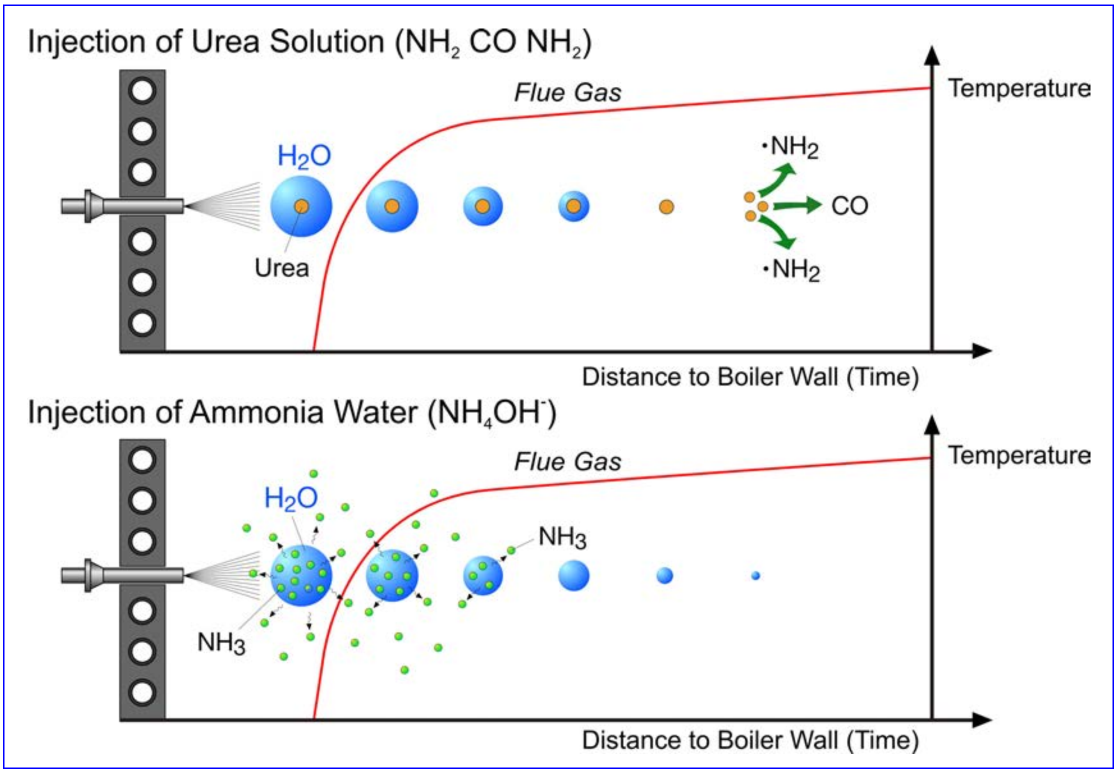


**Fig. 7: NO$_x$ Reduction: Urea Solution versus Ammonia Water**

The major difference between ammonia water and urea solution is shown in a strongly simplified diagram in **figure** 7. 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 position in the furnace where the reaction should take place can be defined in advance by the size and the velocity of the droplets leaving the injection nozzles. By changing the pressures of compressed air and the water/reagent mixture the droplet size and the resulting penetration depth can be adjusted as needed.

If the water droplet is big enough, it is possible to inject into a place that is too hot for $NO_x$ reduction. The reagents are now released at the end of droplet's trajectories. As a consequence, the reaction takes place in a colder location 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 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 under all circumstances.

Ammonia is a very highly volatile reagent which is released near the source of the droplet, which is the exit of the nozzle, immediately after the ammonia water has entered the furnace.

The $NO_x$ reduction will 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 a water droplet. In traditional plants this is accomplished by increasing the pressure of the steam or air flow used as a driving medium.

A homogeneous distribution is very difficult to obtain as flue gases are very viscous. 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 for ammonia water as well.

## 4. Operating Experiences with Various Boilers

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

In Europe remarkable results have been achieved with the SNCR technology for smaller combustion plants fired with municipal waste, RDF, bio mass etc. In the Netherlands a Waste-to-Energy (WtE) plant consisting of three incineration lines has been operating since 1996. Each of these lines was equipped with SCR to reduce $NO_x$. A complete replacement of the catalyst elements would have been necessary due to their ageing.

Because of the favorable cost-benefit-ratio of the SNCR technology the operator decided to replace the existing SCR systems with the SNCR technology. Apart from the economical advantages, the main reason for this decision was that the $NO_x$ emissions reach the same levels as are obtained with the SCR technology.

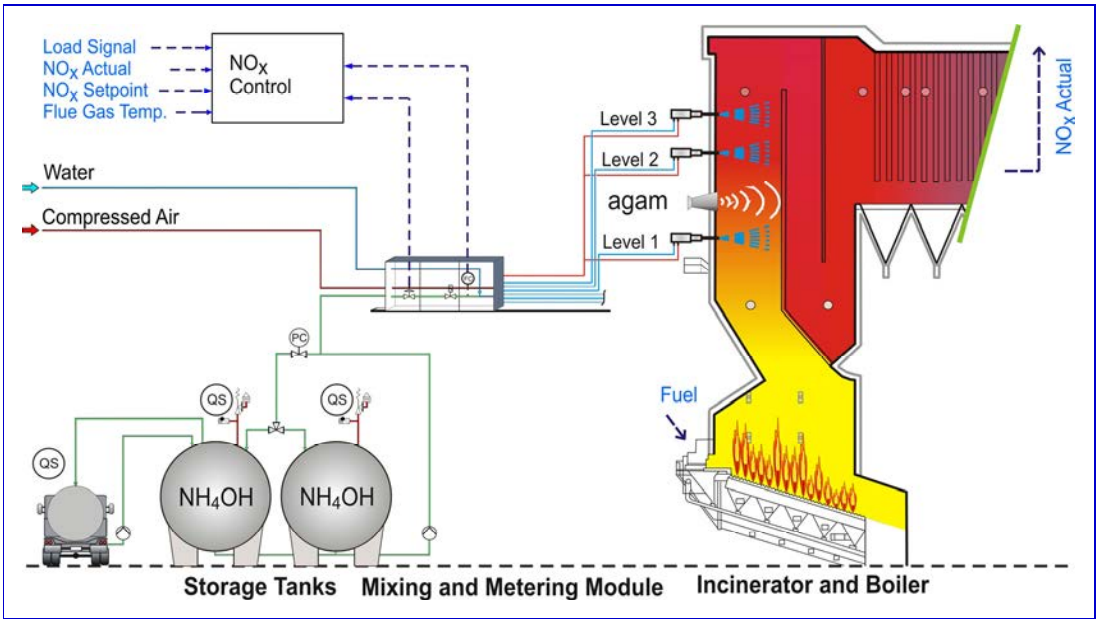


**Fig. 8: Flow Chart SNCR Plant with agam and Three Injection Levels**

The plant has a capacity of burning 25 t/h of municipal waste. The $NO_x$ base line is 330 mg/Nm³. Guaranteed $NO_x$ after SNCR is 60 mg/Nm³. The concept of the retrofitting is shown in **figure 8.**

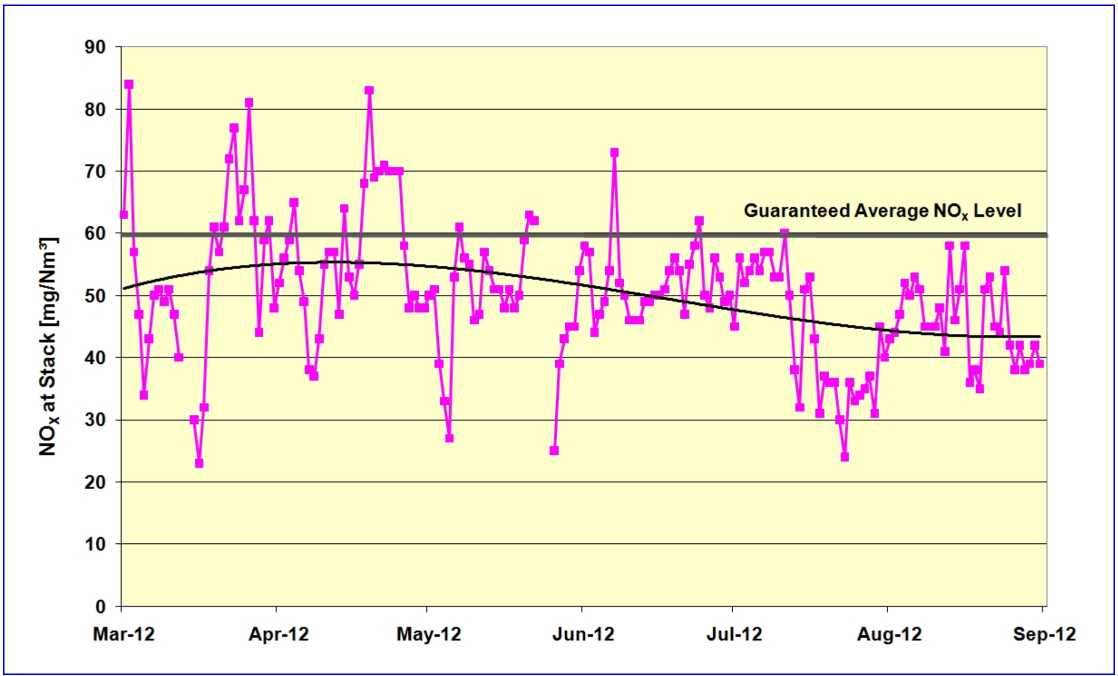


**Fig. 9: Daily Averages Line 11 – March to September 2012**

Compared to the SCR, the savings of natural gas for reheating the flue gas upstream the catalyst are 6.6 million Nm³/a and approximately 6,100 MWh/a savings in electricity, since no energy is needed to overcome the pressure drop in the catalyst.

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 $NO_x$ emissions of 50 mg/Nm³ (**figure 9**).

## 4.2. Pulverized Coal Fired Boiler (ca. 200 $MW_{el}$) in Germany

The simplified process flow chart **(figure 10)** shows the function and the scope of supply of the commercial SNCR plant as designed, installed and commissioned in a power plant in Germany. Due to the significant temperature variations between low load and full load as well as the extreme temperature imbalances, five levels with 12 injectors per level are 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.

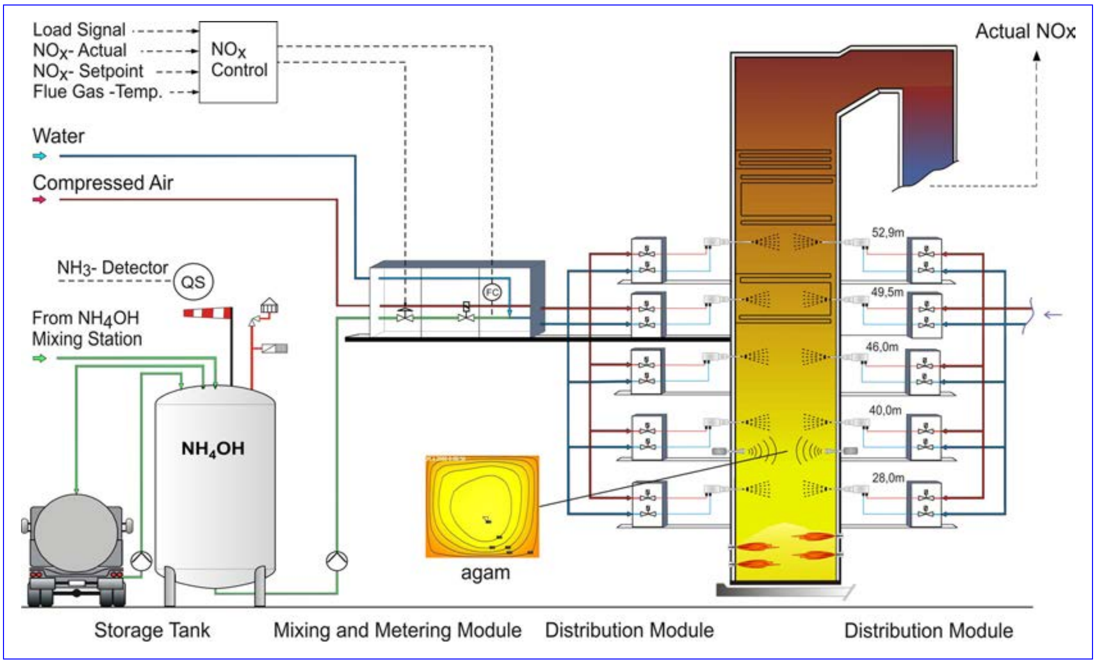


**Fig. 10: Flow Chart of SNCR with Five Injection Levels and agam**

**Fig. 11: Mixing and Metering Module Distribution Module**

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 **(figure 11)**.

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 %.

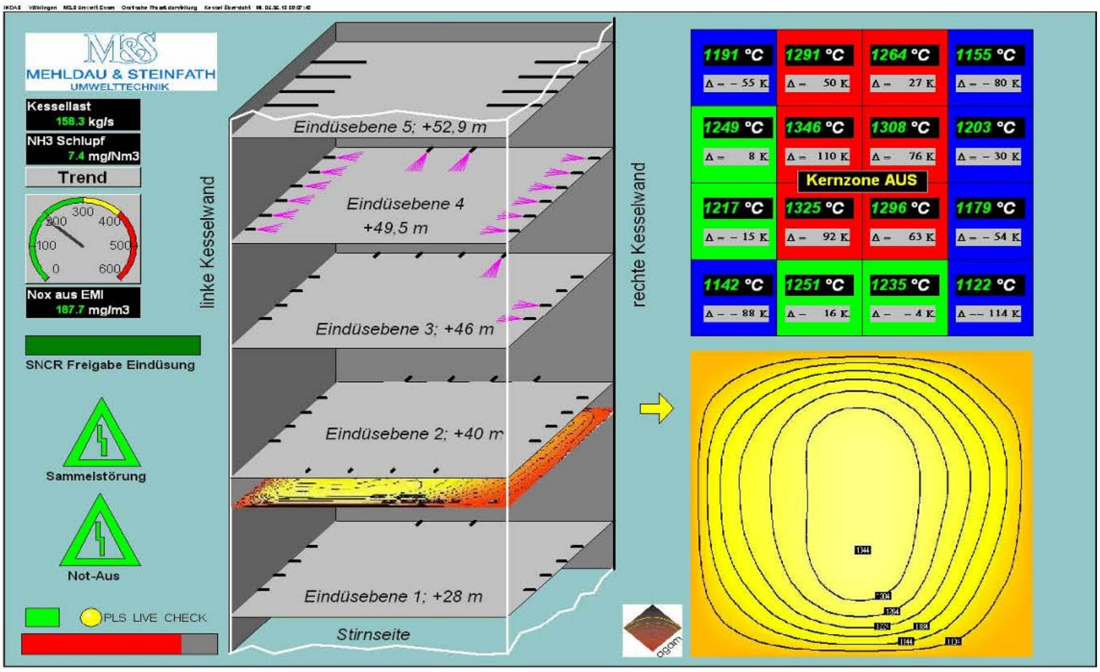


**Fig. 12: Display of Temperature Profile, Average Temperature in Zones, Injectors in Operation**

The operating 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 12**).

### 4.3. Demonstration in Pulverized Coal-Fired Boiler (ca. 225 $MW_{el}$) in Poland

A typical boiler design operating in many power plants in Poland is type OP650 with a capacity of 225 $MW_{el}$. At two different power plants tests were performed with this type of boiler. Objective of these tests was to provide reliable information that sufficient $NO_x$ reduction can be achieved with SNCR while at the same time the $NO_x$ level in the stack would not exceed 200 mg/Nm³ at any boiler load between 40 and 100 % (**figure 13**).

Temperature measurements which could only be conducted in two openings at each boiler showed that there were temperature imbalances of more than 120 K between the measuring points. Further measurements were not possible, since there were no more openings large enough for accommodating the pyrometer lance. During the tests at the boiler described below, the urea was injected through openings at levels 37.9 m and 47.4 m from the front wall as well as from the side walls at 37.9 m **(figure 14)**.

## Design Data

| | | |
|---|---|---|
| **Corner Firing** | | |
| **Capacity** | **[$MW_{el}$]** | **225** |
| **Flue gas flow rate STP** | **[$m^3/h$]** | **625.000** |
| **Fuel** | | **Coal** |
| **$SO_2$** | **[$mg/Nm^3$]** | **800 - 2.000** |
| **$NO_x$ @ 6% $O_2$ without SNCR** | **[$mg/Nm^3$]** | **250** |
| **$NO_x$ @ 6% $O_2$ with SNCR** | **[$mg/Nm^3$]** | **190** |
| **$NH_3$ with SNCR** | **[mg/Nm3]** | **5** |
| **Load Range** | | **40 – 100 %** |

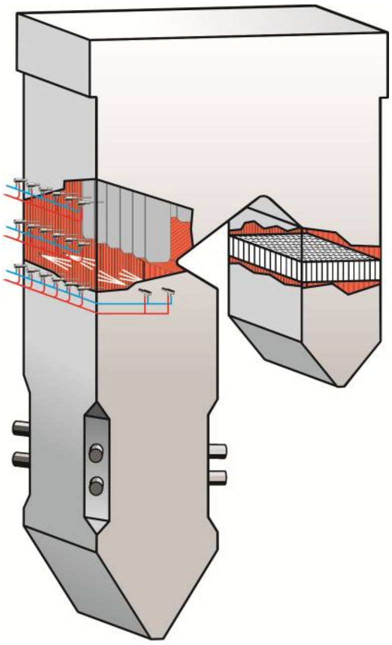

**Fig. 13: Design Data of a Coal-Fired Boiler in Poland with Corner Firing**

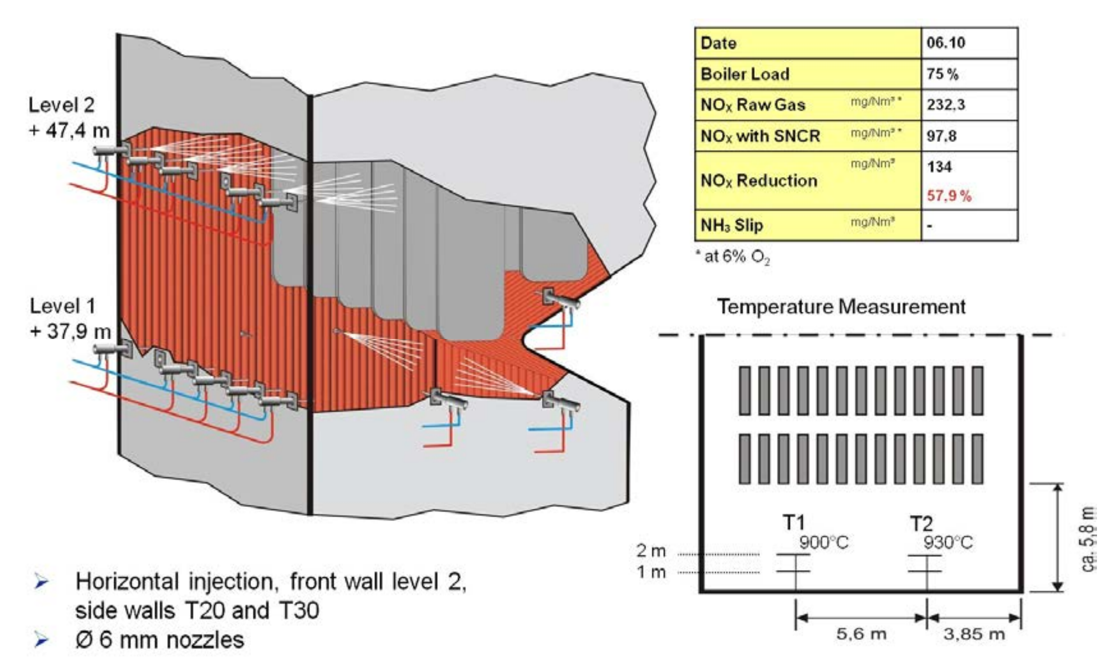


**Fig. 14: Operating Results of the SNCR Plant with a Coal-Fired Boiler (225 $MW_{el}$)**

Despite of these difficulties, the results were very positive. The required $NO_x$ reduction of 25 % was exceeded considerably at all loads reaching a maximum $NO_x$ reduction of close to 60 % at 75 % boiler load.

## 4.4. Commercial Application in a Coal-Fired Boiler (225 $MW_{el}$)

At a different power plant location in Poland, six coal-fired boilers of the same type (OP 650) as described above are operating. The major difference is that these boilers are equipped with front firing instead corner firing as the other boiler described above. In addition, the distance between the front wall and the platen heat exchangers was only 1.8 m compared to 6.0 m.

**Design Data**

| | | |
|---|---|---|
| **Front Firing** | | |
| **Capacity** | **[$MW_{el}$]** | **225** |
| **Flue gas flow rate STP** | **[$m^3/h$]** | **740.000** |
| **Fuel** | | **Coal** |
| **$SO_2$** | **[$mg/Nm^3$]** | **800 - 2.000** |
| **$NO_x$ @ 6% $O_2$ without SNCR** | **[$mg/Nm^3$]** | **250** |
| **$NO_x$ @ 6% $O_2$ with SNCR** | **[$mg/Nm^3$]** | **190** |
| **$NH_3$ with SNCR** | **[mg/Nm3]** | **5** |
| **Load Range** | | **60 – 100 %** |

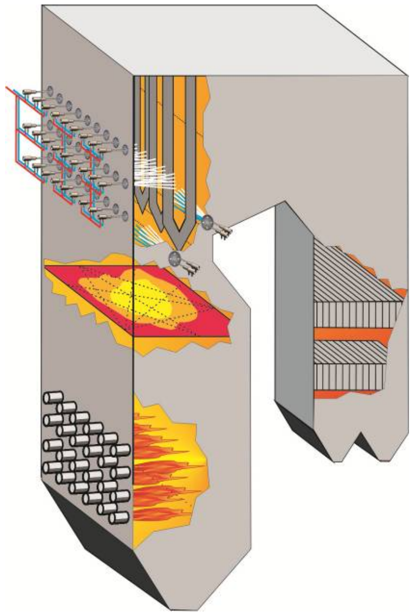

**Fig. 15: Design Data of a Coal-Fired Boiler in Poland with Front Firing**

After retrofitting of the combustion had been completed a commercial SNCR was installed for one of these boilers. For the optimum arrangement of the injectors the experiences gathered during the trials described above were applied as much as possible.

The major improvements compared to the trial plant are that three injection levels have been installed in order to follow more closely the load changes of the boiler. 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 locations and the temperature gradient between the two agam levels (**figure 16**).

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

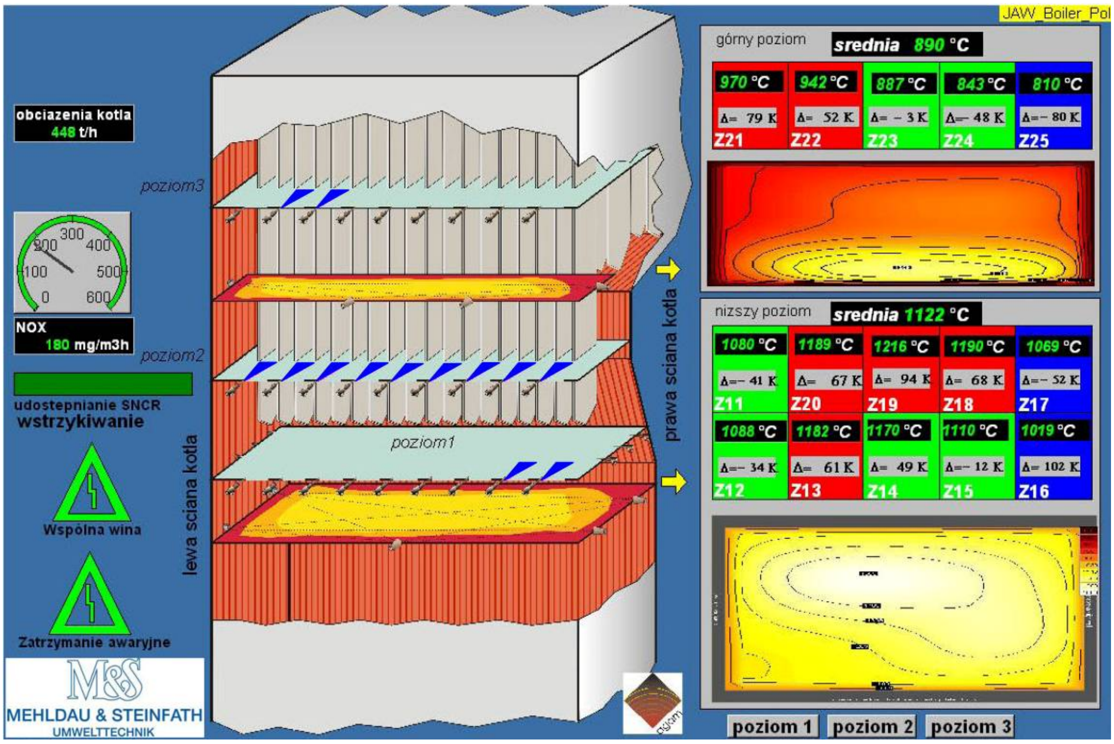


**Fig. 16: Display with Temperature Profiles in 2 Levels, Injectors in Operation, Perfomance Data**

- Each coal mill supplies six burners with coal and primary combustion air. Due to various 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 17**). As a result of this, the temperature distribution in the furnace varies considerably.
- The burners are installed at the front wall of the boiler so that the flue gas flow is directed straight to the entrance of the heat exchangers. Due to the relatively short residence time, temperature imbalances cannot be equalized and temperatures at full load are too hot at the entrance into the heat exchangers close to the nose.
- 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 do not cause major problems.

The SNCR plant was commissioned successfully in March 2012 and handed over to the operator shortly after. The plant is operating commercially since then to the satisfaction of the operator.

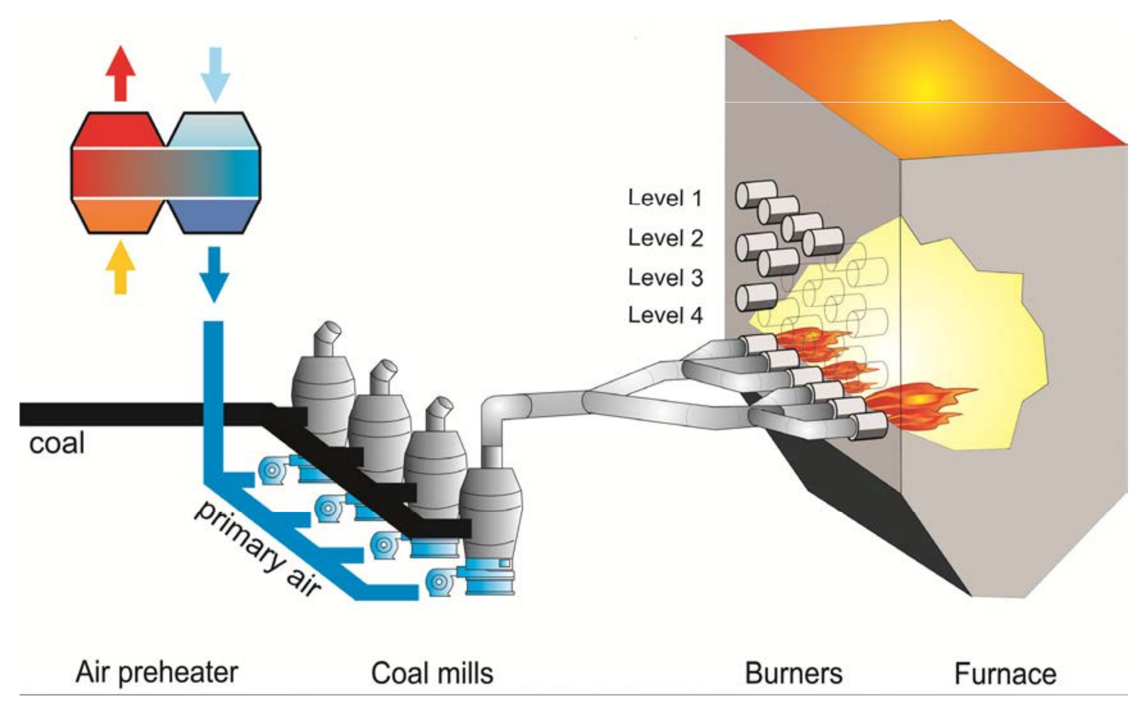


**Fig. 17: Irregular Combustion Caused by Uneven Coal Distribution**

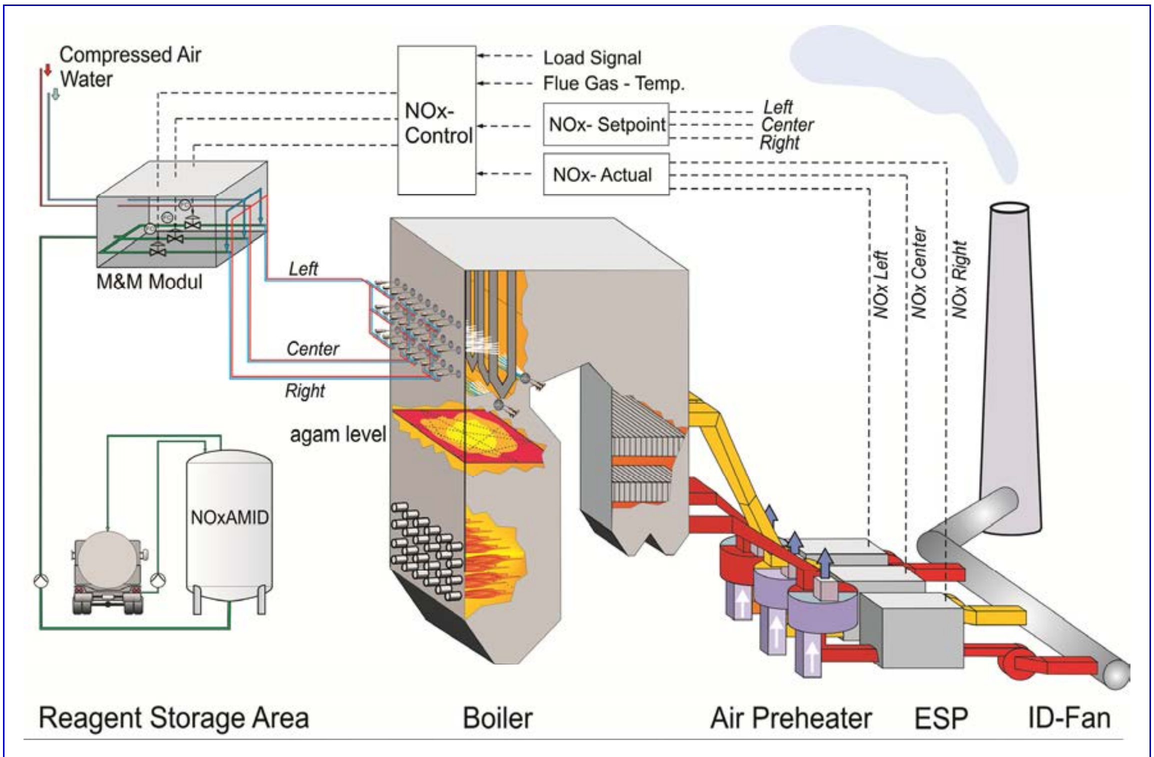


**Fig. 18: Flow Chart with 3 x $NO_x$ Control Valves to Limit Slip**

A second boiler was completed in September 2012. The third one is under construction and expected to start operation in September 2013. Since it became obvious during the commissioning that the flue gas temperature at full load is higher than expected, the upper injection level for the second boiler was moved up to a higher level where the temperatures are lower. It also turned out that there are also considerable imbalances of $NO_x$ concentrations. In order to optimize the performance of the SNCR, three control valves were installed (**figure 18**). This results in lower ammonia slip both in the flue gas and the ash and decreases the consumption of ammonia water.

In combination with the primary measures the required $NO_x$ level < 200 mg/Nm³ is maintained at all operating conditions.

## 5. Improvements and Further Potential

Although the three commercial boilers with a capacity of > 200 $MW_{el}$ have been in continuous operation after hand-over and are fulfilling all requirements, further efforts are being made in order to improve the system and utilize additional potentials for future needs.

### 5.1. TWIN-$NO_x$® Process – Combining Urea Solution and Ammonia Water

During the preliminary testing of the SNCR process in the 200 $MW_{el}$ coal-fired boiler, urea solution was used as reagent while the commercial plant was built for the operation with ammonia water.

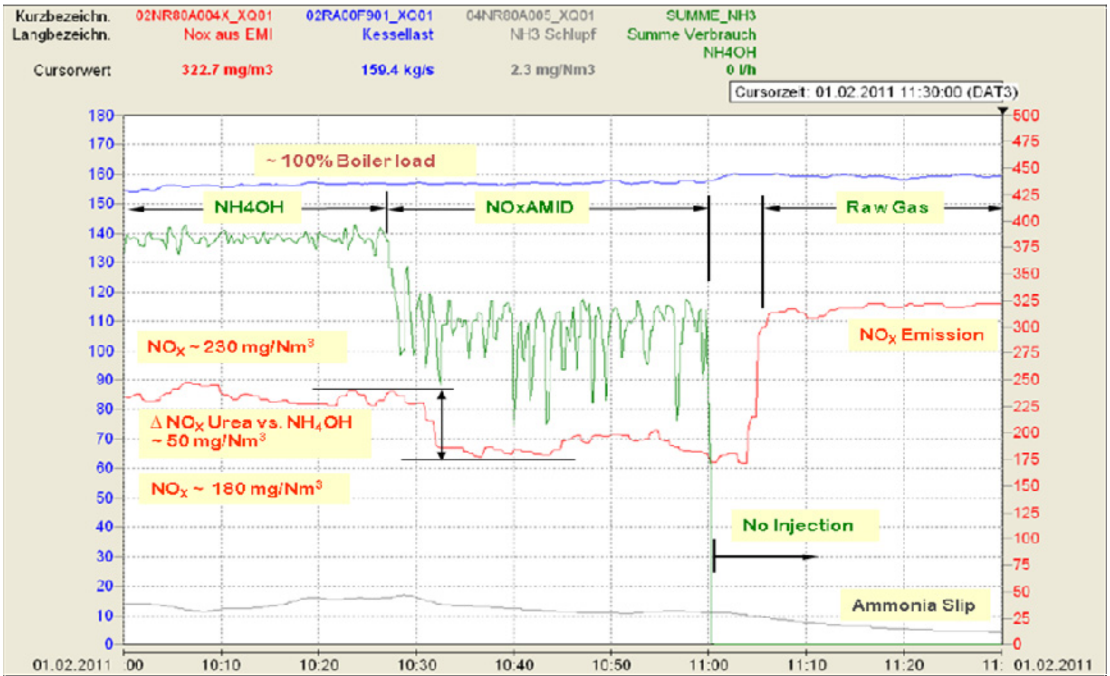


**Fig. 19: Operating Results – Alternating Injection with Ammonia Water and Urea Solution (NOxAMID)**

When commissioning the commercial plant, it became obvious that the SNCR with automatic control did not provide better results than achieved with the manually controlled trial equipment. Since the only significant difference between the two systems is that ammonia water is used as reagent for the commercial plant instead of urea solution, it was assumed that the performance of urea is better for this application. To verify this assumption, additional tests with urea were executed in the commercial plant as well.

The results showed that immediately after injection of urea the $NO_x$ reduction increased and the consumption of the reagent decreased (**figure 19**). This indicated at first glance that urea is the preferable reagent for this special boiler design 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 of droplets and consequent corrosion of the boiler tubes.

The objective of further tests was to confirm the expected advantages and disadvantages respectively the different behavior of ammonia water versus urea solution as discussed above (**figure 20**).

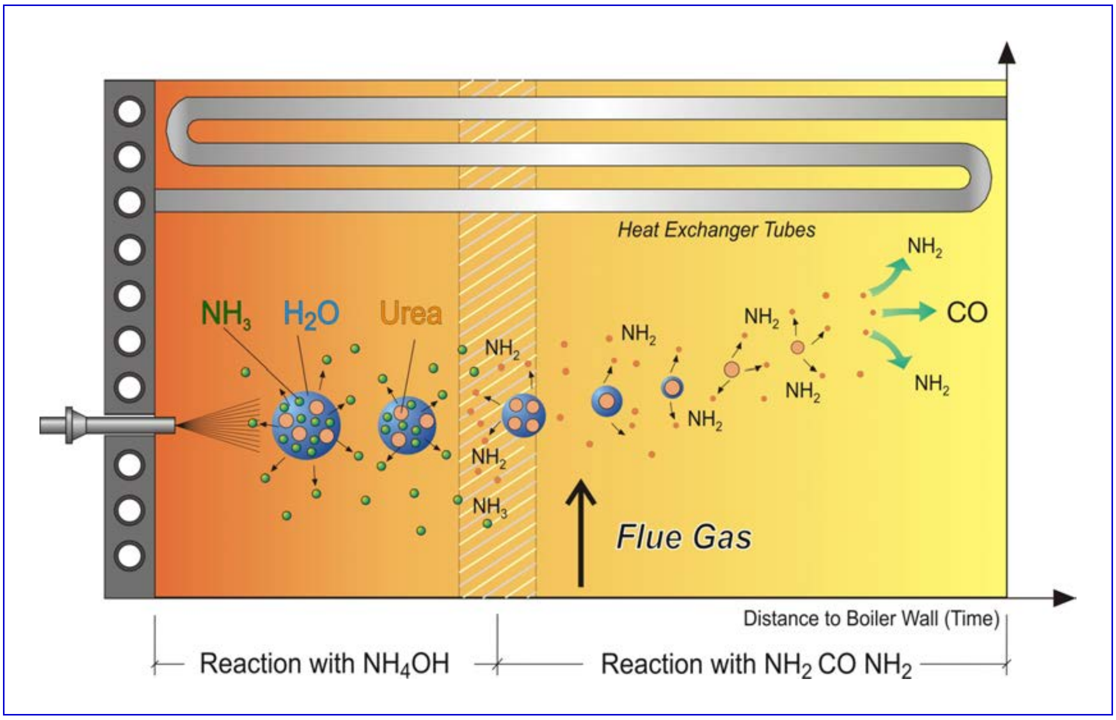


**Fig. 20: $NO_x$ Reduction – Mixing of Ammonia Water ($NH_4OH$) and Urea ($NH_2CO\ NH_2$)**

The tests proved that the low volatility reagents (NOxAMID) are indeed released at the end of the droplet's trajectory while the high volatility reagents ($NH_3$) are released near the nozzles close to the boiler walls. Additional tests showed that by changing the reagents depending on the operating conditions the performance of the SNCR could be further improved.

Thereafter, it was only a small step to mix both reagents together and inject various mixtures into the furnace, in order to combine, add and optimize the respective positive features. The new process which was developed from these experiences is registered under the trademark TWIN-$NO_x$®. The advantages of TWIN-$NO_x$® 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. Since the application of the TWIN-$NO_x$® process is only at its beginning, further potentials and improvements are expected to develop.

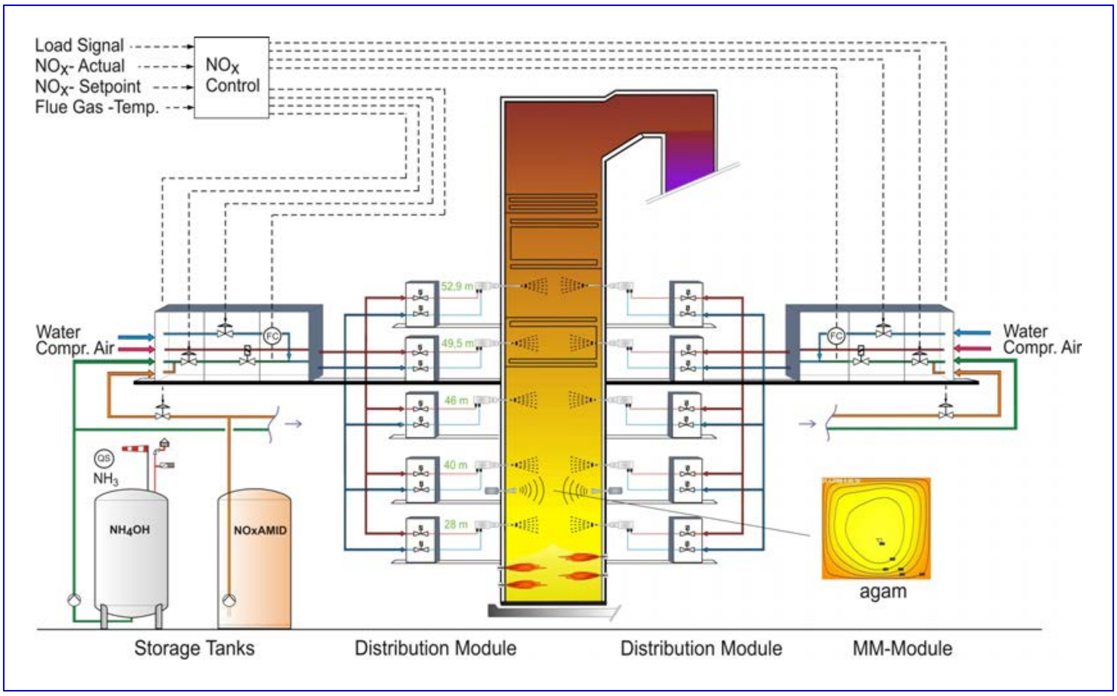


**Fig. 21: TWIN-$NO_x$® SNCR Process with Five Injection Levels for Mixing Ammonia Water and Urea Solution**

## 5.2. Selective Cooling of Flue Gases

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 many times possible, but can only be realized with a lot of technical effort and at high costs in existing boilers. In new boilers, sufficient space could be provided with reasonable effort if it were already considered during the planning stage of a project.

In cases when the flue gas temperatures are too hot, as is mostly the case at load peaks and/or in limited areas, cooling of the flue gas might be a viable alternative. This simply could be accomplished by increasing the quantity of process water. Since the changing of the fluid flow in the injectors would change the spraying pattern as well, a better solution is to install additional injectors for cooling water close to the respective injectors (**figures 23 and 24**).

With this concept, cooling water can be switched on or off for each injector independently when needed depending on the flue gas temperature in this location, while the distribution of the reagent would not be affected.

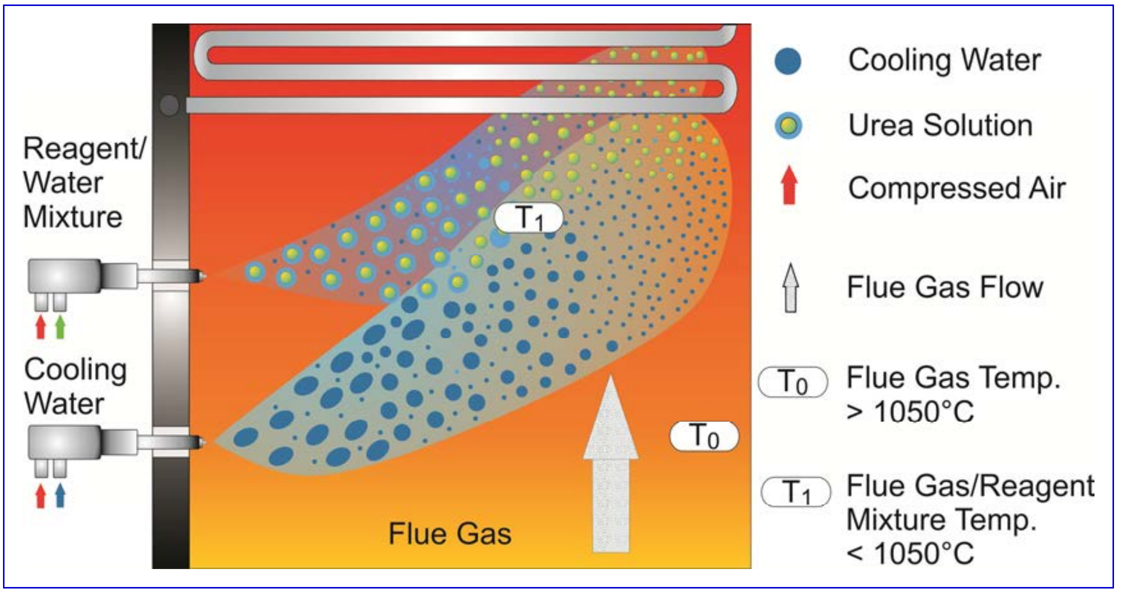


**Fig. 23: Selective Cooling of Flue Gases – Principle**

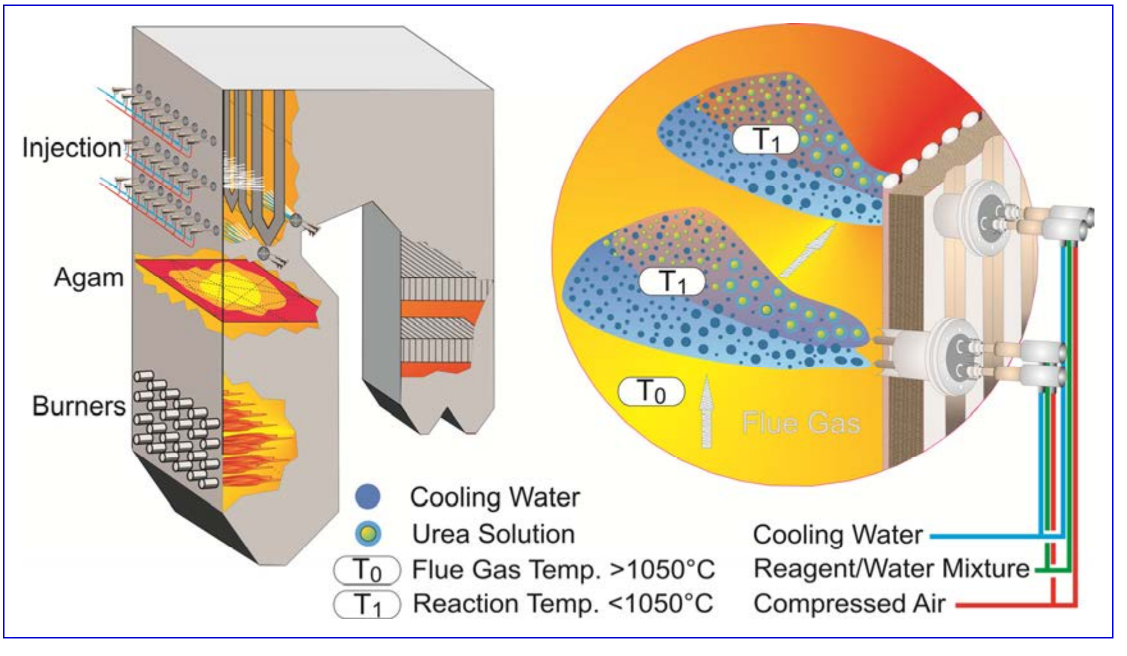


**Fig. 24: Selective Cooling of Flue Gases for Coal-Fired Boiler**

**Fig. 25: Mixing and Metering Modules for a Coal-Fired Power Plant in Poland**

## 6. Summary and Outlook

Over many years of experience in continuous operation in various combustion plants, the SNCR process has proven to be a reliable and economical process for $NO_x$ reduction to meet the required $NO_x$ limits. In the discussed power plants all guarantees were met and in many cases exceeded by far. From the process point of view, it is practically of no relevance whether urea solution, ammonia water or a mixture of both is used as reagent. If a plant is engineered, installed and operated appropriately, neither media is expected to have an impact on the availability of the overall plant.

During the decision-taking process for a DeNOx system, some attention should be paid to the fact that the protection level for the environment in the sense of BAT is mostly not achieved with SCR. The investment costs for one SCR plant alone, for instance, are so high that ten or even more SNCR plants could be built for that amount. Each of them would be able to comply with the future $NO_x$ regulations, and all these plants together would assure multiple reliefs for the environment, at the same time lowering the costs for the owners compared to one SCR plant alone.

Because of the low investment and operating costs of an SNCR system it could be beneficial for the owners of power plants to take a closer look at the potential of SNCR for their plant and to install pilot plants in order to find answers to the open questions.

Results gathered in oil and coal-fired combustion plants with a capacity of over 200 $MW_{el}$ are promising. In some Eastern European countries like Poland, Czech Republic, Romania, and

Estonia decisions in favor of the SNCR technology for large power plants have been taken and first plants are operating successfully. A significant improvement of the temperature profile and the prevention of extreme $NO_x$ peaks could be obtained, if the temperatures measured by the agam system were used not only for the regulation of the SCNR plant but also for optimizing the combustion process. Little additional effort would be required as most components which would be needed are already installed in the SNCR plant.

Furthermore, all technological measures like optimizing the combustion and flue gas recirculation should be taken if they are technically feasible as well as commercially justified. New boilers could be designed in such a way that they meet the requirement of SNCR which is basically an extension of the space in the area of the injection levels. The cost involved would be negligible in comparison to the cost of the whole boiler. The application of the SNCR technology for large power boilers still leaves open questions and not all problems are solved yet. However, the situation was not much different five years ago for waste incinerators. Today $NO_x$ levels < 100 mg/Nm³ are state of the art.

## 7. Literature


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