

# **The TWIN-NO<sub>x</sub><sup>®</sup> Process – Combination of Urea Solution and Ammonia Water increases the Performance of SNCR**

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## **1. Introduction**

During the last years, the SNCR process has been continuously improved for small and medium sized boilers like waste incineration plants, and is widely considered now as the ‘Best Available Technology’ (BAT) for this type of boilers.

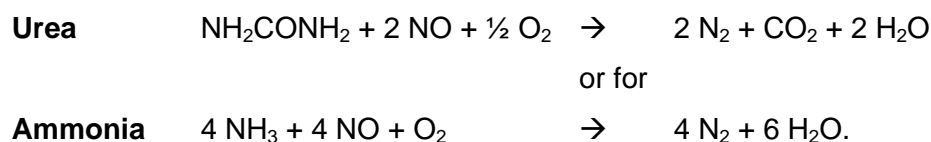
With this in mind, an increasing number of owners of power plants are seriously investigating today if the SNCR process is feasible for their large boilers as well. Besides the NO<sub>x</sub> reduction and overall cost compared to SCR, special attention is also being paid to the formation of ammonia 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.

In most SNCR plants operating today, either urea solution or ammonia water are being used as reagents. Both have their special advantages and disadvantages. The TWIN-NO<sub>x</sub><sup>®</sup> process of M&S combines the advantages by injecting urea solution and ammonia water alternating or mixing them depending on the operating conditions in the furnace.

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. Post-Combustion NO<sub>x</sub>-Control Technologies

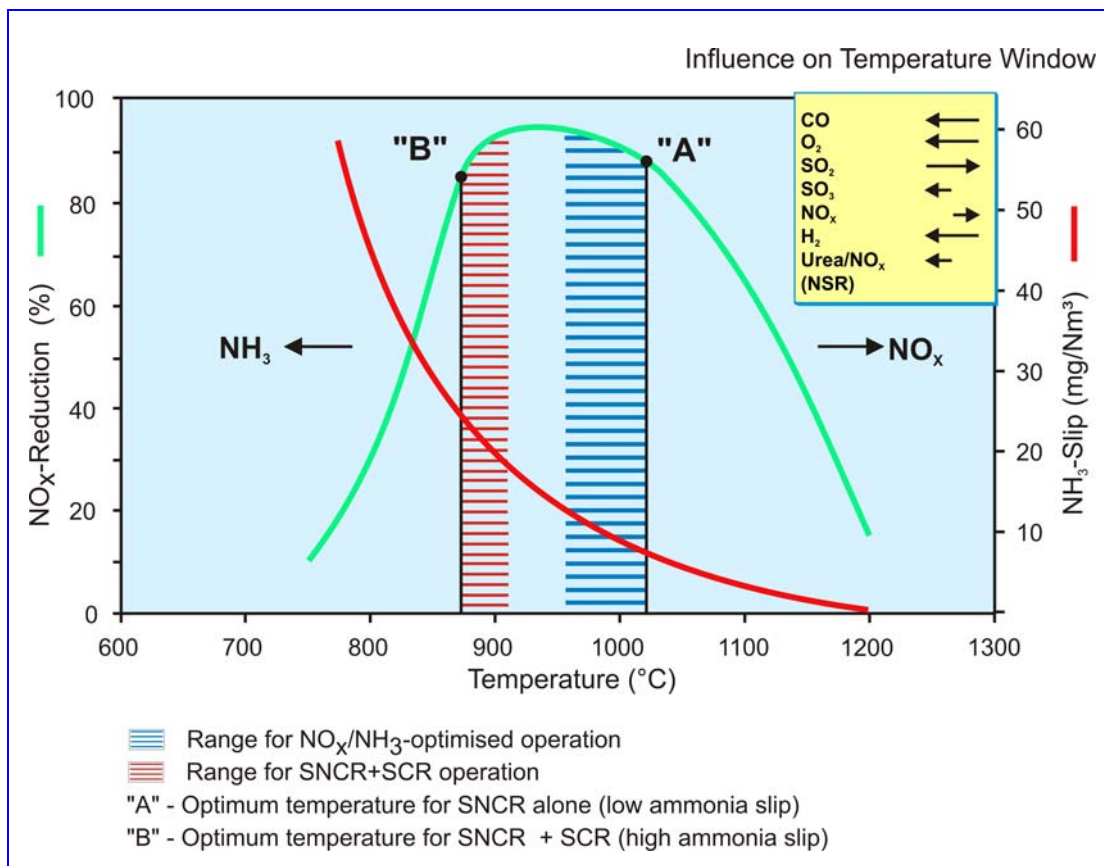
Post-combustion NO<sub>x</sub>-control technologies which are widely used are the Selective Catalytic Reduction (SCR) process and the Selective Non-Catalytic Reduction (SNCR) process. The major difference between the two systems is that without catalyst the reaction takes place in a temperature range between 900 °C and 1,050 °C whereas with catalyst this temperature window lies between 160 °C and 350 °C. In the SNCR process reagents in aqueous solution (ammonia water, urea) or in gaseous form (ammonia) are injected into hot flue gases following the overall post-combustion reactions for



For an optimum NO<sub>x</sub> reduction with a minimum NH<sub>3</sub> slip it is "only" necessary to evenly distribute and thoroughly mix the reagent in the flue gases within the appropriate temperature window. The optimum temperature range to achieve a high NO<sub>x</sub> 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 (**figure 1**).

For coal-fired boilers the optimum temperature lies between about 960 and 1,020 °C. Above this temperature range an increasing amount of ammonia is oxidised, i. e. nitrogen oxides are formed. At lower temperatures, the reaction rate is slowed down causing an 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.



**Fig. 1: NO<sub>x</sub> Reduction as a Function of Temperature**

Since the temperatures over the cross-section in the furnace are rarely uniform and considerable imbalances are often found, special measures need to be taken to identify the right positions for the injectors to distribute the reagent properly into the flue gas under all operating conditions.

### 3. SNCR Concepts for Different Requirements

The technical scope and the investment costs for SCR systems depend mainly on the flue gas volume and the local requirements like the length of flue gas ducts and the necessity of reheating the flue gases. The NO<sub>x</sub> reduction and the volume of the catalyst have no major influence on the total investment costs.

SNCR plants can be adapted much better to the specific requirements. Thus the number of injection levels and injectors and as a result of this the investment costs may vary considerably from case to case.

Application	Load Range	NO <sub>x</sub> Clean Gas [mg/Nm <sup>3</sup> ]* <sup>1</sup>	NH <sub>3</sub> Slip [mg/Nm <sup>3</sup> ]* <sup>1</sup>	Injection Levels	Miscellaneous
Small combustion plants	80 – 100 %	< 200	< 20	1	With integrated storage tank
Moderate NO <sub>x</sub> reduction	90 – 100 %	< 200	< 15	1	
Moderate NO <sub>x</sub> reduction	60 – 100 %	< 150 - 200	< 15	2	
High NO <sub>x</sub> reduction	50 – 100 %	< 100 - 150	< 15	3	
High NO <sub>x</sub> reduction, low NH <sub>3</sub> slip	50 – 100 %	< 100	< 5- 10	3	Acoustic temperature measurement (agam)
* <sup>1</sup> referring to O <sub>2</sub> operating values					

**Table 1: SNCR for Different Applications**

#### 3.1. Small Combustion Plants

For small combustion plants (< 10 MW) and plants with minimal NO<sub>x</sub> reduction standard SNCR modules which are pre-assembled are in operation since several years. Beside all instrumentation, interconnecting cabling and piping also pumps and storage containers for reagents are integrated in the module so that the installation costs on site are low (**figure 2**).

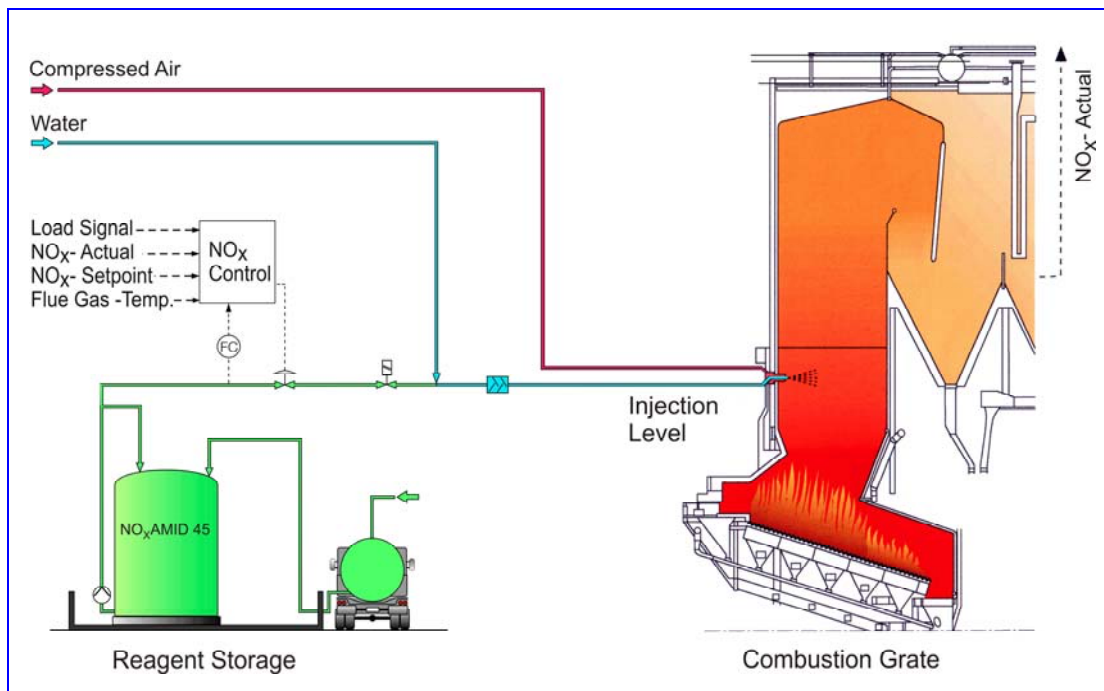


**Fig. 2:   Mixing and Metering Module and Container for Urea Solution**

### **3.2.   Medium and Larger Combustion Plants with Moderate NO<sub>x</sub> Reduction**

The simplified process flow scheme (**figure 3**) shows the function and the scope of equipment of a typical SNCR system for urea solution as installed in numerous grate fired plants with various fuels, such as municipal waste, bio-mass, RDF, coal, oil etc., which are operated according to the current regulations with NO<sub>x</sub> reduction rates of up to 50 to 60 %. Subject to the specific requirements, these plants are generally equipped with one or two injection levels, which can be operated alternating depending on the boiler load and/or the flue gas temperature.

With this concept, NO<sub>x</sub> values of 120 to 150 mg/Nm<sup>3</sup> and an NH<sub>3</sub> slip of 10 to 15 mg/Nm<sup>3</sup> can be maintained if the injection lances are arranged in such a way that a wide temperature window for the injection is covered. Temperature variations and imbalances, which cause insufficient reduction in one area, are compensated for by higher reduction rates in another area. To follow larger temperature variations and imbalances during operation, two injection levels which can be operated alternating depending on the mean temperature have proven to be successful.



**Fig. 3: Process Flow Scheme of an SNCR with Urea Solution for an MSW**

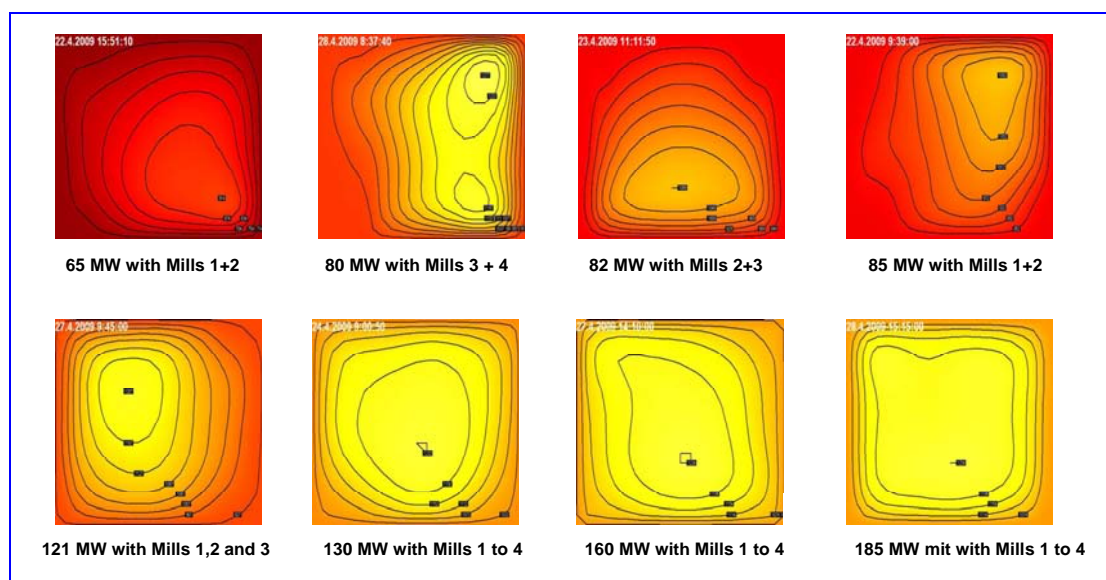
Under favorable operating conditions as can be found when homogeneous fuels are burnt at constant loads, even  $\text{NO}_x$  clean gas values below  $100 \text{ mg/Nm}^3$  can be achieved with this configuration while the  $\text{NH}_3$  slip still remains moderate.

#### **4. SNCR Technology for the Future**

The above mentioned engineering concept is not sufficient for ambitious objectives as are being discussed in Europe for further limiting the emissions of waste incineration plants, alternative fuel power stations, for co-incineration processes at cement works and power plants. 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  $\text{NO}_x/\text{NH}_3$ -optimised temperature window, which is only about 50 K wide and is marked in **figure 1**. With the traditional concept this cannot be reliably achieved during any given operating condition of incineration plants and large power boilers.

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 deposits 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 4**).

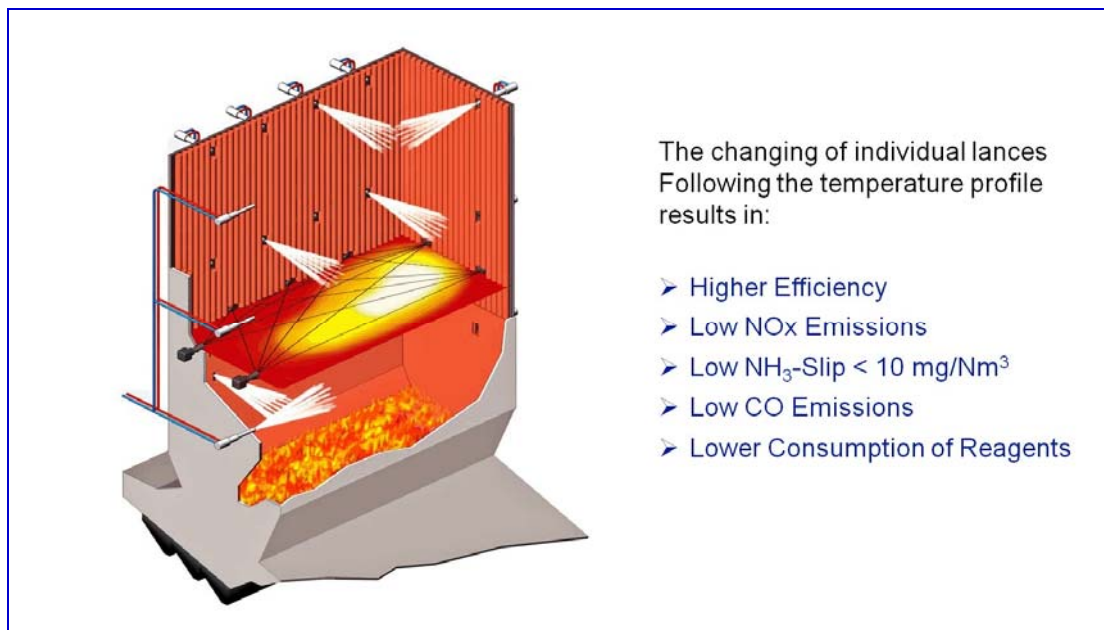


**Fig. 4: Temperature Profiles in agam Measurement Level at Different Boiler Loads and Configuration of Mills**

Depending on the fuel type, fuel distribution and air supply, temperature imbalances of up to 150 °C - and sometimes even higher - are typical. The furnace temperatures 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.

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<sub>x</sub> reduction is highest and the NH<sub>3</sub> slip is lowest, acoustic gas temperature measurement systems (agam) are used where 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.





**Fig. 5: Temperature Measuring Points for the SNCR Process in the Furnace of an MSW**

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 (**figure 5**). 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<sub>x</sub> reduction, NH<sub>3</sub> slip and reagent consumption.

In Germany, Sweden, Austria, Switzerland and the Netherlands, SNCR plants designed for NO<sub>x</sub> limits of < 100 or even 60 mg/Nm<sup>3</sup> have been operated for several years. They reliably comply with the guaranteed emission values in continuous operation. The newer are equipped with an acoustic temperature measurement (agam) and three or more injection levels to switch each individual lance. They usually have to comply with specifically low NH<sub>3</sub> slip apart from their low NO<sub>x</sub> clean gas values and high efficiency.

## 5. Results with SNCR in Typical Power Boilers

To generate reliable data for a decision whether SCR or SNCR is preferable, the feasibility of retrofitting a plant in Germany with an SCR-system has been estimated thoroughly before the trials with SNCR were started. For this specific application (**figure 5**) and for most other boilers the results are summarised as follows:

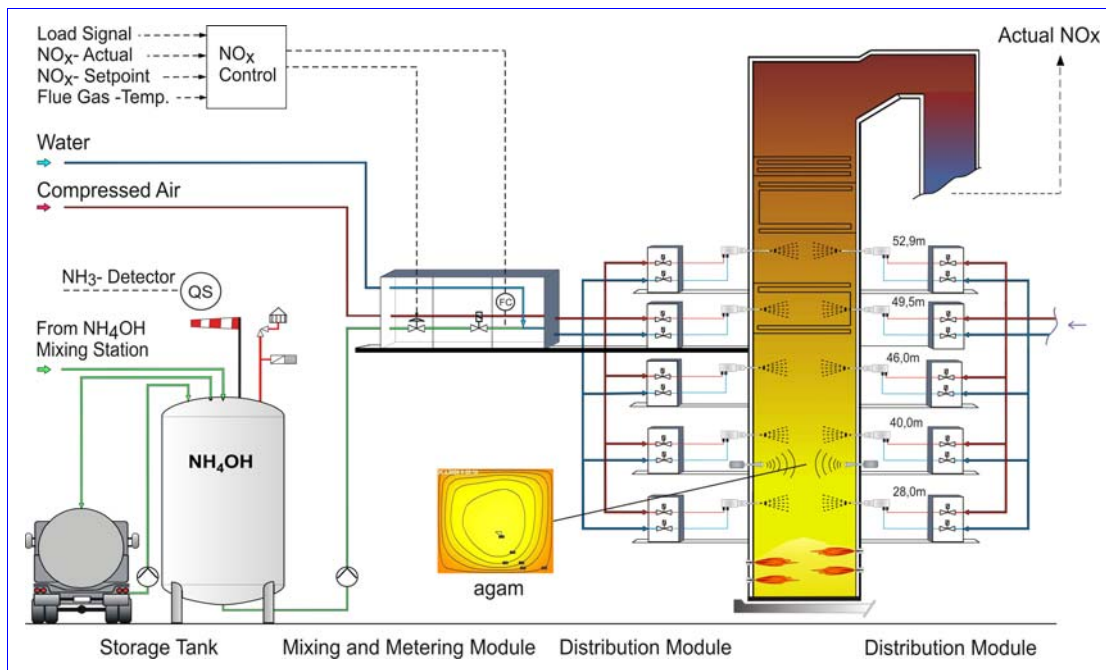


- The investment costs for an SCR-system are at least about ten times higher than those of an SNCR system.
- Despite the more efficient use of the reagent, the operating cost of a High Dust SCR would be significantly higher, especially due to the pressure losses in the catalyst, flue gas reheating and ducts.
- In most cases, the installed blower capacity has to be increased to compensate for the additional pressure loss within the catalyst.
- In an induced draught system it is mostly necessary to reinforce the flue gas ducts on the suction side due to the decreasing pressure.
- The SO<sub>2</sub>/SO<sub>3</sub> conversion in the catalyst may cause corrosion, when the flue gas temperature falls below the dew point of sulphuric acid.
- The retrofitting would be very time consuming and would at the same time interfere considerably with the plant's normal operation.
- The availability of the SNCR system is practically unlimited, as all main components are redundant so that they can be exchanged during regular operation.
- In plants using SCR many operating hours are lost when catalysts are exchanged or regenerated.

Considering all relevant aspects like the degree of NO<sub>x</sub> reduction, cost-benefit-ratio and availability, utility companies in Germany, Poland and Czech Republic, etc. are more and more choosing the SCNR-system for commercial use, after tests have been completed successfully. The commercial plant in Germany with a capacity of 200 MW<sub>el</sub> is in operation since 2010 and another one in Poland with a capacity of 225 MW<sub>el</sub> since 2012.

### **5.1. Pulverised Coal Fired Boiler (ca. 200 MW<sub>el</sub>) in Germany**

The simplified process flow diagram (**figure 6**) 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 differences 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. 6: Flow Diagram of SNCR with Five Injection Levels and agam**

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 7).



**Fig. 7: Mixing and Metering Module - Distribution Module**

The SNCR plant was put into operation in March 2010. The guaranteed  $\text{NO}_x$  and  $\text{NH}_3$  clean gas values were instantly reached in most cases with boiler loads ranging from 20 to 100 %.

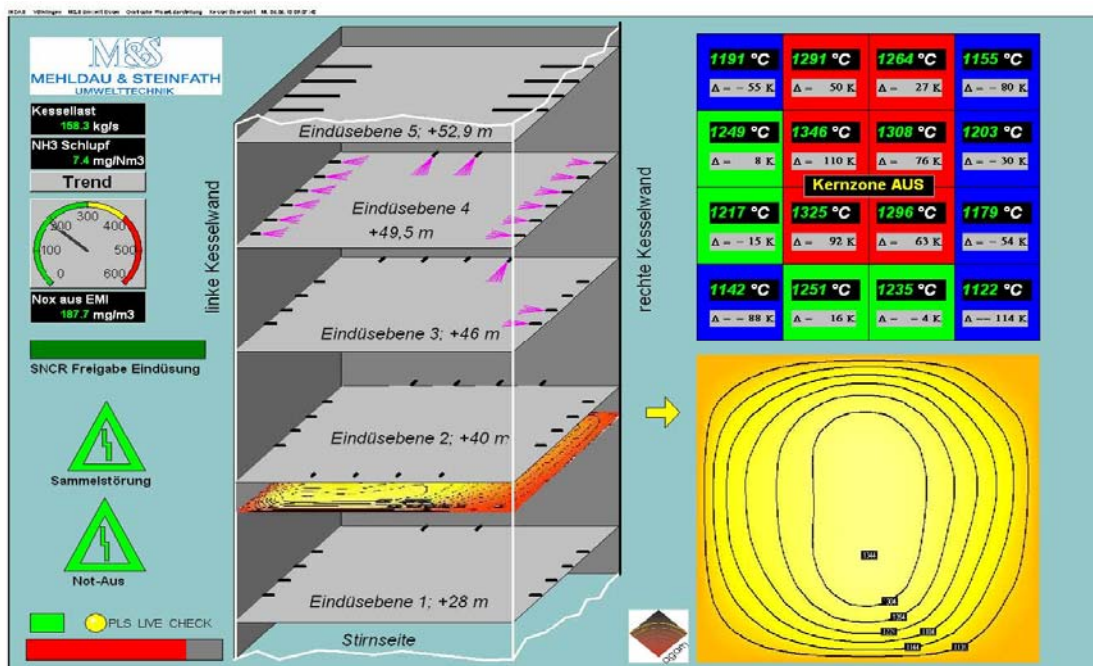


Fig. 8: Display of Temperature Profile, Average Temperature in Zones, Injectors in Operation

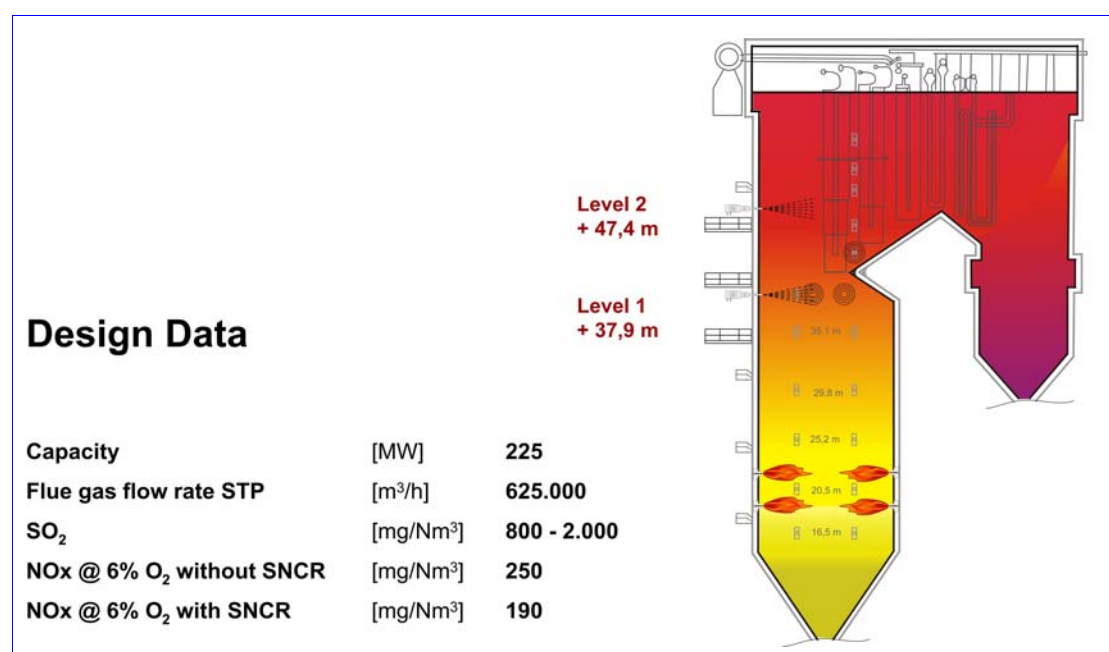


Fig. 9: Operating Results with SNCR Plant in 200 MWel Coal fired Boiler

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 8**). The quick reaction after injection of ammonia water and the degree of NO<sub>x</sub> reduction can be seen on **figure 9**.

## 5.2. Pulverised Coal Fired Boiler (ca. 225 MW<sub>el</sub>) in Poland

A typical boiler design operating in many power plants in Poland is type OP650 with a capacity of 225 MW<sub>el</sub>. 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<sub>x</sub> reduction can be achieved with SNCR while at the same time the NO<sub>x</sub> level in the stack would not exceed 200 mg/Nm<sup>3</sup> at any boiler load between 40 and 100 % (**figure 10**).



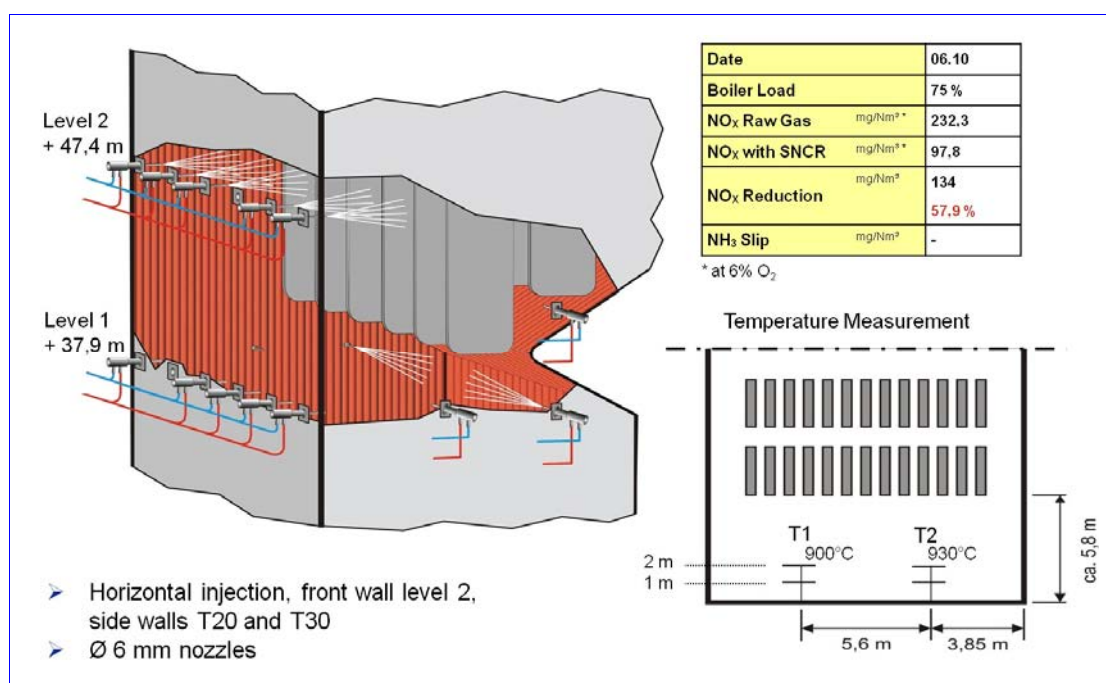
**Fig. 10: Design Data of a Coal-Fired Boiler in Poland**

Temperature measurements which could only be conducted at 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 11**).



Despite of these difficulties, the results were very positive. The required NO<sub>x</sub> reduction of 25 % was exceeded considerably at all loads (**table 2**) reaching a maximum NO<sub>x</sub> reduction of close to 60 % at 75 % boiler load.

In a commercial plant it is recommendable to install a third level for injecting the reagent and an acoustic temperature measurement system (agam). This would improve the performance considerably, especially with regard to efficiency and ammonia slip, since the reagent always could be injected into the flue gas with optimum temperatures.



**Fig. 11: Operating Results of the SNCR Plant with a Coal-Fired Boiler**

No.	Date	Boiler Load	NO <sub>x</sub> Base Line mg/Nm <sup>3</sup> *	NO <sub>x</sub> with SNCR mg/Nm <sup>3</sup> *	NO <sub>x</sub> Reduction mg/Nm <sup>3</sup> %	
1	08.10.2009	100 %	197,8	125,3	72	36,7
2	16.09.2009	90 %	233,6	137,0	97	41,4
3	06.10.2009	75 %	232,3	97,8	134	57,9
4	07.10.2009	60 %	150,0	75,0	75	50,0
5	18.09.2009	40 %	456,1	244,3	212	46,4
at 6 % O <sub>2</sub>						

**Table 2: NO<sub>x</sub> Reduction with SNCR Demonstration Plant at Different Boiler Loads**

In a different power plant location in Poland, several boilers of the same type (OP 650) are operating. After the retrofit 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 employed as much as possible.

The major improvements 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 (**figure 12**). The second level is helpful in order to obtain more precise information on the flue gas temperatures near the injector locations. These temperatures are fluctuating very much subject to the boiler load, the burners and coal mills in operation.

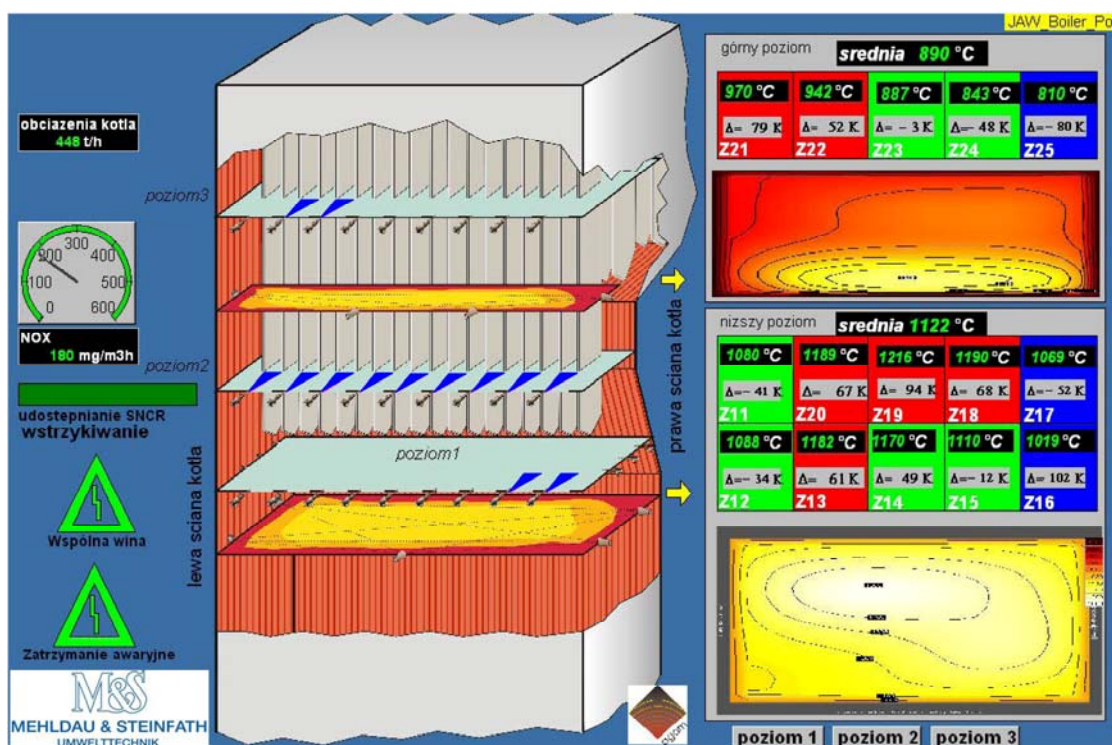


Fig. 12: Display with Temperature Profiles in 2 Levels, Injectors in Operation, Performance Data

The SNCR plant was commissioned successfully in March 2012 and is operating since then commercially. In combination with the primary measures the required NO<sub>x</sub>-level < 200 mg/Nm<sup>3</sup> is maintained at all operating conditions.

## 6. Differences between Urea and Ammonia

After the general decision has been taken in favor of SNCR, it is as important to select the optimum reagent for each application. The availability, logistics and cost of urea solution compared to ammonia water are certainly valid points. But more often there are significant reasons from the process point of view to favor either one of the two reagents depending on the special application.

The major difference between ammonia water and urea solution is shown in a strongly simplified diagram in **figure 13**. Urea dissolved in water can only be decomposed into reactive  $\text{NH}_2$ -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.

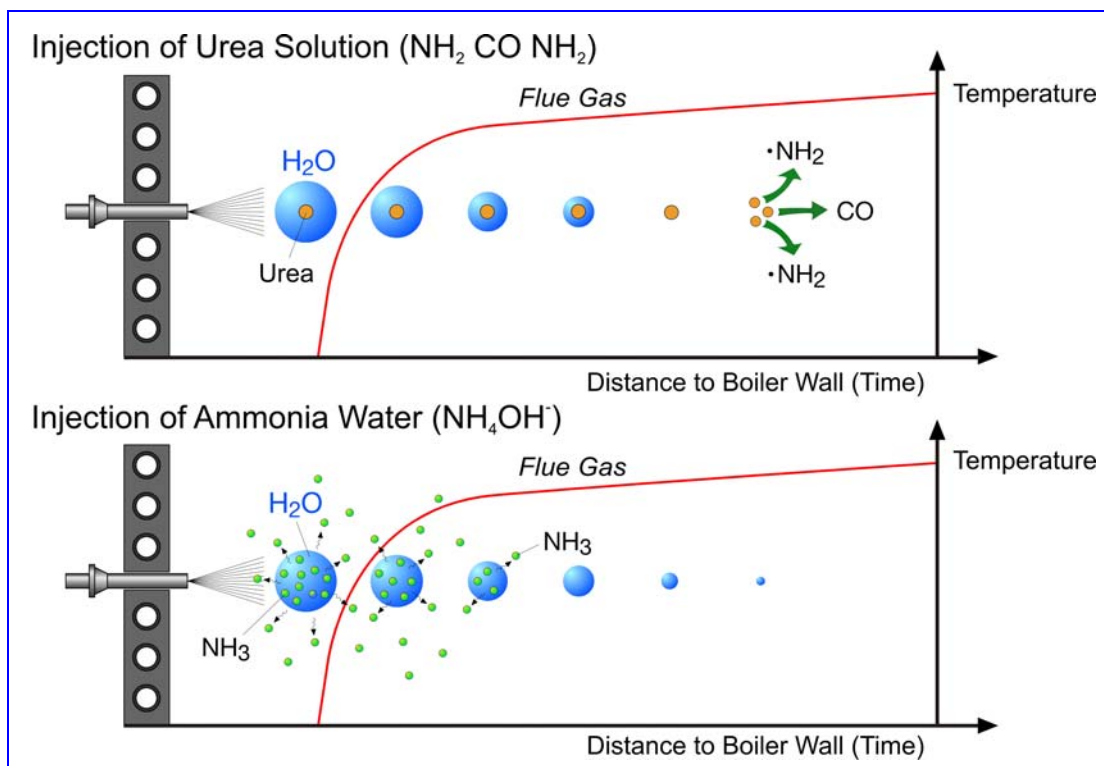


Fig. 13:  $\text{NO}_x$  Reduction: Urea Solution versus Ammonia Water



If the water droplet is big enough, it is possible to inject into a place that is too hot for NO<sub>x</sub> 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, that is the exit of the nozzle, immediately after the ammonia water has entered the furnace. The NO<sub>x</sub> 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.

The greater mass flow of water causes a lower pressure in the jet stream, compared to using compressed air or steam alone. Due to the resulting pressure difference, the surrounding flue gas containing the evaporated ammonia is mixed with the jet stream which carries ammonia almost as far as urea. This concept produces similar results with regard to NO<sub>x</sub> reduction and ammonia slip as do applications where urea is used as reagent – especially when the flue gas velocity is low like in grate fired boilers where no heat exchangers are built into the furnace.

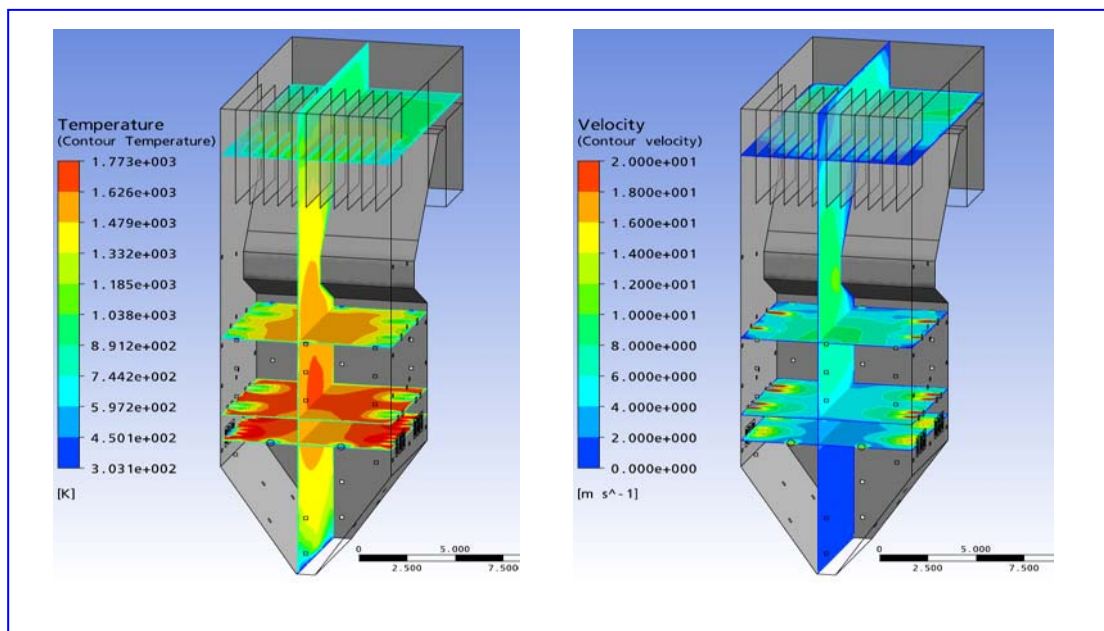
## **7. TWIN-NO<sub>x</sub><sup>®</sup> Process – Combining Urea Solution and Ammonia Water**

There are basically two typical design concepts of coal-fired utility boilers. The main boiler design has two flue gas passes and a nose at the end of the furnace, as is typical for the boiler

type OP 650 widely operated in Poland. The other design is the tower boiler. The significant differences of the two designs which have an impact on the SNCR technology are as follows:

In the two pass boiler, the vertical flue gas flow depending on the burner configuration is directed towards the front wall of the boiler by the contraction nose (**figure 14**). At the front wall it is turned horizontally and directed to the platen-type super heaters. At full load the optimum temperature is generally in the level of or even within the super heaters. 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 already to  $\text{NO}_x$  before it could reach the area with appropriate temperatures within the heat exchangers. The overall  $\text{NO}_x$  reduction would not be satisfying.

With urea solution this problem is easier to handle since by the time the water droplet surrounding the urea particle has evaporated, the  $\text{NH}_2$  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. 14: Temperature and Flue Gas Velocities in a Coal-Fired Boiler**

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<sub>x</sub> 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<sub>x</sub>.

Only the area marked in green color between those two areas has an optimum temperature range for the reactions (**figure 15**). 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 in several levels simultaneously with different penetration depths and/or lances with different lengths. An optimum distribution of the reagent is still difficult to realise. 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. If more than three injection levels are installed a second level with an acoustic temperature measurement system is strongly recommended to improve the performance of the SNCR notably.

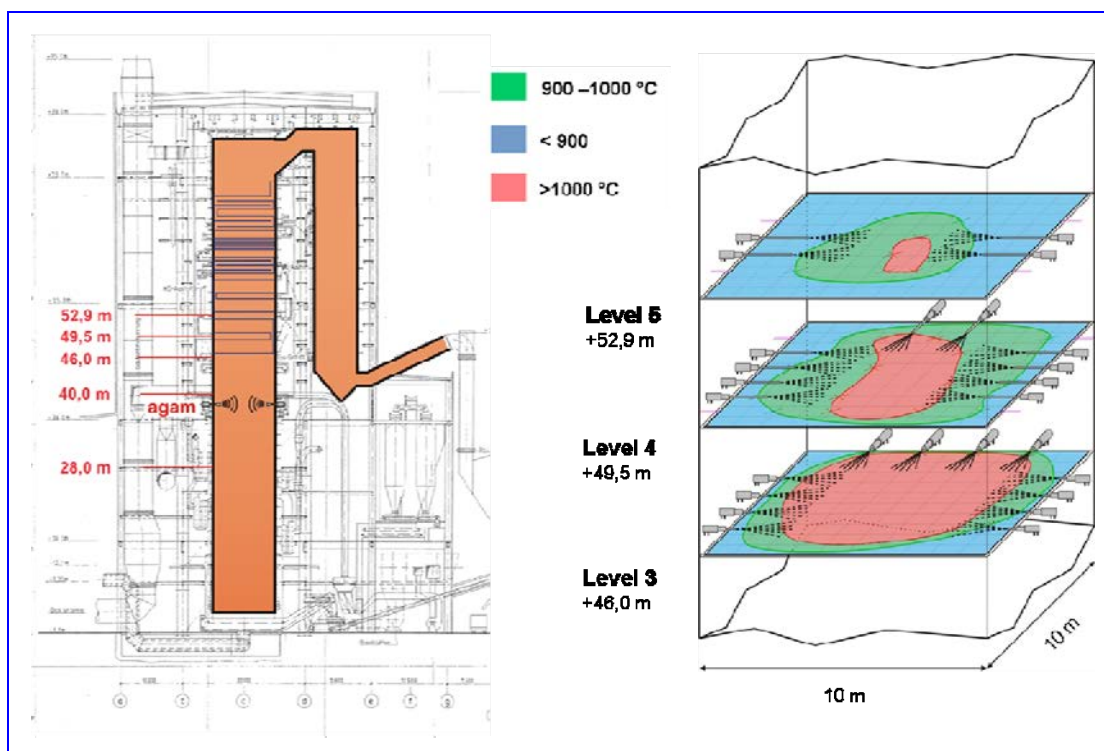
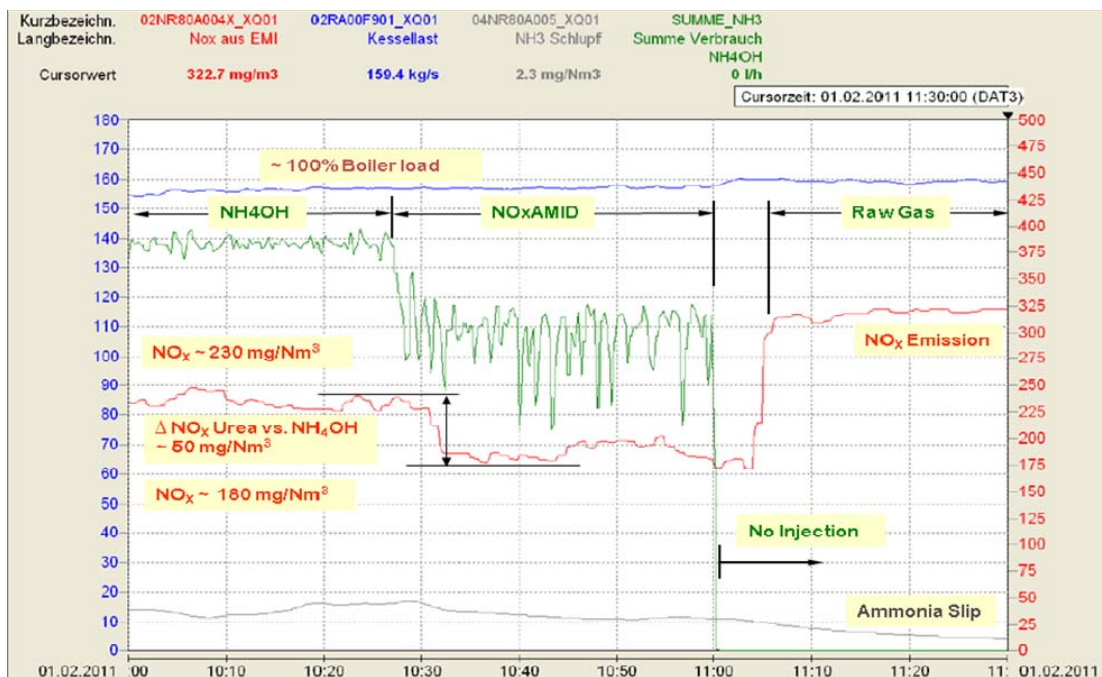


Fig. 15: SNCR Process for a Coal-Fired Boiler in Germany

During preliminary testing of the SNCR process in the 200 MW<sub>el</sub> coal fired boiler described above, urea solution was used as reagent while the commercial plant was built for the operation with ammonia water. During the commissioning of 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. The only significant difference between the two systems is that ammonia water is used as reagent for the commercial plant instead of urea solution. This leads to the assumption that the performance of urea is better for this application than ammonia water.

In order to verify this assumption, additional tests with urea were performed in the commercial plant as well. The realisation 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 reagents.

The results showed that immediately after injection of urea the NO<sub>x</sub> reduction increased and the consumption of the reagent decreased (**figure 16**). This indicated at first glance that urea is the preferable reagent for this special boiler design with regard to the NO<sub>x</sub> emission values



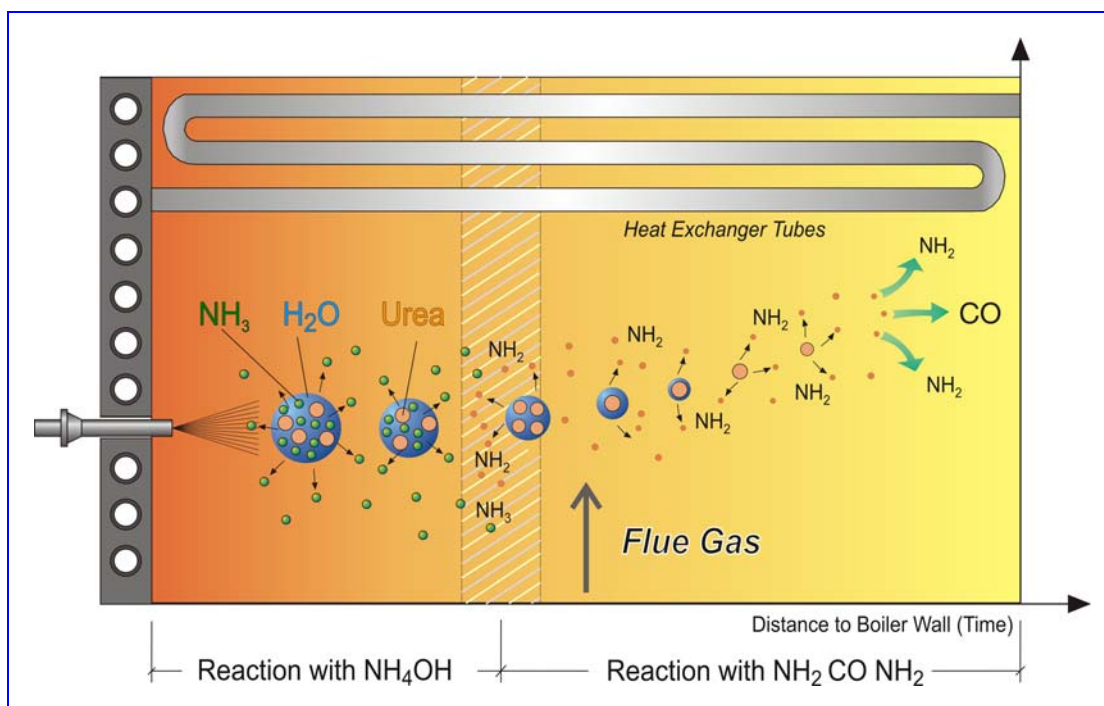
**Fig. 16: Operating Results – Alternating Injection with Ammonia Water and Urea Solution (NO<sub>x</sub>AMID)**

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 verify the expected advantages and disadvantages respectively to confirm the different behavior of ammonia water versus urea solution as discussed above.

The tests confirmed that the low volatility reagents ( $\text{NO}_x\text{AMID}$ ) are indeed released at the end of the droplet's trajectory while the high volatility reagents ( $\text{NH}_3$ ) 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 (**figure 17**), in order to combine, add and optimise the respective positive features. The new process which was developed from these experiences is registered under the trademark  $\text{TWIN-NO}_x^{\text{®}}$ .



**Fig. 17:  $\text{NO}_x$  Reduction - Mixing of Ammonia Water ( $\text{NH}_4\text{OH}$ ) and Urea ( $\text{NH}_2$  CO  $\text{NH}_2$ )**

## 8. Commercial Application of TWIN-NO<sub>x</sub><sup>®</sup> Process

At the end of 2011, a commercial SNCR plant has been built for an oil fired boiler which is operated alternately or simultaneously with urea solution and/or ammonia water.

The boiler has a steam capacity of 154 t/h and is operating in a load range from 20 to 100 %. The SNCR was originally designed for ammonia water as reagent following successful trials with urea solution. But similar as with the coal fired tower boiler, the results of the trials could not be met at full load in the commercial plant when operated with ammonia water. At full load the flue gas temperatures of around 1,240 °C are obviously too high for a sufficient NO<sub>x</sub> reduction. Ammonia reacts too early in the high temperature close to the injection nozzles while urea is carried to the area within the super heater where the temperature is appropriate. At lower load ammonia or a mixture of both reagents is injected, so that the NO<sub>x</sub> level of < 200 mg/Nm<sup>3</sup> can be maintained at all loads. **Figure 18** shows the flow diagram. In **figure 19** the different reaction areas of the two reagents are illustrated.

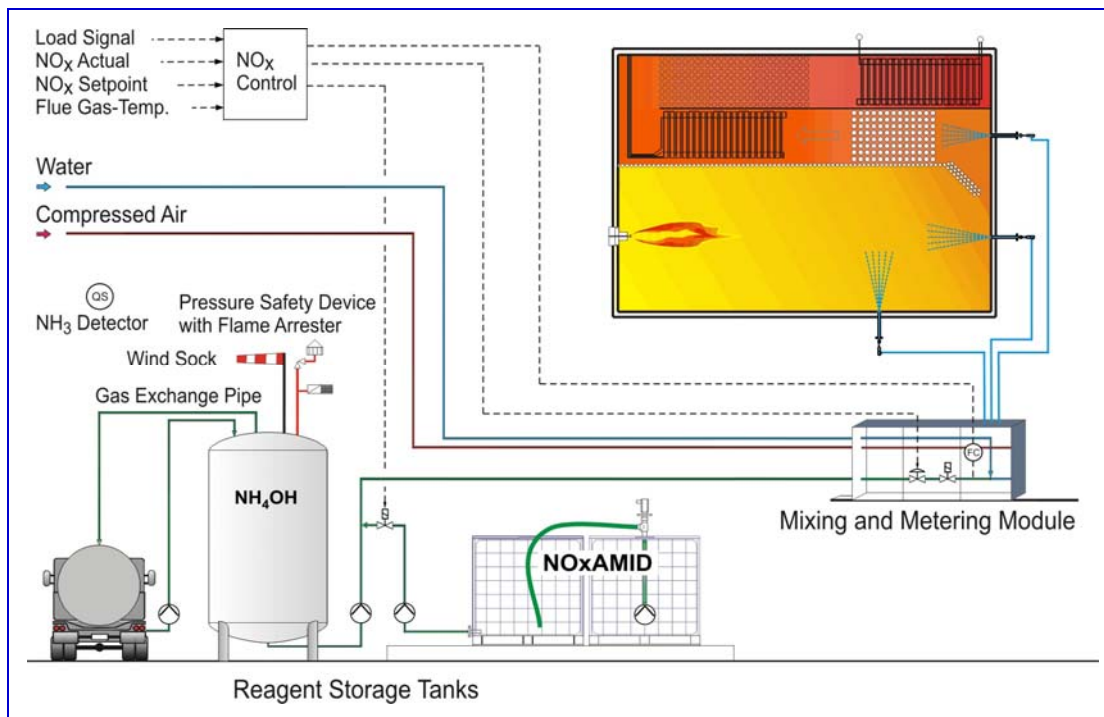
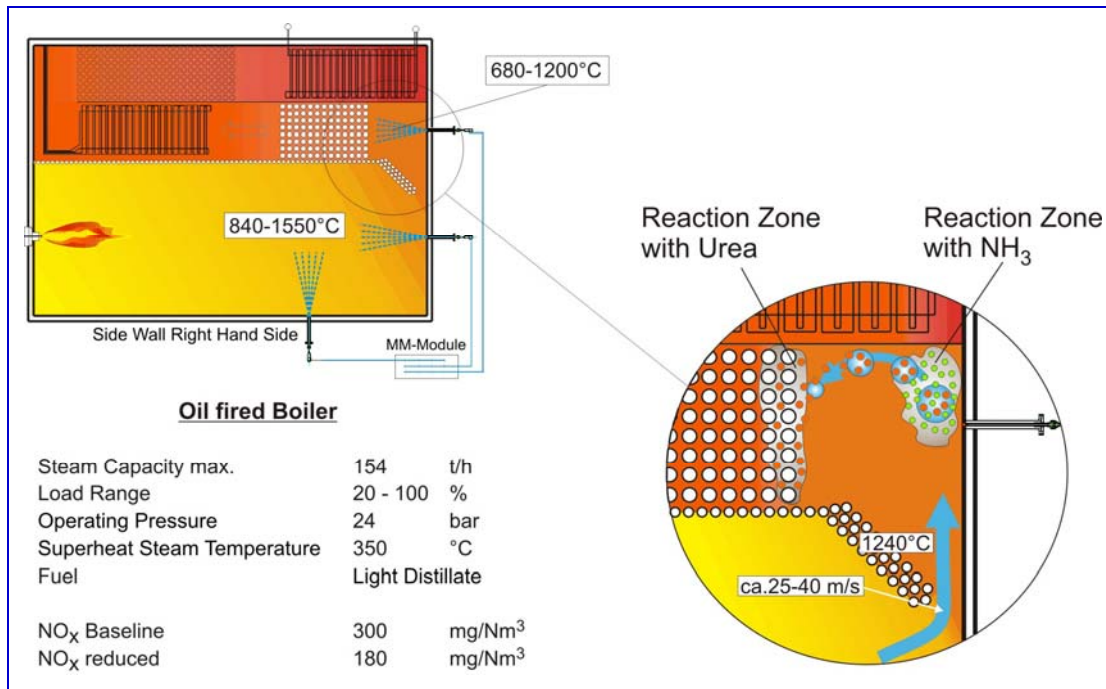


Fig. 18 Flow Diagram of TWIN-NO<sub>x</sub><sup>®</sup> Process for Oil Fired Boiler





**Fig. 19: Reaction Zones of Urea and Ammonia Water in a Fire Tube Boiler**

The advantages of TWIN-NO<sub>x</sub><sup>®</sup> summarise 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<sub>x</sub><sup>®</sup> process is only at its beginning, further potentials and improvements are expected to develop.

## 9. 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<sub>x</sub> reduction to meet the required NO<sub>x</sub> 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.

Although slightly higher NO<sub>x</sub> reduction levels are achievable with the SCR-technology, the cost-benefit-ratio is mostly not as good as with the SNCR technology - in particular when



taking into account that by now,  $\text{NO}_x$  values below  $300 \text{ mg/Nm}^3$  or even  $200 \text{ mg/Nm}^3$  are obtained for large coal-fired boilers with combustion modifications alone.

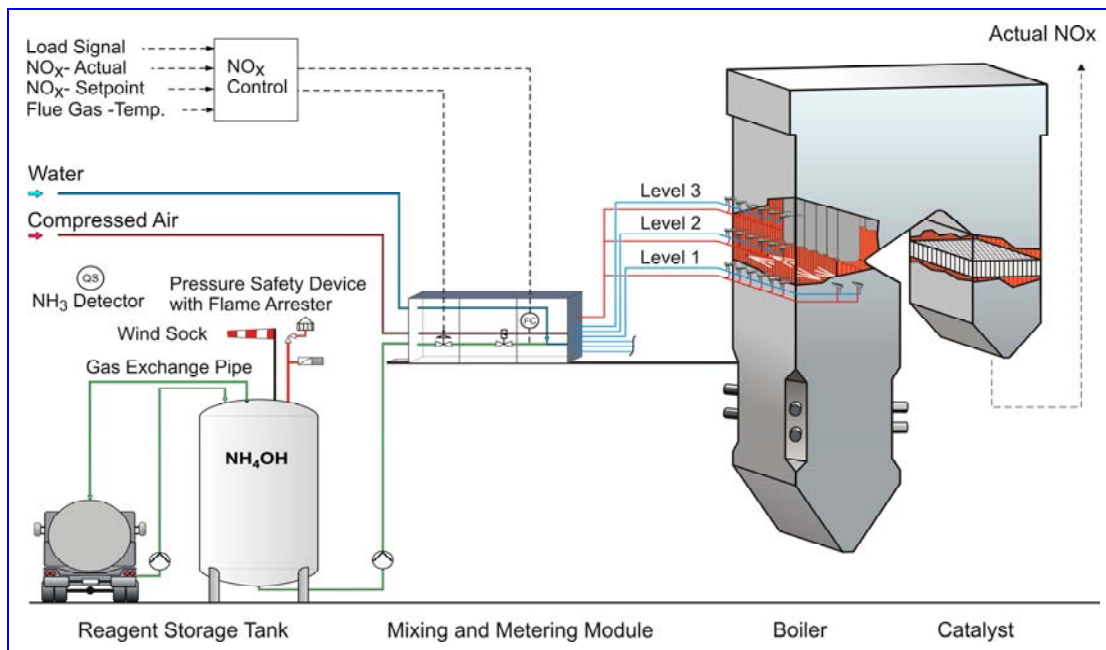
During the decision-taking process for a denox system, some attention should be paid to the fact that the protection level for the environment in the sense of BAT is mostly not achieved with SCR. The investment costs for one SCR plant alone, for instance, are so high that ten or even more SNCR plants could be built for that amount. Each of them would be able to comply with the future  $\text{NO}_x$  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 profitable for the owners of power plants to take a closer look at the potential of SNCR for their plant and to install a pilot plant in order to find answers to the open questions.

Results gathered in oil and coal fired combustion plants with a capacity of over  $200 \text{ MW}_{\text{el}}$  are promising. In the accession countries Poland and the Czech Republic first decisions in favor of the SNCR technology for large power plants have been taken. A significant improvement of the temperature profile and the prevention of extreme  $\text{NO}_x$  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. With a small additional slice of catalyst at the tail end of the boiler, the ammonia slip could further be minimised (**figure 20**).

New boilers could be designed in such a way that they meet the requirement of SNCR which is basically the 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  $\text{NO}_x$  levels  $< 100 \text{ mg/Nm}^3$  are state of the art.



**Fig. 20: SNCR with Ammonia Water and Catalyst**

Taking only into account the large number of utility boilers in the range of 100 – 200 MW<sub>el</sub> which are common in Poland, the Czech Republic and all the other Eastern European Countries and which have to be retrofitted with NO<sub>x</sub> control systems in the next few years, challenging tasks lie ahead. If all these plants have to be completed at the same time, a number of prototypes have to be built in parallel and the usual guarantee conditions will pose unacceptable risks on the suppliers of SNCR plants. Therefore, it is only fair that they get the time needed to further improve the existing technologies and gather sufficient experiences. The alternative to equip all these boilers with SCR for at least ten times the costs of an SNCR system is a heavy financial burden and not in compliance with BAT.

For this reason it would make a lot of sense to look rather at the chances than the risks, especially since the costs for a semi-commercial trial with a demonstration plant amount to less than 1 % of the installation costs of an SCR for a typical power plant with five or more boilers. Even if the results of such trials would be negative the costs would be justified.

Last but not least, the money saved could be spent for further flue gas cleaning projects.

## 10. Literature

Chvalina J., Seitz A., von der Heide, B.: “Langjährige Erfahrungen mit nichtkatalytischer Entstickung in kohlegefeuerten Kesseln in der Tschechischen Republik“, VGB-Tagung, Düsseldorf, 17. April 1997

von der Heide, B.; Bärnthaler K.; Barok I.: “Nichtkatalytische Entstickung von Rauchgasen aus zwei Kesseln mit Schmelzkammerfeuerung im Kraftwerk Vojany, Slowakische Republik“, VGB-Konferenz Kraftwerk und Umwelt 2000, 4.-5.4.2000 in Leipzig

Kaufmann, K. et. al.: “The Combustion of Different Fuels in a 180 MWth Circulating Fluidized Bed Steam Generator in Świecie (Poland)”, Power-Gen Europe, 28.-30. June 2005 in Milano

von der Heide, B.: “Ist das SNCR-Verfahren noch Stand der Technik“ in: Thomé-Kosmiensky, Michael Beckmann (Hrsg.): Energie aus Abfall – Band 4. Neuruppin: TK Verlag Karl Thomé-Kosmiensky, 2008, S. 275 – 293

von der Heide, Bernd: “SNCR-process – Best Available Technology for NO<sub>x</sub> Reduction in Waste to Energy Plants”, Power-Gen Europe, Milan, June 3 – 5, 2008

von der Heide, B. Langer, P.: “Effizienz und Wartungsfreundlichkeit des SNCR-Verfahrens” in: Thomé-Kosmiensky, Michael Beckmann (Hrsg.): Energie aus Abfall – Band 7. Neuruppin: TK Verlag Karl Thomé-Kosmiensky, 2010, S. 729 – 753

von der Heide, Bernd: “Advanced SNCR Technology for Coal Fired Boilers –200 MW<sub>el</sub> in Germany and 225 MW<sub>el</sub> in Poland”, Power-Gen Europe, Amsterdam, July 3 – 5, 2010

von der Heide, Bernd: “Advanced SNCR Technology for Power Plants”, Power-Gen International, Las Vegas, December 13 – 15, 2011