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Complying with the New EU NO_x Emission Standards – Combining Advanced SNCR Technologies –

Bernd von der Heide

The valid emission limits in the EU, for example NO_x emissions of waste-to-energy plants and combustion plants fired with other fuels like coal, oil, biomass, etc. have to be adjusted from time to time reflecting the progress of technical developments as well as environmental concerns.

A technology which is best suited to reach a high level of environmental protection by keeping a reasonable cost/benefit ratio is called Best Available Technology (BAT).

This paper shows how the improvements that have been achieved with the technology of Selective Non-Catalytic NO_x Reduction (SNCR) can be applied not only in new but also in existing combustion plants which have been operating for many years with an older DeNOX system.

1. Future NO_x emission limits for combustion plants

BREF is the abbreviation for Best Available Technique REFerence Document, or in short: BAT reference Document. In German a *BVT* leaflet defines the Best Available Technique corresponding to BREF.

The Final Draft of the BVT leaflet for waste-to-energy plants defines the NO_x emission requirements which are shown in Table 1.

When the first SNCR plants were put into operation in the 80s of the last century, the NO_x limits of < 200 mg/Nm³ in accordance with the German Federal Emission Control Act (17. BImSchV) could reliably be complied with although the technical configuration was relatively simple. This was owed to the fact that the combustion plants were mostly operated at full load. Therefore, the variation of flue gas temperatures in the first boiler pass stayed within an acceptable range. Furthermore, ammonia slip was not of major concern at that time. According to *TA Luft*, another German regulation, the limit was < 30 mg/Nm³ so that an SNCR plant equipped with only one injection level was sufficient to fulfil the requirements imposed by the regulators.

Table 1: Final draft of the BVT leaflet for Waste-to-Energy plants

Emissions	Unit	New plants	Existing plants
NO_x	mg/Nm³	< 120	< 150
CO		< 50	< 50
NH_3 slip		< 10	< 10

Figure 1 shows the concept and the functions of a typical first generation SNCR plant with urea solution as reagent which used to be operated in combustion plants according to *17. BlmSchV*, reaching a NO_x reduction of up to 60 %. Depending on the requirements the SNCR plants are equipped with one or two injection levels.

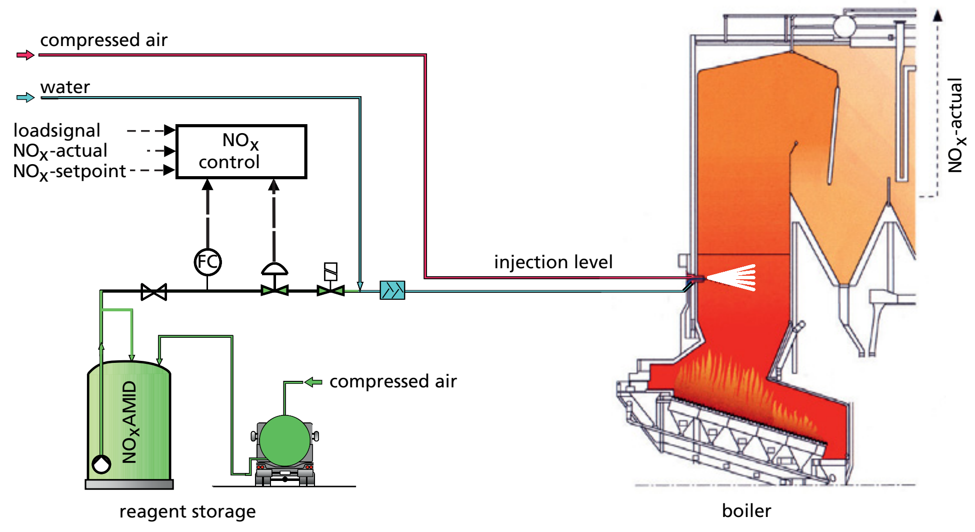

Figure 1: Process diagram of a first generation SNCR plant

Source: von der Heide, B.: Ist das SNCR-Verfahren noch Stand der Technik? In: Thomé-Kozmiensky, K. J.; Beckmann, M. (Eds.): Energie aus Abfall, Band 4. Neuruppin: TK Verlag Karl Thomé-Kozmiensky, 2008, pp. 275-293

In response to load changes and/or to the flue gas temperatures the injection levels can be switched to follow the average flue gas temperatures in the injection levels.

In order to follow major temperature variations and imbalances which typically arise during operation, to reduce NH_3 slip and to optimize the consumption of reagent, two injection levels proved to be most effective in waste-to-energy plants which were equipped in the 1990s in accordance with the *17. BlmSchV* (Figure 2). These two injection levels are switched on or off depending on the average temperatures measured with thermocouples at the boiler roof in the first flue gas path.

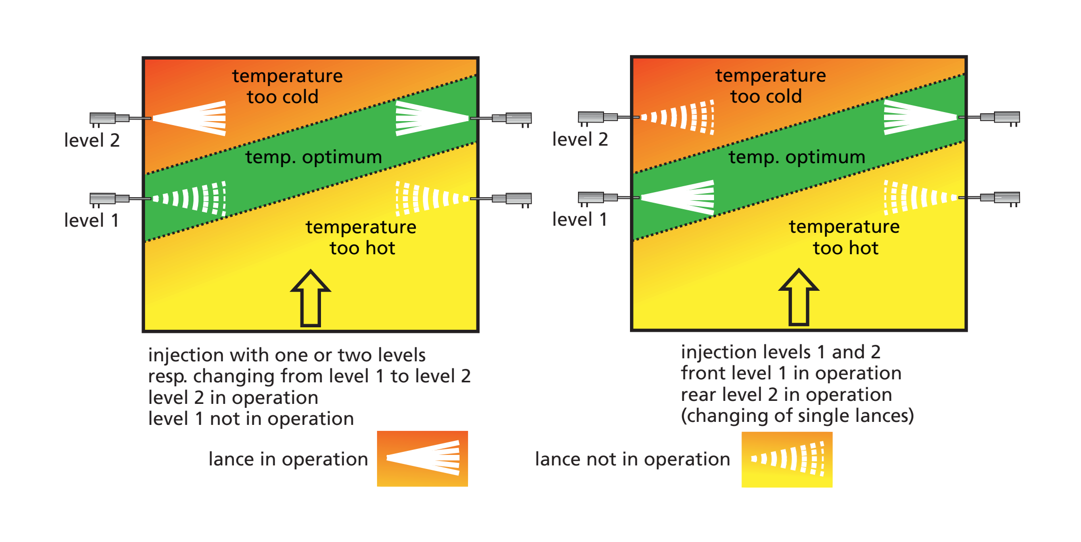

Figure 2: Changing injection levels following temperature imbalances

Under favourable operating conditions, when homogeneous fuel is used and the boiler is operated at constant load, NO_x clean gas values of < 150 mg/Nm³ can be achieved with this concept. However, imbalances of the flue gas temperatures and the flue gas flow may affect NH_3 slip and consumption of reagent. In case major temperature imbalances are found between the front and the rear walls of the furnace activating only one half of the injection level – front or rear – is a very successful solution.

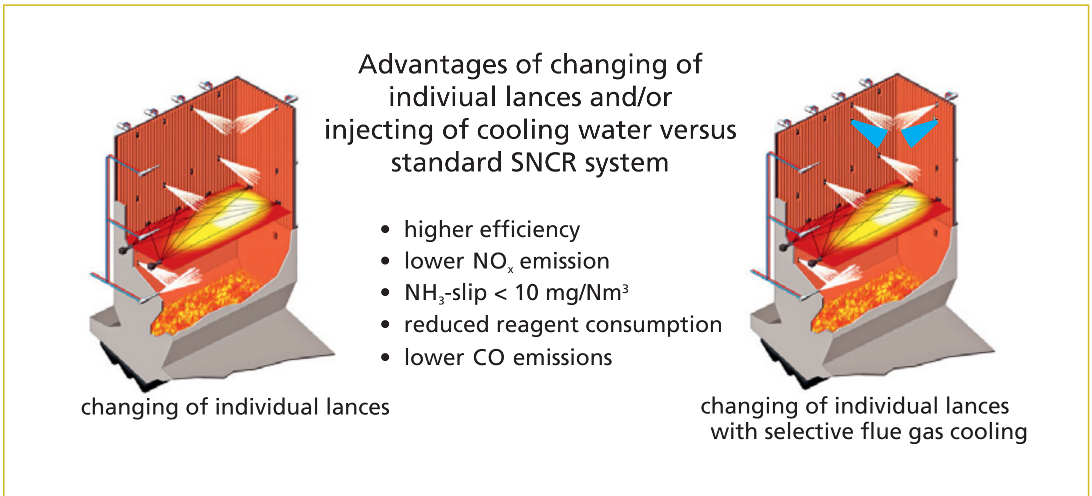

Figure 3: Changing of individual lances with and without selective cooling versus standard SNCR

However, the concepts described above are not sufficient for modern plants which are operated in accordance with the current BREF standards.

The next step in the technological progress was that individual lances or groups of lances were activated or deactivated in order to make sure for any location that the reagent is always injected into the range of the temperature window where NO_x reduction, NH_3 slip and consumption of reagent reach their optimum (Figure 3).

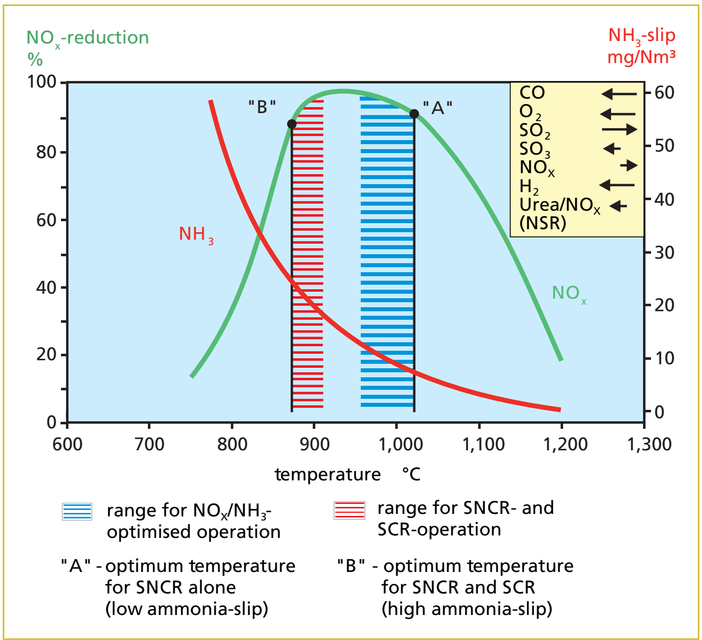

Figure 4:

Influence of the flue gas composition on the temperature window

For optimum performance both the flue gas composition and the flue gas temperatures are essential for controlling the SNCR process. Where the optimal temperature window for SNCR lies depends very much on the flue gas composition (Figure 4). This means, for example, that CO shifts the temperature window towards lower temperatures, while SO_2 has the contrary effect. The optimal temperature window for waste-to-energy is located between 980 to 1,030 °C, for fluidized bed boilers where CO is generally high it is below 900 °C, and for furnaces with a high SO_2 content in the flue gases it is up to 1,050 °C. Depending on the desired performance of the SNCR one of the following temperature measurement methods could be applied:

- Thermocouples are very sensitive to the influence of heat radiation from the furnace, as well as to cold radiation from the boiler walls and the heat exchangers. In the past they were installed in SNCR plants which had to comply with *17. BlmSchV* only, but due to the described limitations this method does not meet the requirements of more stringent NO_x limits.
- The measurements with suction pyrometers are quite accurate and are mainly used for manual temperature measurements to verify the continuous measurement systems. They are not suitable for continuous measurements since their handling is time-consuming.
- Broad experience has been gathered with acoustic gas temperature measurement systems which have proven to be suitable for the most demanding applications. This method is therefore recommended where NO_x emission values < 100 mg/Nm³ and NH_3 slip < 10 mg/Nm³ have to be guaranteed.

- Since several years spectral pyrometers have been put into operation increasingly. The results achieved with this optical method show that – in relation to acoustic measurements – comparable degrees of NO_x reduction can be obtained at lower cost.

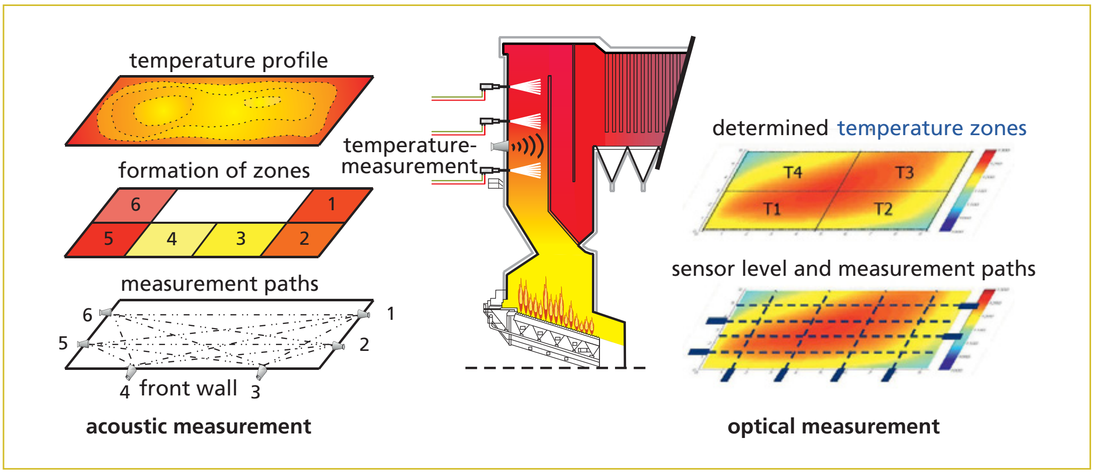

Figure 5: Methods of contact-free temperature measurement

- Both methods, the optical and acoustical temperature measurement, have advantages and disadvantages (Figure 5 and 6): During the acoustic measurement each transceiver at the boiler wall communicates in turns with all the other transceivers. Thus, a multitude of temperature paths is formed which provide a high resolution.
- In contrast, each spectral pyrometer measures one path only which results in a lower resolution. The advantage of this method is that it provides sufficiently accurate temperature measurements even in areas which are otherwise difficult to access, for example between the heat exchangers and individual injection lances.

At the waste-to-energy plant Wijster in the Netherlands, three SCR units of the plant were shut down and replaced by SNCR systems. In response to the ambitious requirements (NO_x reduction from approximately 330 to 350 mg/Nm^3 to < 60 mg/Nm^3 and an NH_3 slip < 10 mg/Nm^3) three injection levels with six lances each were installed. In this concept each lance is activated individually depending on zone temperatures.

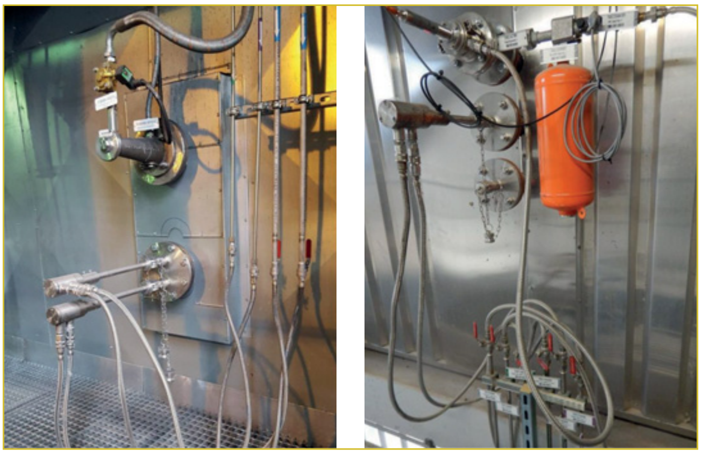

Figure 6:

Methods of contract-free temperature measurement – acoustic (left), optical (right)

After determining the temperature profile, it is divided into sections and can be assigned to a certain lance or group of lances which can then be activated depending on the flue gas temperatures. Even when there are sudden changes in the flue gas temperatures this method ensures that the reagent is injected into those areas where optimum results regarding NO_x reduction, NH_3 slip and consumption of reagent can be achieved.

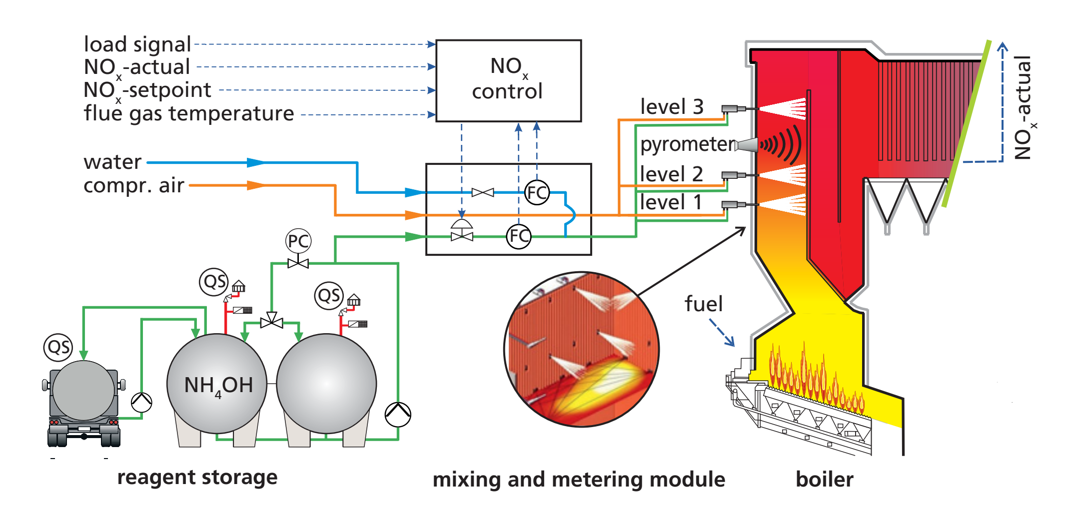

Figure 7: SNCR with individual change of lances in three levels – Waste-to-Energy plant

The results that were measured in continuous operation of several combustion plants show that NO_x clean gas values of < 100 mg/Nm³ and an NH_3 slip of < 10 mg/Nm³ can be guaranteed and even noticeably better results are possible under favourable operating conditions.

2. Retrofitting or refurbishing of existing SNCR systems

Older SNCR plants which have been operated successfully for 20 years or more, have a limited ability to meet the recent requirements or cannot meet them at all. Considering the future NO_x limits of < 100 mg/Nm³, NH_3 slip < 5 mg/Nm³ and minimized consumption of reagent, these plants need to be refurbished.

Measures for refurbishing include the extension of the system to three injection levels, changing of individual lances and acoustic or optical pyrometers for the continuous measurement of the flue gas temperatures (Figure 8).

Depending on age and condition of the SNCR plant it may be feasible to include the additionally needed armatures in the existing mixing and metering modules. In most cases, however, this cannot be recommended, and often it is not possible either since the additional components need more space than is available in the mixing and metering modules of the simple types of first generation SNCR. If space in the modules is too restricted, this may hinder the necessary access for maintenance works and should therefore be taken into consideration as well.

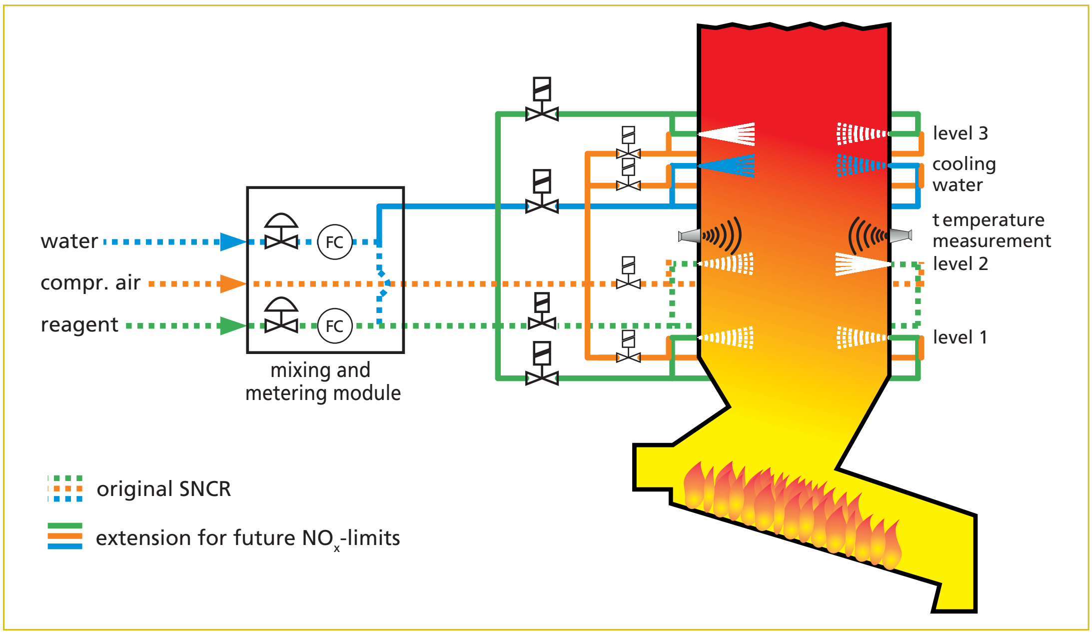

Figure 8: SNCR process – flow diagram before and after retrofitting

Sometimes the limited space in the boiler house does not allow for the installation of a bigger mixing and metering module. In such a case a possible solution may be to install the additional instruments between the module and the injection lances directly on the boiler walls.

Figure 9: Mixing and metering modules before and after retrofitting – original (left), refurbished (right)

Figure 10: Installation of additional equipment on the boiler walls

Even if the further use of the existing components (e. g. control valves, pressure retaining valves, ball valves etc.) is intended, in many cases, it makes more sense to use new and larger cabinets and to complement them with new armatures. Mostly it is easier and more cost-efficient to set up the mixing and metering modules in bigger new cabinets in the workshop than to use the old smaller cabinets for the mounting of additional parts at site (Figure 9 and 10).

3. Adaptation to changed operating conditions

Many waste-to-energy plants are operated at a capacity range which is higher than originally designed for. As a result the flue gas temperatures are higher than they were at the time when the plant was first put into operation. Consequently, the optimum temperature range for the SNCR process is often shifted to the second pass, especially at the end of the service interval and when ammonia water is used as the reagent. With the rising temperatures the reagent is increasingly burnt to NO_x. The required NO_x reduction can, therefore, in many cases only be achieved with a higher consumption of reagent and an increased ammonia slip (Figure 11).

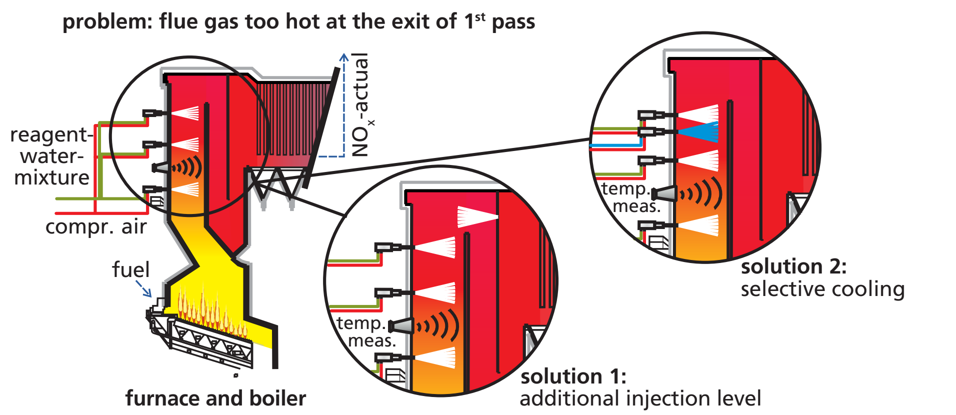

Figure 11: Technical solutions when flue gas temperatures are too hot

A possible solution is the installation of additional injection lances in the second pass which can be activated when the flue gas temperatures are too high. Should this not be possible, the same effect can be realized by injecting additional cooling water beneath the hottest lances of the highest injection level (Figure 12).

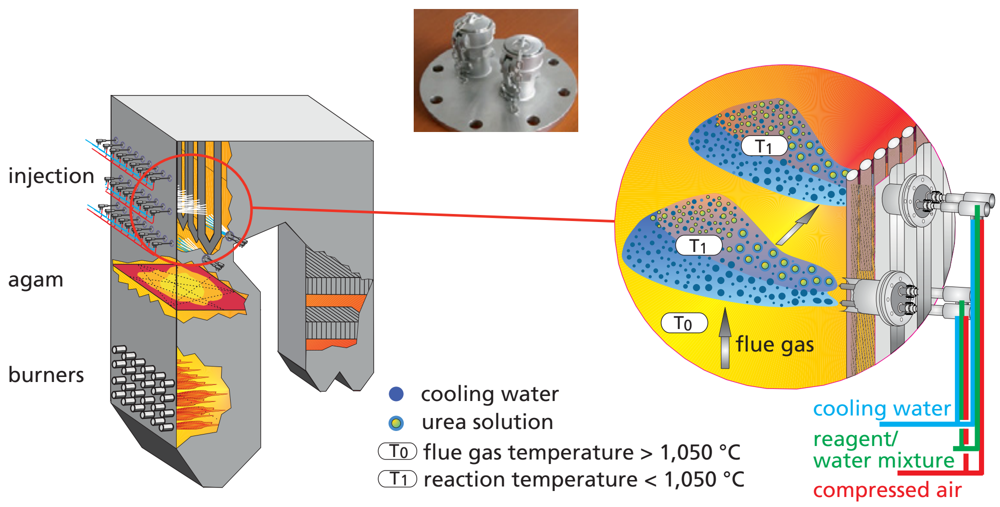

Figure 12: Principle of selective cooling

Relevant results and experiences with this method, protected by patent as *Selective Cooling*, showed in many cases a significant improvement of NO_x reduction and the consumption of reagent. Selective Cooling cools the flue gases locally and temporarily. The major advantage of this method is that even at high boiler loads and flue gas temperatures, i. e. the complete load range, by changing individual lances injection is possible in the areas with optimum flue gas temperatures which are free of installations at the end of the furnace. This means that costly modifications of the heat-exchangers can be avoided.

Another method which has performed well is the *TWIN-NO_x* process which combines the benefits of both reagents, urea and ammonia, in such a way that the effective temperature window is practically expanded (Figure 13 and 14).

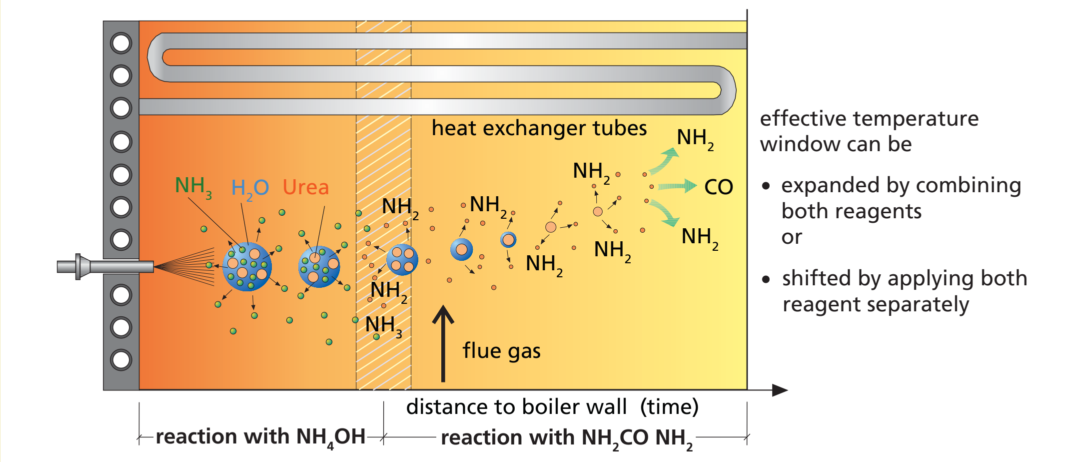

Figure 13: Expansion of temperature window – combination of urea solution and ammonia water

This means that the highly volatile ammonia water is applied at low loads where the ammonia is released immediately and can react with NO_x. When using urea solution, the reaction is delayed because the NO_x reduction can only begin after the process water has evaporated and the urea molecules have been decomposed to NH_2 radicals and CO. Figure 14 shows a simplified process diagram of an SNCR plant which can be operated alternatively with urea solution or ammonia water as well as with a mixture of both reagents.

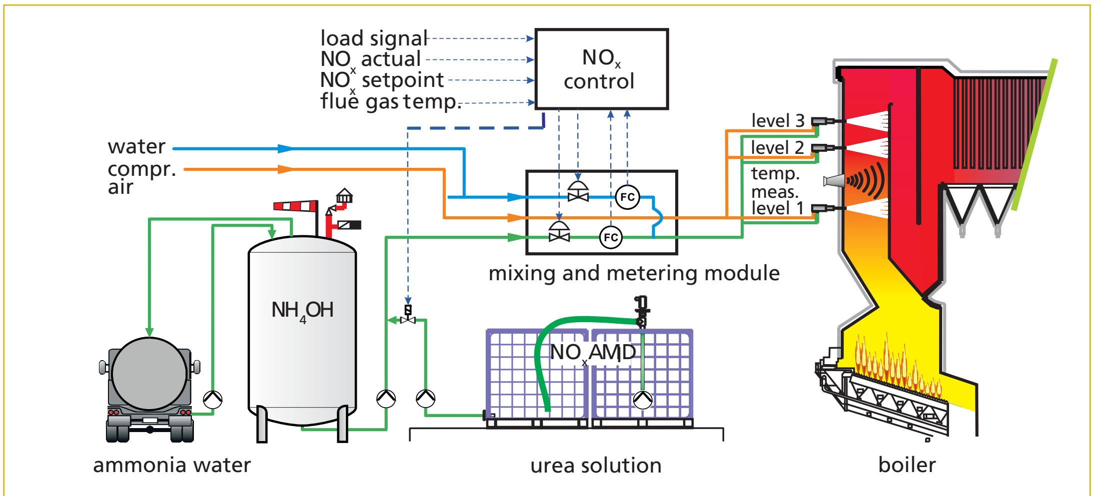

Figure 14: Process diagram of the TWIN-NO_x process

4. Results and practical experiences

The results and experiences with SNCR systems which have been retrofitted show that the future emission limits for NO_x and ammonia can be met reliably.

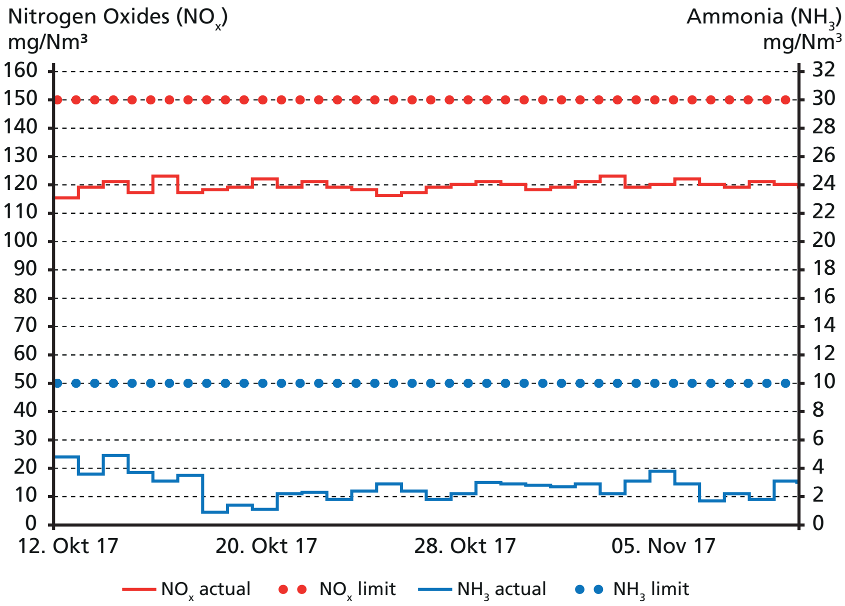

Figure 15: Emission levels – IKW Rüdersdorf

Source: IKW Rüdersdorf GmbH: IKW Rüdersdorf – Emissionswerte. Retrieved: November 12, 2017; from: http://ikw-rüdersdorf.de/emissionswerte.htm

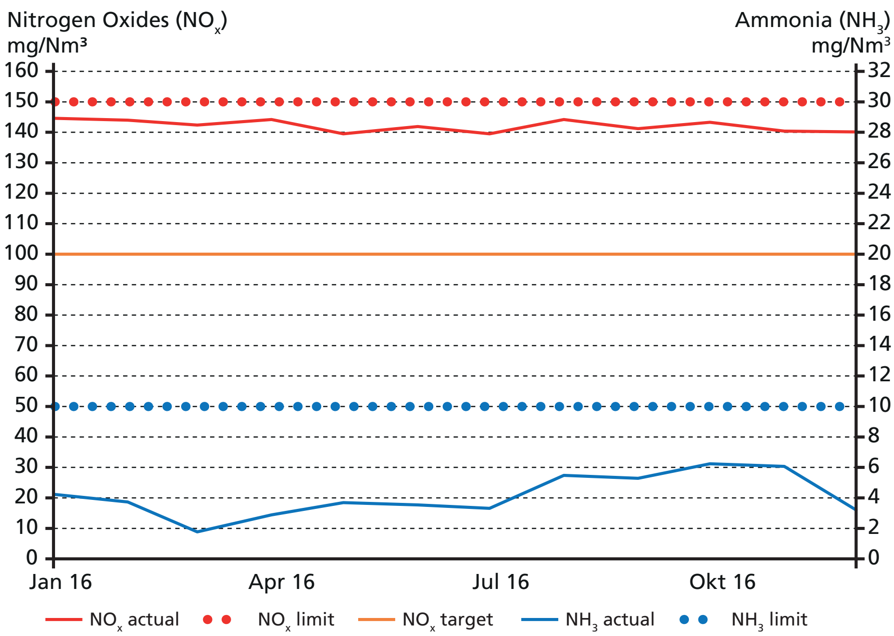

Figure 16: Emission levels – Waste-to Energy plant Salzbergen

Source: SRS EcoTherm GmbH: Emissionswerte der MVA Salzbergen 2016. Retrieved: November 12, 2017; from: http://www.bisalzbergen.de/2016ZusammenfassungMVAwerte.pdf

The combustion plants in Salzbergen (municipal waste) and Rüdersdorf (refuse derived fuels) have been retrofitted and safely comply with the present regulations of NO_x < 150 mg/Nm³ and NH_3 < 5 mg/Nm³, as can be seen from the results shown in Figure 15 and Figure 16.

These and other plants, which are presently being retrofitted, require relatively little efforts in order to enable them to guarantee NO_x levels < 100 mg/Nm³.

5. Comparing SCR to SCNR under energy and environmental aspects

In the waste-to-energy plant in Wijster, Netherlands, the existing SCR plant was replaced with an SNCR system in order to save operating costs (Figure 17). The SCR was installed downstream a wet flue gas cleaning system. The pressure drop across the heat-exchangers, the mixer, the flue gas ducts, and the catalyst elements amounted to approximately 25 mbar. To overcome the pressure drop, a blower with an electrical consumption of 250 kW per combustion line was required, whereas this additional energy is not needed in an SNCR plant. The temperature loss of the flue gas over the heat exchanger was about 30 K. The power required to raise the temperature again, was provided by gas burners consuming 2,200,000 m³ of natural gas per year and per plant. After removing the three catalysts the flue gas temperature at the stack decreased from 150 °C to approximately 95 °C. [3]

Although the utilization of ammonia water is less efficient in SNCR than in SCR plants, the total amount of all operating costs is much lower in SNCR plants.

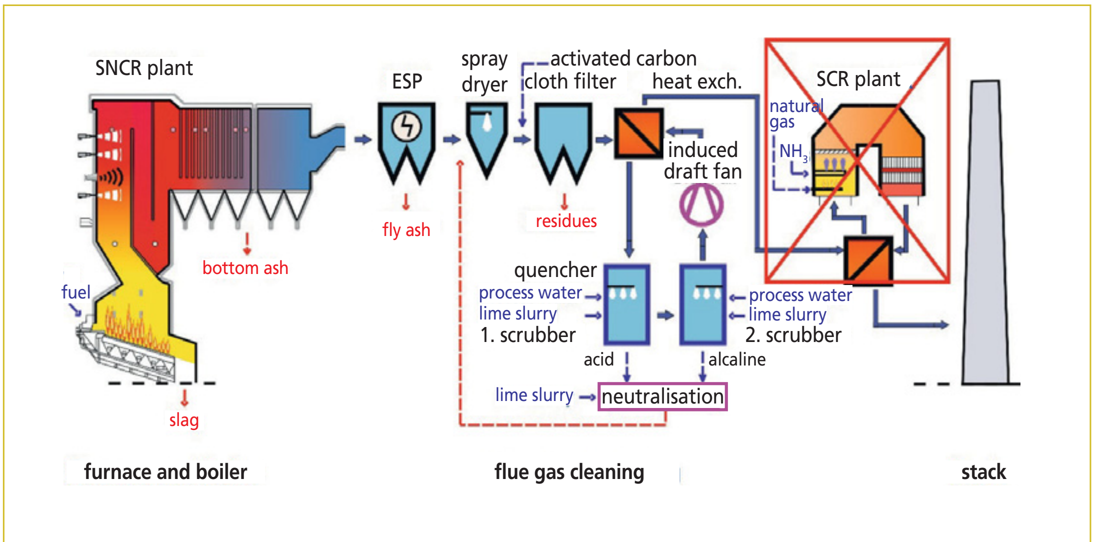

Figure 17: Waste-to-Energy plant Wijster after retrofitting

Source: Moorman, F.; Stubenhöfer, C.; von der Heide, B.: Umrüstung der Abfallverbrennungsanlage Wijster/Niederlande von SCR auf SNCR. In: Thomé-Kozmiensky, K. J.; Beckmann, M. (Eds.): Energie aus Abfall, Band 10. Neuruppin: TK Verlag Karl Thomé-Kozmiensky, 2013, pp. 683-702

Also from the environmental point of view the SNCR technology appears in a positive light: Consuming less energy also means reducing emissions like CO_2 while the NO_x emissions with SNCR are on the same level as with SCR.

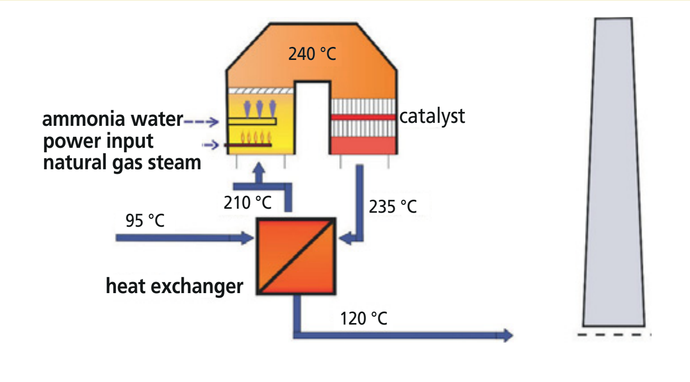

Figure 18:

SCR and flue gas reheating

As opposed to that, an SCR plant produces additional CO_2 emissions of 15,000 t/h just because it consumes a lot of additional energy for the generation of electricity which is needed for the higher blower capacity and for the gas-fired duct burners (Figure 18).

Table 2: Operating data – SCR versus SNCR (per line)

operating data	unit	SCR NH_4OH	SNCR NH_4OH
		24.5 %	
throughput of waste	t/h	25	25
flue gas volume flow	Nm³/h, tr.	100,000	100,000
operating hours	h/a	8,000	8,000
NO_x raw gas concentration	mg/Nm³	330	330
NO_x clean gas concentration		45	50
NO_x reduction per line	kg/h	28.5	28
NO_x reduction (three lines)	t/a	684	672
ammonia water 24.5 % (three lines)		800	4,000
consumption of compressed air incl. agam	Nm³/h	–	500
consumption of deionized water	m³/h	–	1.2
additional electr. consumption of ID fan	MWh/a	6,100	–
CO_2 for additional energy (three lines)	t/a	12,000	–
consumption of natural gas	Nm³/a	6,600,000	–

Table 2 indicates that operating costs for reducing one ton of NO_x are by far higher when using SCR technology than they would be in an SNCR plant. From other studies it can be concluded that the investment costs for SCR are at least five times higher than for SNCR which clearly shows that an SNCR plant with its better cost/benefit ratio is more economical and therefore much more effective protecting the environment.

6. Summary and outlook

The results of several years of operation with a number of SNCR plants show that the current and future BREF standards can not only be met, but even exceeded in many cases. Many plants which have been operated for many years were retrofitted recently and comply now with the new standards.

The modification of an existing SNCR system is relatively easy: Generally, some extra lances, advanced temperature measurement systems and a modernized control system are sufficient.

It is known that the investment costs for SCR exceed those for SNCR, but – depending on the design of the individual projects – these costs can be five to ten times higher for SCR than for SNCR. Another well-known fact is that because of the chemical conditions in the SNCR process, the consumption of reagent is approximately three times higher than with SCR. However, it is usually not considered that this effect is by far compensated due to the savings of other consumables.

Furthermore, the SNCR process has been continuously developed and improved over the last years. It has reached a high technological standard and has widely found acceptance in the meantime, especially with regard to NO_x reduction in the flue gas of small to medium sized combustion plants burning for example waste, refuse derived fuel, and biomass. Depending on the design of the plant it is possible to maintain emission limits of < 100 mg/Nm³ NO_x in clean gas and NH_3 slip < 10 mg/Nm³, particularly when taking into account the cost/benefit ratio, the SNCR technology is well-established and accepted as Best Available Technology (BAT) for NO_x reduction.

7. Literature

[1] IKW Rüdersdorf GmbH: IKW Rüdersdorf – Emissionswerte. Retrieved: November 12, 2017; from: http://ikw-rüdersdorf.de/emissionswerte.htm

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[3] SRS EcoTherm GmbH: Emissionswerte der MVA Salzbergen 2016. Retrieved: November 12, 2017; from: http://www.bisalzbergen.de/2016ZusammenfassungMVAwerte.pdf

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