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Simple and effective – Replies to the increasing requirements on the flue gas treatment downstream incineration plants regarding the separation of HCl, SOx and NOx by means of practical examples

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1 Introduction

For years the chemisorption with particle and gas conditioning using $Ca(OH)_2$ as additive powder has proven to be a reliable procedure for the flue gas treatment downstream incineration plants. As a result of the processing of waste to refused derived fuels (RDF), the requirements especially on the HCl and SO_2 separation increased considerably. Additional measures for the increase in efficiency of basic process and for the reliable observance of all emission limit values in continuous operation will be necessary.

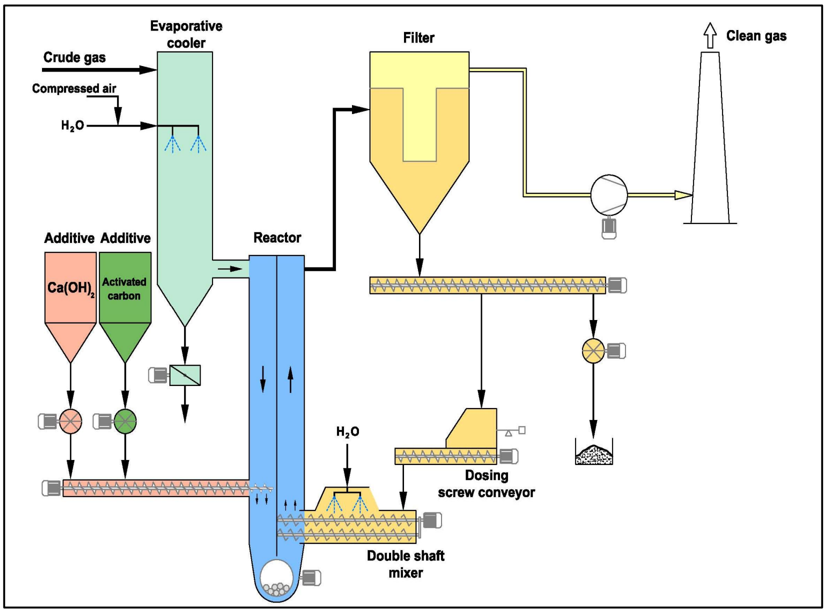
Another challenge for today's and prospective concept determination of flue gas cleaning systems is for many projects the demand of lower emission limit values compared to those specified in the 17 BImSchV. An example for this is the NO_x limit value.

The gas cleaning system has to be adapted flexibly to the corresponding requirements of each separate project, without endangering the economic efficiency. This lecture presents different concepts, each based on the conditioned dry sorption.

2 Chemisorption with gas and particle conditioning

2.1 Basic variant

Illustration 1 below shows a schematic view of this process technology which has successfully been applied for years downstream waste incineration plants for the observance of emission values accord. to 17 BImSchV. It mainly comprises the units evaporative cooler, additive powder injection, reactor, fabric filter as well as particle recirculation with integrated particle conditioning.



Ill. 1: Chemisorption with gas and particle

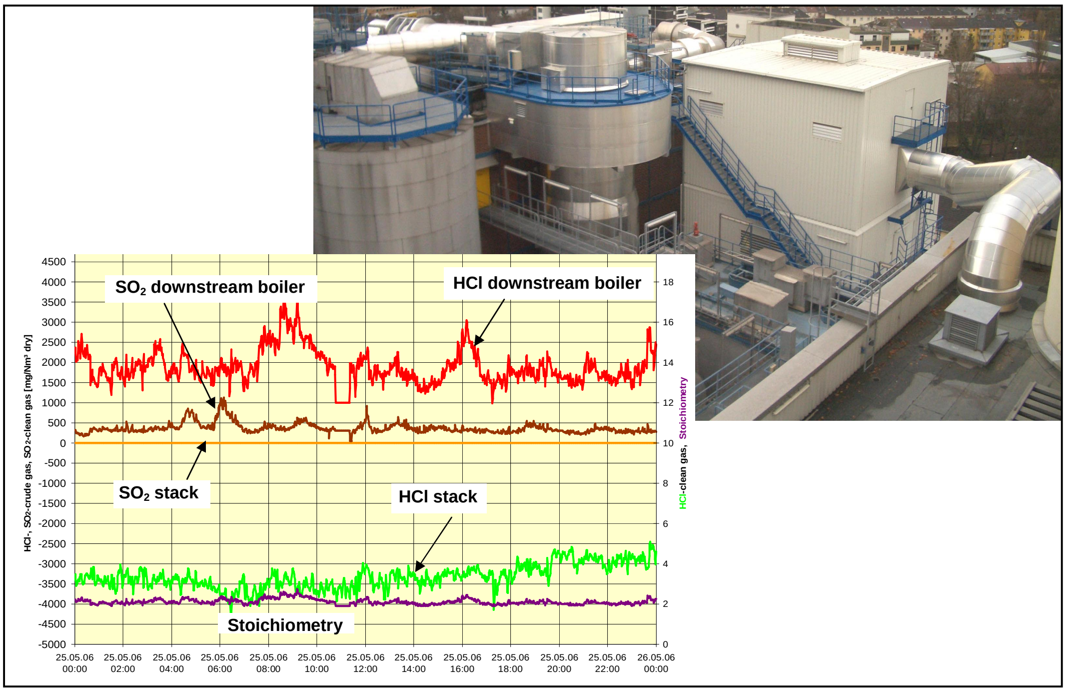
The evaporative cooler (gas conditioning) serves for the optimum adjustment of the reaction temperature, combined with an increase in the absolute and relative humidity in order to optimise the separation and additive powder efficiency. Due to the fact that especially in case of RDF incinerators and as a result of the fuel composition, the gas humidity is often lower than e.g. in domestic waste incinerators, the possibility of a separate adjustment of an optimum gas temperature gains special importance.

The crude gas sorption and separation of all relevant components takes place in the reactor – filter combination with $Ca(OH)_2$ injection and multiple particle re-circulation, including conditioning of the re-circulated particulate.

The objectives of this stage are:

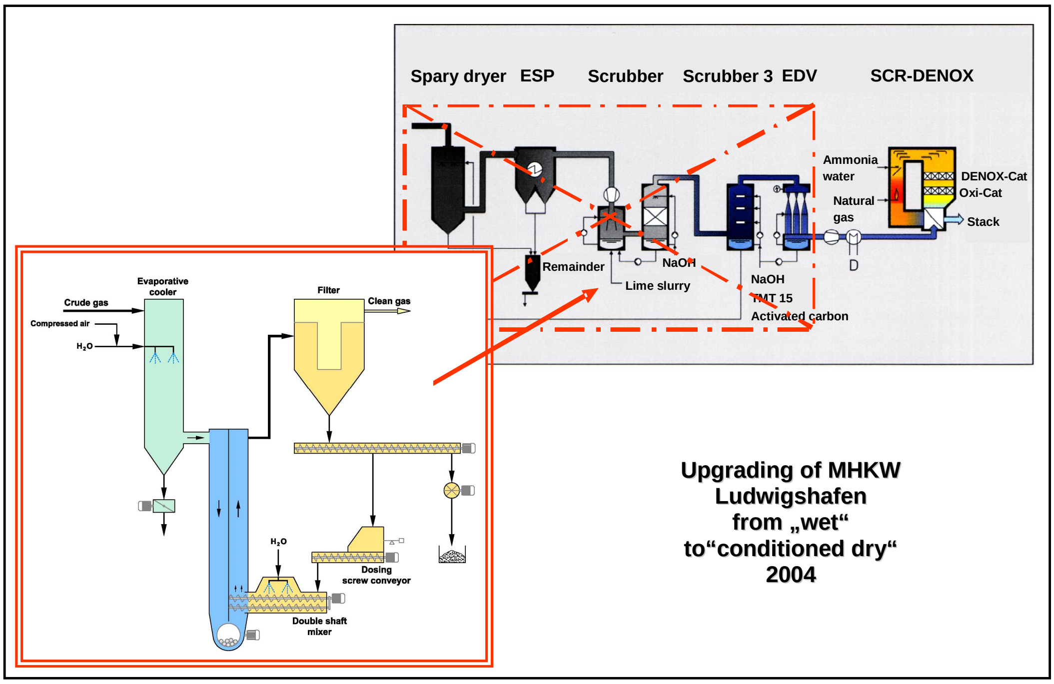
- Creation of good reaction conditions by means of particle re-circulation up to n x 100 g/Nm³.
- Optimisation of SO_2 separation by means of moistening of re-circulated particulate
- Further, even though minor reduction of gas temperature

The effectiveness of the above-described basic variant for the observance of limit values accord. to 17 BImSchV with crude gas contents of HCl up to approx. 2,000 mg/Nm³ dry and SO_2 up to 1,000 mg/Nm³ dry is demonstrated by the plant in the MHKW Ludwigshafen (illustration 2).



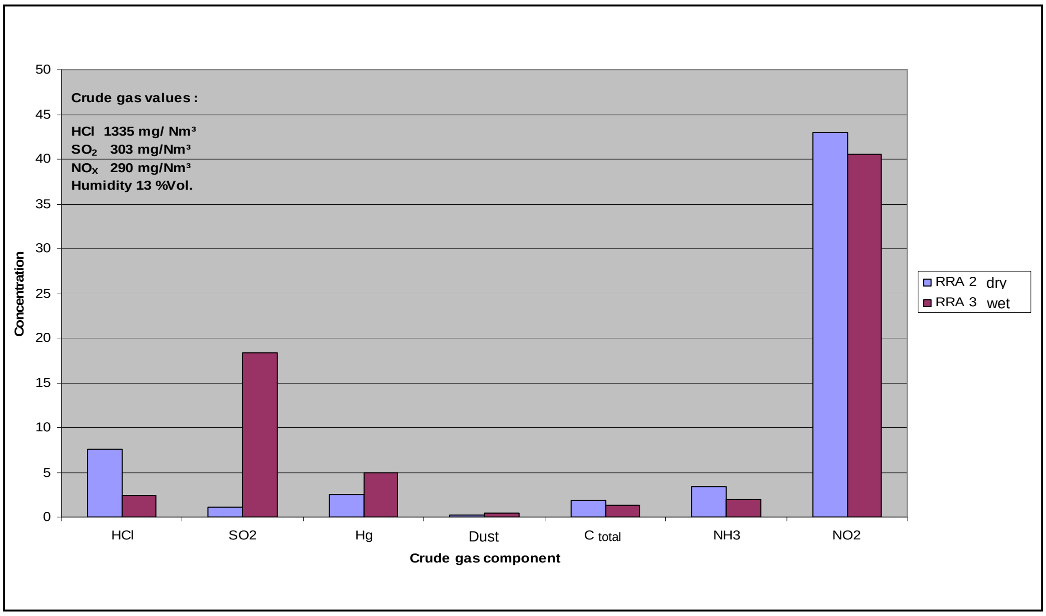
Ill. 2: Conditioned dry sorption in MHKW Ludwigshafen

The conditioned dry gas cleaning system installed in 2004 replaced a definitely more complex wet process, consisting of spray dryer, electrostatic precipitator, multi-stage scrubber and aerosol separator (illustration 3).



Ill. 3: Upgrading of MHKW Ludwigshafen from „wet“ to „conditioned dry“

Up to the year 2008, another wet flue gas treatment plant had been operated in parallel at the MHKW Ludwigshafen until its conversion in 2008, thus allowing a direct comparison of both installed variants. Illustration 4 shows the average values of the year 2005 for selected substances.



Ill. 4: Comparison of gas cleaning systems „wet“ and „conditioned dry“ (2005)

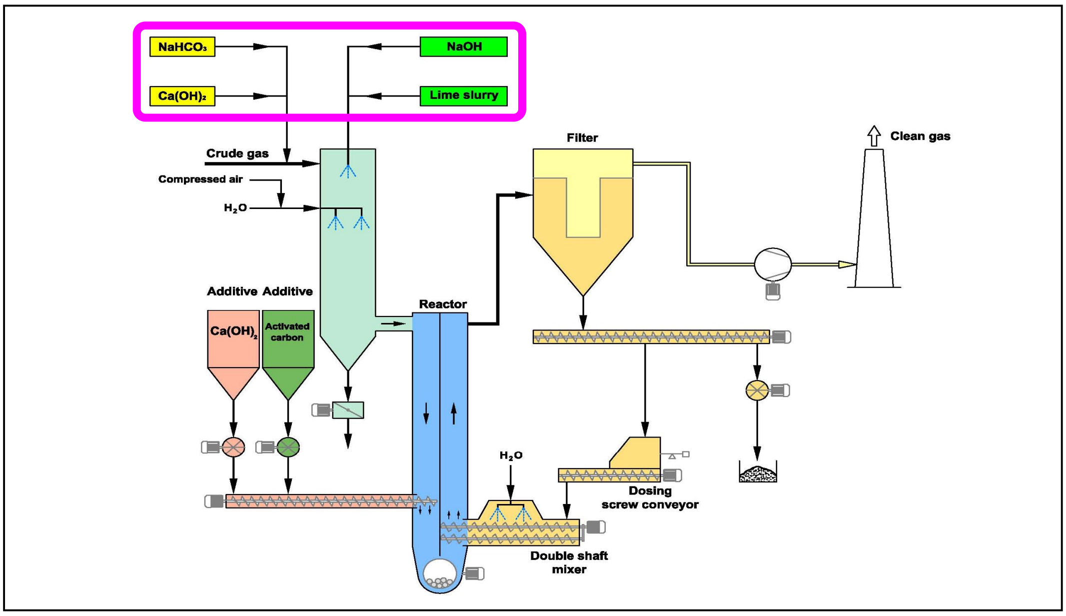
The comparison shows that the conditioned dry sorption process is equal to the more complex wet system. The only difference is the reference variable for the separation of the acid crude gas components, i.e. SO_2 for the scrubber and HCl for the conditioned dry sorption.

The high degree of separation of SO_x combined with a nearly 100 per cent SO_3 sorption by means of the conditioned dry sorption process allows the reduction of the operating temperature of the downstream installed SCR plant from 300° C to 230° C. An additional advantage as to the saving of energy costs is the higher gas temperature upstream SCR stage of approx. 140°C.

It should be mentioned in addition, that compared to the spray sorption, an important advantage of the conditioned dry sorption is the better degree of separation for SO_2. This is especially important in case of downstream installation of SCR plants.

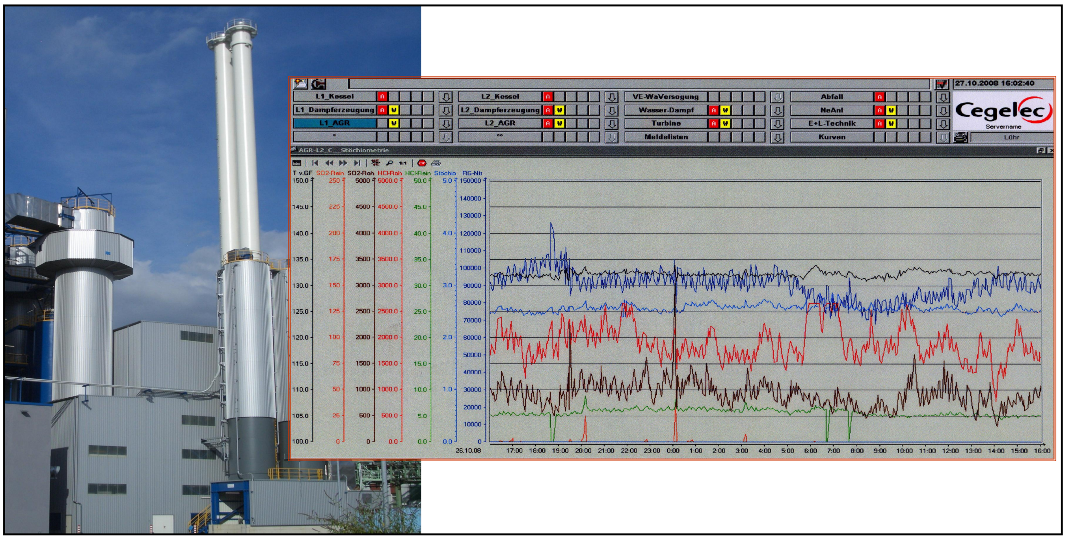
2.2 Graded additive powder injection

In case of increasing crude gas values for HCl and SO_2, the stoichiometry of basic variant of the conditioned dry sorption has to be increased partly definitely above a typical base value of 2 without any additional measures in order to observe reliably the emission limit values. At rising crude gas values it will therefore be advisable to apply a graded additive powder injection, thus using in addition the reaction chamber of evaporative cooler / spray absorber when indicated. Illustration 5 shows different, corresponding process variants. For all concepts, the main quantity of additive powder is injected into the reactor downstream evaporative cooler in the nominal case. The injection of additive powder upstream or within evaporative cooler / spray absorber mainly serves for the corrosion protection as well as for the smoothening of crude gas peaks.



Ill. 5: Conditioned dry sorption with graded additive powder injection

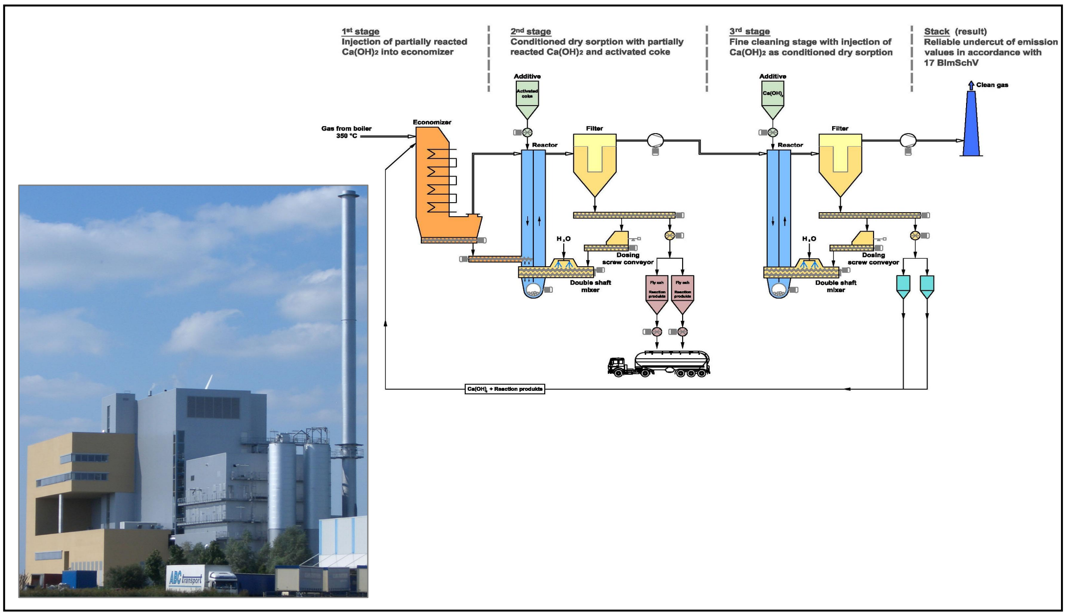
The separation potential is exemplary shown in illustration 6 by means of a gas cleaning system downstream RDF incinerator. In this case the additive powder injection takes place in steps, using lime slurry in the spray absorber and $Ca(OH)_2$ in the reactor of conditioned dry sorption. At mean crude gas values for HCl of 1,800 up to 2,500 mg/Nm³ as well as 1,000 up to 1,500 mg/Nm³ for SO_2 combined with definitely higher crude gas peaks for both crude gases, the limit values of 17 BImSchV will reliably be undercut with at the same time acceptable additive powder consumption.



Ill. 6: Gas cleaning with graded additive powder injection downstream RDF incinerator

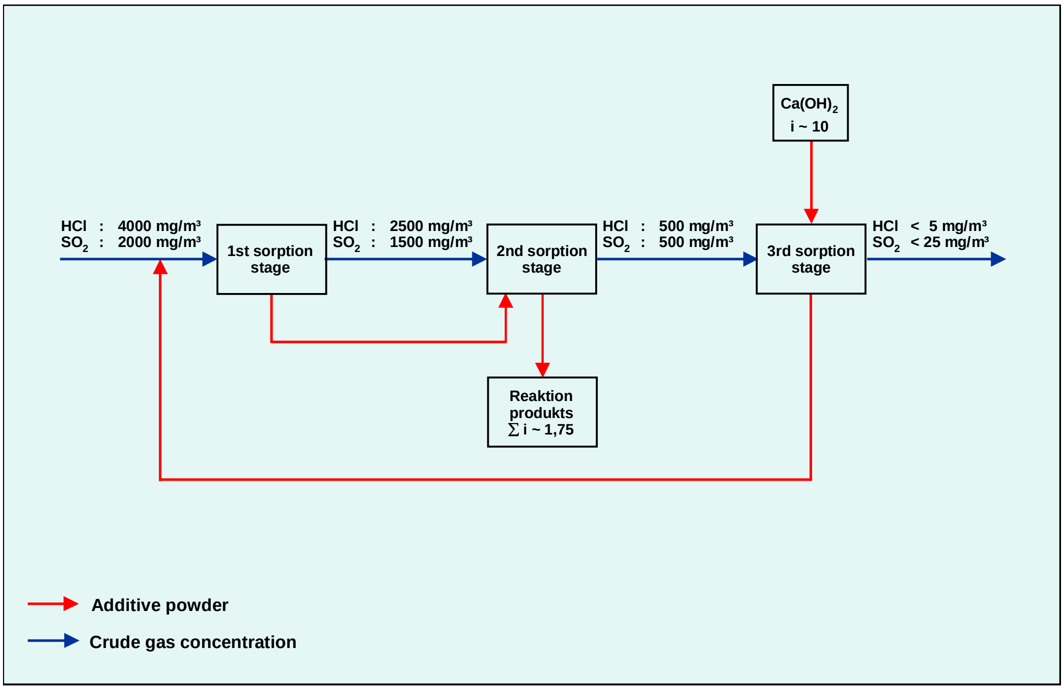
2.3 Multi-stage conditioned dry sorption

If the requirements on the separation will grow, e.g. with regard to permanently higher chlorine and/or sulphur contents in the fuel and/or regarding the request for emission limit values, e.g. accord. to 50% of the values of 17 BimSchV, the additive powder consumption of so far presented process technologies will rise above average. To solve such types of applications, alternative sorption procedures have to be taken into consideration. From the author’s point of view, the most suited process variant for these applications is the two-stage conditioned dry sorption with additive powder guidance in counterflow. Since many years LÜHR FILTER has gathered operating experiences from this process technology, i.a. also for thermal waste disposal plants. Illustration 7 exemplary shows the gas cleaning of the steam power plant Weener. Relating to the separation of HCl and SO_x , this plant has been realised in three stages.



Ill. 7: Process scheme steam power plant Weener/ PROKON NORD

The main advantage of this process technology is the additive powder guidance in counterflow. As a result of the pre-separation of acid crude gas components in the fine cleaning stage and in the upstream installed economiser, definitely higher stoichiometries than the resulting total stoichiometry will be achieved (illustration 8).



Ill. 8: Stoichiometry of fine cleaning stage and total stoichiometry

Even in case of high input concentrations and reduced emission limit values, the additive powder efficiency is mainly determined by the chloride concentration in the remainder product, maximum allowable for the product handling.

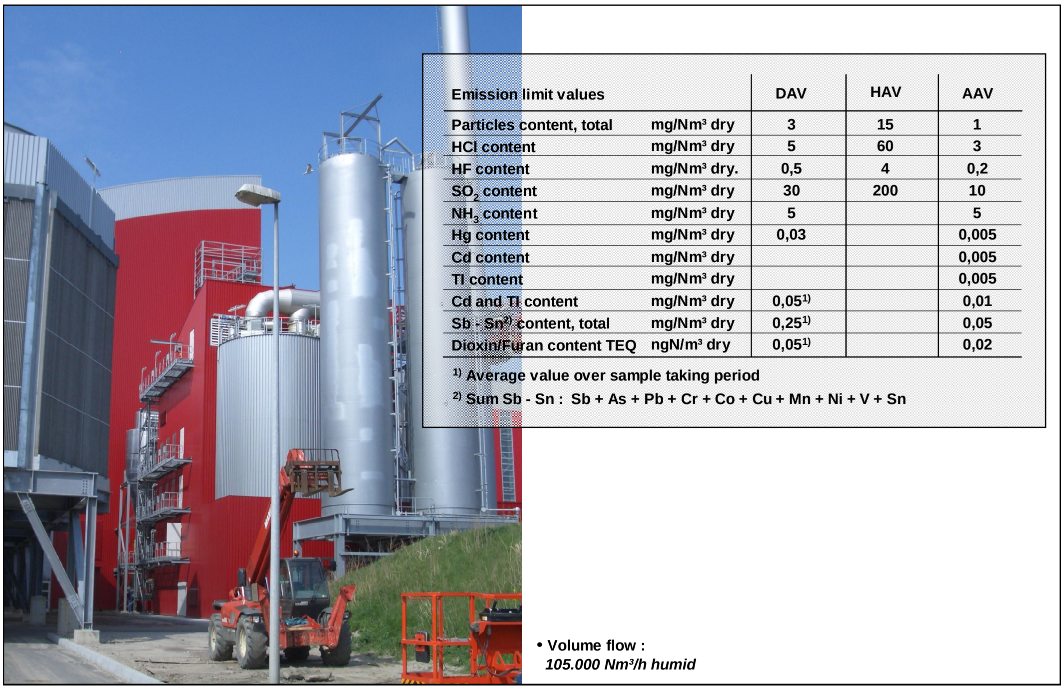
3 Concepts for low emission limit values, considering NO_x

3.1 SNCR with NH_3 separation

Operating results gathered from modern incineration plants with SNCR procedures for the NO_x reduction demonstrated that in most of the cases the reliable observance of the tightened NO_x limit value of 100 mg/m³ will be possible. Even in case of requested lower NO_x emission limit values, the installation of a catalyst is not imperative. Also in this case a SNCR procedure can be applied, but then a further separation stage for NH_3 has possibly to be integrated in the concept, depending on the max. admissible NH_3 slippage.

Illustration 9 shows an example for a gas cleaning system downstream circulating vortex bed for biomass combustion in the Netherlands. In order to observe the requested NO_x limit value of 70 mg/m³, the constructor of boiler installed a SNCR plant. The NH_3 slippage downstream boiler is limited to max. 15 mg/m³. In addition to this, illustration 9 shows a table with the requested emission limit values to be observed by means of the downstream installed gas cleaning system. The following concept has been chosen for this gas cleaning system:

- Cyclones for separate fly ash removal
- Conditioned dry sorption at approx. 150° C
- Heat exchanger for cooling down of gases to approx. 100° C
- Wet ESP with integrated acid and basic stage



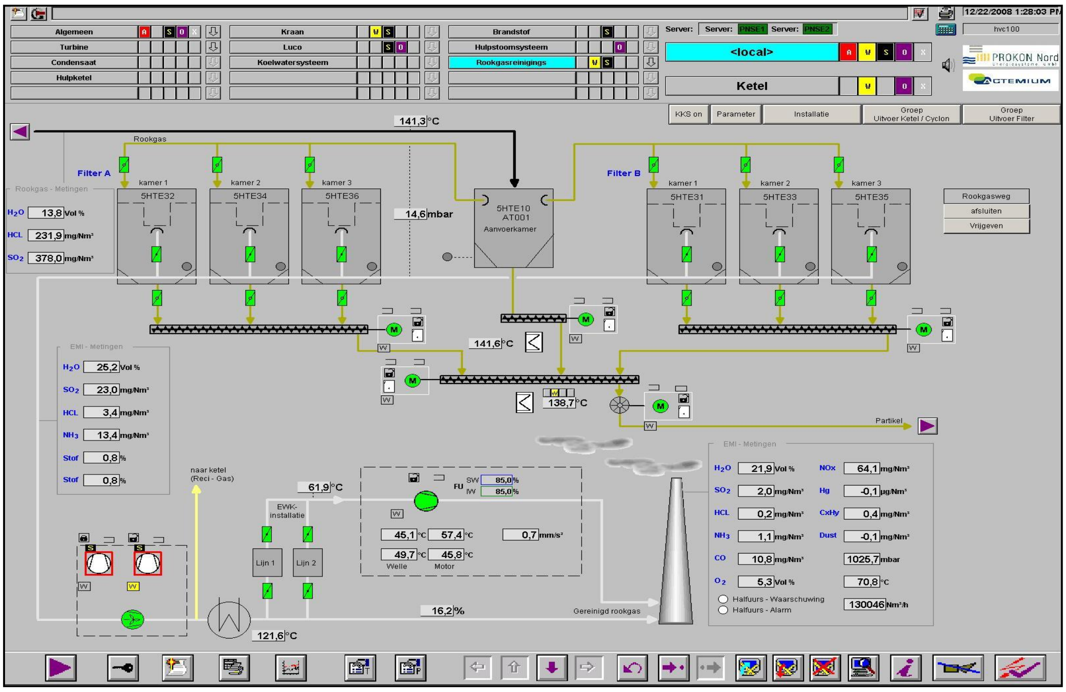
Emission limit values		DAV	HAV	AAV
Particles content, total	mg/Nm³ dry	3	15	1
HCl content	mg/Nm³ dry	5	60	3
HF content	mg/Nm³ dry.	0,5	4	0,2
SO_2 content	mg/Nm³ dry	30	200	10
NH_3 content	mg/Nm³ dry	5		5
Hg content	mg/Nm³ dry	0,03		0,005
Cd content	mg/Nm³ dry			0,005
Tl content	mg/Nm³ dry			0,005
Cd and Tl content	mg/Nm³ dry	0,05[1)]		0,01
Sb - Sn[2)] content, total	mg/Nm³ dry	0,25[1)]		0,05
Dioxin/Furan content TEQ	ngN/m³ dry	0,05[1)]		0,02

[1)] Average value over sample taking period
[2)] Sum Sb - Sn : Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V + Sn

Ill. 9: Gas cleaning system for biomass combustion HVC, Alkmaar/ Netherlands

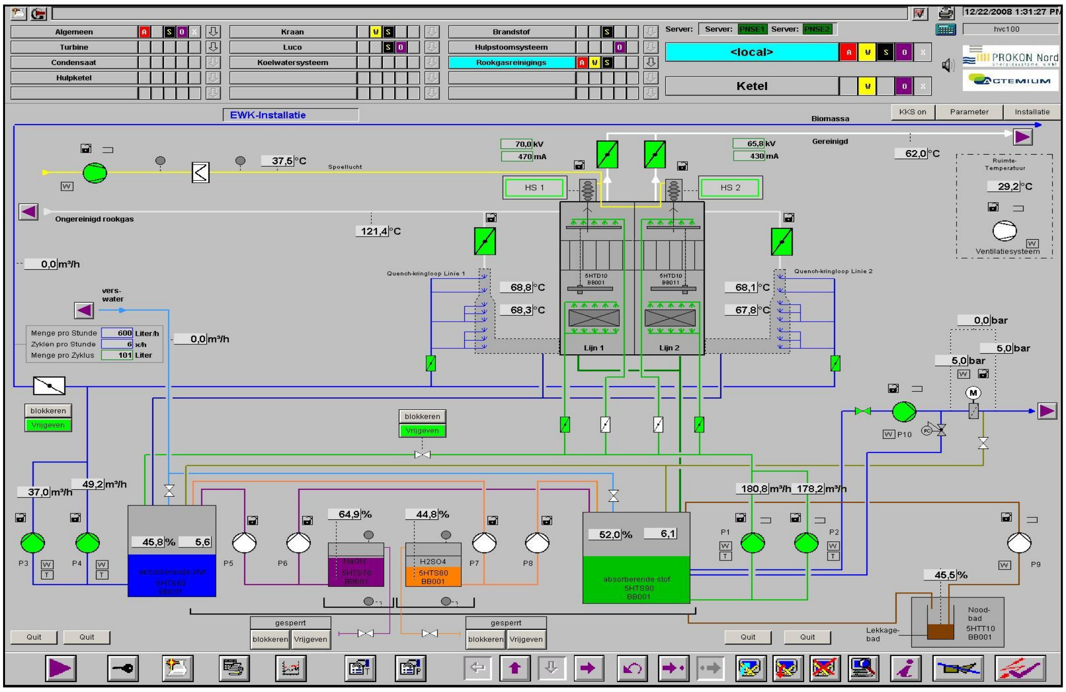
In addition to an integrated NH_3 separation, this concept also offers the reliable observance of extremely low emission values in a cost-effective way.

Illustration 10 shows the structure of this plant, based on the scheme taken from the process control system. The wet stage downstream conditioned dry sorption serves for the reliable undercut of all requested emission limit values.



Ill. 10: Schematic view of gas cleaning system for biomass combustion HVC, Alkmaar/ Netherlands

The NH_3 separation takes place in the acid scrubbing stage (illustration 11) which is installed upstream of wet ESP. The pH-value of this stage is adjusted to approx. 5.6. In order to grant a sufficient SO_2 separation, a ph-value of 6.1 has been chosen for the second scrubbing stage.



Ill. 11: Schematic view of wet ESP with integrated two-stage scrubbing process

The waste water from the basic scrubbing stage is reused in the humidifying mixers for the conditioned dry sorption. The NH_3-laden water from the acid stage (max. approx. 0.5 m³/h) is directed towards a central water processing of location.

3.2 Integration of a catalyst into the overall concept

A lot of different concepts are available for the integration of a catalyst into a complete system. The objective of nearly all of these concepts is to limit the operating temperature of catalyst to max. approx. 240° C. In this connection the catalyst has at any rate to be protected against toxication by means of upstream installed cleaning stages. Catalyst toxicants and their corresponding admissible concentrations are listed in illustration 12. Furthermore, an adequate SO_2 separation has to be granted to avoid problems due to deposits of $(NH_4)_2SO_4$. In case of an operating temperature of 240°C, the max. admissible SO_2 concentration lies in a range of max. 25 mg/m³. Up to SO_2 contents in the crude gas downstream boiler of 1,000 mg/m³ and longer lasting peaks up to max. 1,500 mg/m³ this can be realised economically by means of upstream installed single stage, dry procedures with utilisation of $NaHCO_3$ or conditioned dry procedures with $Ca(OH)_2$ and heat recycling.

In case it will not be possible to realise a corresponding limitation of the SO_2 concentration on the crude gas side, either a multi-stage process technology has to grant the reliable observance of the max. admissible SO_2 concentrations or, as alternative, the operating temperature of catalyst has to be increased.

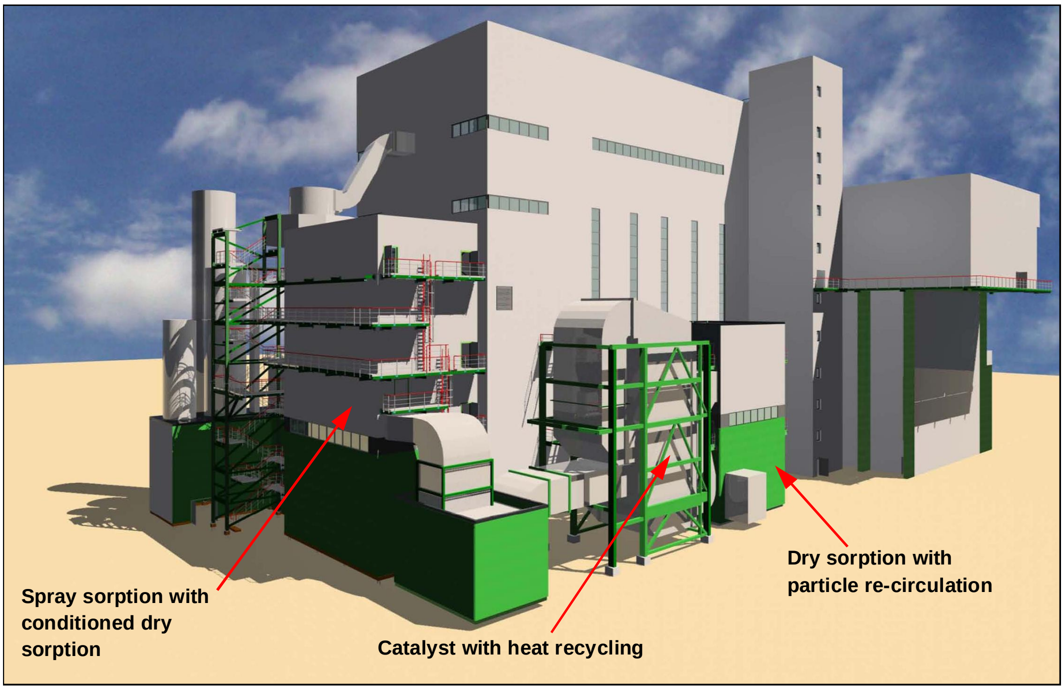
In case of integration of a catalyst into the flue gas treatment system, the process concept has to be chosen in accordance with the focal points and basic conditions of the corresponding application. The advantages and disadvantages of Ca and Na-based process technologies have to be assessed by comparison and depending on the project. When using $NaHCO_3$ it has to be checked to what extent a further process stage for the separation of dioxins / furans and mercury and/or mercury compounds as well as other heavy metals has to be installed downstream catalyst at low temperatures.

Alkaline metals	**mg/Nm³ humid**	**max. 5**
Alkaline earth metals	**mg/Nm³ humid**	**max. 1**
Hydrogen chloride, Chloride	**mg/Nm³ humid**	**max. 100**
Hydrogen fluoride, Fluoride	**mg/Nm³ humid**	**max. 1**
P_2O_5, Phosphor - Organica, As, As compounds, Si - Organica, Si - Halogenides	**mg/Nm³ humid mg/Nm³ humid**	**max. 0,005**
Pb + Zn	**mg/Nm³ humid**	**max. 0,1**
Hg + Cd	**mg/Nm³ humid**	**max. 0,1**

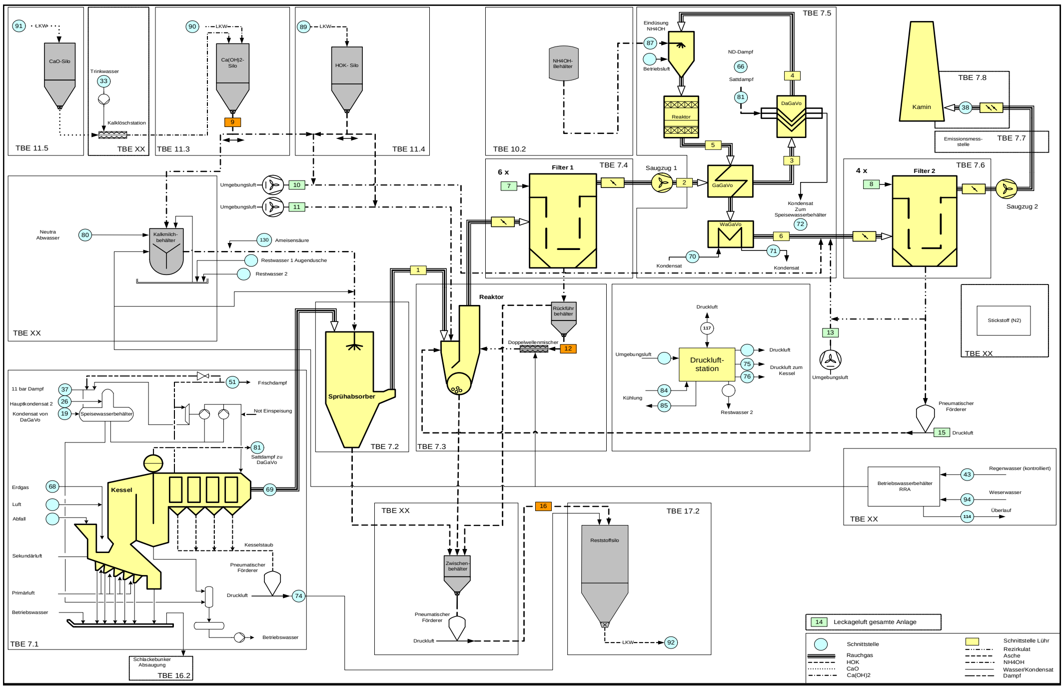
[Source : Argillon]

Ill. 12: Catalyst toxicants

Illustrations 13 and 14 show an example for the integration of a catalyst into a gas cleaning system downstream RDF combustion. At present this project is in progress of realisation. A condition for the concept determination was the observance of half of the values of the 17 BImSchV. The emission limit value for NO_x totals to 70 mg/Nm³ dry with a max. NH_3 slippage of 5 ppm. Another requirement was that in each case one separation stage for mercury compounds will be installed upstream and downstream of catalyst.



Ill. 13: Gas cleaning with integrated catalyst downstream RDF combustion



Ill. 14: Plant scheme of gas cleaning with integrated catalyst

The chosen concept mainly comprises the following stages:

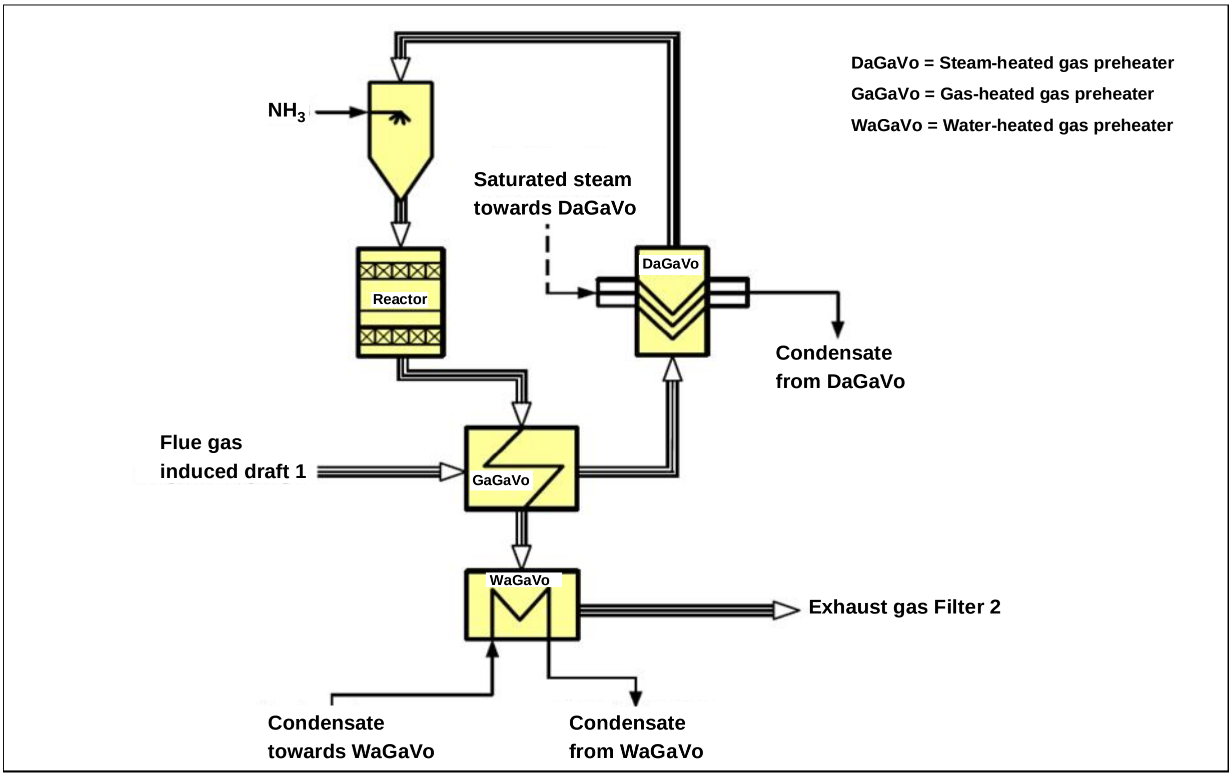
- Combination of spray absorber and conditioned dry sorption as first sorption stage
- Catalyst with gas-heated gas preheater, steam-heated gas preheater as well as water-heated gas preheater for heat recycling
- Dry sorption stage with reactor and particle re-circulation as second filter stage
- Counterflow principle for activated coke and a partial quantity of $Ca(OH)_2$
- Generation of $Ca(OH)_2$ from CaO in a hydrator

In case of Hg peaks, fresh activated coke can additionally be injected in the first stage in parallel to the second filter stage.

The main advantages of the chosen concept are:

- Utilisation of CaO as cost-effective additive powder. Regarding the separation of acid crude gas components, no further additive powder qualities will be necessary.
- Good separation of heavy metals due to a low gas temperature of approx. 140°C in the first stage
- Two-stage separation of mercury and mercury compounds as well as dioxins / furans and all other heavy metals
- Activated coke guidance in counterflow
- Graded additive powder injection already in the first sorption stage

The advantages of this variant are confronted with the disadvantage of the low inlet temperature of SCR plant downstream first sorption stage. Illustration 15 gives a schematic view of the temperature curve in the SCR stage. A steam-heated gas preheater will be necessary for the gas heating from approx. 212°C to approx. 243°C. The downstream installed water–heated gas preheater will indeed recapture the heat but at a definitely lower temperature level.



Ill. 15: Schematic view of heat recycling around catalyst

4 Selection of process technology

In addition to the presented concept variants concerning the conditioned dry sorption, a large number of other procedures for the gas cleaning downstream incineration plants for waste, RDF and other substances is of course available. An example for this is the dry sorption based on $NaHCO_3$.

However, from the author’s point of view, with regard to the design of new plants for the gas cleaning downstream RDF incinerators, the conditioned dry sorption, often in connection with graded additive powder injection or also multi-stage plants, gained an outstanding position and became accepted for many projects in the last years in Germany. Following to the corresponding requirements and conditions of the separate applications, it will be necessary to adjust the base variant by means of complementary measures or also by additional separation stages.

Each application has to be considered separately. Criterions of choice for the assessment are:

- Requested degrees of separation (Nominal and max. values as well as peaks)
- Emission limit values
- Investment costs
- Operating costs as e.g. additive powder supply and disposal as well as energy costs for power and compressed air
- Costs for maintenance and upkeep
- Plant availability and reliability of operation
- Part load behaviour
- Flexibility with regard to changing crude gas values, emission limit values and specific operating costs
- Energy efficiency

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