

Practical experiences gathered from the application of the conditioned dry sorption process downstream RDF power plants and waste incineration plants

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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 HCI and SO₂ separation increased considerably. Additional measures for the increase in efficiency of the basic process and for the reliable observance of all emission limit values in continuous operation became necessary.

Another challenge for today's and prospective concept determination of flue cleaning systems is for many projects the demand for lower emission limit values compared to those specified in the 17 BlmSchV. An example for this is the NO_x limit value of 100 mg/m³.

The gas cleaning system based on the conditioned dry sorption has to be adapted flexibly to the corresponding requirements of each separate project.

This lecture presents different concepts by means of practical examples.

2 Separation of acid crude gas components HCI and SO_x

2.1 Basic variant dry sorption with gas and particle conditioning

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.



III. 1: Dry sorption with gas and particle conditioning

It mainly comprises the units evaporative cooler, additive powder injection, reactor, fabric filter as well as particle re-circulation with integrated particle conditioning.

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 the 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 second separation stage comprises 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 particularly of SO₂ separation by means of moistening of recirculated particulate
- Further, even though minor reduction of gas temperature

The process offers the following, advantageous features:

- Simple plant structure
- Compact design
- Low maintenance
- Use of a favourably priced additive powder

The facing disadvantages are:

- The evaporative cooler has to be protected in addition against corrosion by means of adequate measures
- The evaporative cooler with a possible contact time of several seconds in case of good reaction conditions, will not be used for the crude gas separation
- In order to maintain the advantage of low procurement costs when using CaO instead of Ca(OH)₂, the use of a dry hydrator will be necessary, involving higher investment costs.

The efficiency of the above-described basic variant for the observance of the limit values accord. to 17 BImSchV. with crude gas contents of HCl up to approx. 2,000 mg/Nm³ dry and SO₂ up to 1,000 mg/Nm³ dry is demonstrated by the plant GML in Ludwigshafen. Illustration 2 shows the application and illustration 3 the separation potential for HCl and SO₂.

Volume flow : 90.000 Nm³/h humid					
		Gas take-over		Emission limit values	
		DAV	HAV	DAV	HAV
Overall dust	[mg/Nm³ dry]	1,600	5,000	10	20
нсі	[mg/Nm³ dry]	1,000	2,000	10	60
HF	[mg/Nm³ dry]	15	30	1	4
SO ₂	[mg/Nm³ dry]	400	600	25	150
Hg	[mg/Nm³ dry]	0.3	0.3	0.015	0.03
Cd + TI	[mg/Nm ³ dry]	1.0	3.0	0.05 *	

ngTE/Nm ³ dry]	3.0	5.0	0.1 *
mg/Nm³ dry]	20	50	0.5 *
	mg/Nm³ dry]	mg/Nm³ dry] 20	mg/Nm ³ dry] 20 50

III. 2: MHKW Ludwigshafen FGT line 2



Ill. 3: Trend curves of crude gas / clean gas values and stoichiometry

Upon closer inspection of stoichiometric curves it becomes apparent that in case of increasing crude gas values regarding HCl and SO_2 , the stoichiometry has partly to be increased considerably above the set base value of 2 in order to observe reliably the emission limit values.

2.2 Graded additive powder injection

Not only due to the missing corrosion protection within the evaporative cooler and the higher additive powder consumption in case of rising crude gas values, it is in principle advisable to use a graded additive powder injection. Illustration 4 shows corresponding, different process variants. With regard to all concepts, the main quantity of additive powder is in the nominal case injected into the reactor downstream evaporative cooler. 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.



III. 4: Conditioned dry sorption with graded additive powder injection

2.2.1 Combination of spray absorber – particle conditioning

Compared to the other concepts, this is surely the most expensive one for a graded additive powder injection. However, the plants realised in practice downstream RDF incinerators confirm the effectiveness.



III. 5: Stoichiometry at graded additive powder injection

The advantages of this procedure are:

• Graded additive powder injection

The example shown in illustration 5 presents the advantages of a graded additive powder injection. In the first stage with low stoichiometry referring to the crude gas input, already a large part of the HCl as well as a limited amount of the SO_2 content are separated. Related to the crude gas contents to be expected after the first stage and compared to the summarised stoichiometry, a considerably higher stoichiometric injection quantity will be available for the fine cleaning in the second stage.

• The overall system is comparatively insensitive with regard to strongly fluctuating crude gas components in the crude gas.

The facing disadvantages are:

- Comparatively high investment costs
- Formation of CaCO₃ in the spray absorber At some plants a distinct reaction of Ca(OH)₂ with the CO₂ in the gas with formation of CaCO₃ was found. This may possibly lead to an increased additive powder consumption
- Maintenance for lime slurry operation

Illustration 6 shows the RDF heat-and-power-station Stavenhagen as representative for several realised plants and illustration 7 presents as result for the separation efficiency some trend curves from the control system of this plant.

The average stoichiometric factor actually reached in continuous operation has repeatedly been determined by means of remainder analyses. It lies in a range of 1.8

up to 2.0. The chloride content in the remainder totals to approx. 20 up to 22 % thus lying in a range that is non-critical for the product handling.

Volume flow : 104.000 Nm³/h humid			
		DAV	DAV
		nominal	maximal
Particles	mg/Nm³ dry	1,000	1,000
HCL	mg/Nm³ dry	1,300	2,000
HF	mg/Nm³ dry	25	50
SO ₂	mg/Nm³ dry	1,100	1,900
Hg	mg/Nm³ dry	0.12	0.12
Σ Heavy metals	mg/Nm³ dry	27.5 *	100 *
Cd / TI	mg/Nm³ dry	1.3 *	6.0 *
PCDD / PCDF	ng/Nm³ dry	3.0 *	4.0 *
* Average value over sample taking p	eriod		

III. 6: RDF HKW Stavenhagen



III. 7: Trend curves for crude / clean gas values, temperatures, gas humidity and volume flow

The separation potential of this concept could be proven by another, operating plant. At average 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 SO₂ combined with definitely higher crude gas peaks for both crude gas components, the limit values of 17 BlmSchV. are reliably undercut. The determined stoichiometric factors lie in a range of 2.3.

2.2.2 Graded injection of Ca(OH)2 upstream and downstream of evaporative cooler

This concept is clearly simpler than the above-described process variant and has been provided for some projects currently in progress of realisation and/or commissioning. First operating experiences are expected within a short time.

The advantages of this procedure are:

- Simple plant structure
- Long contact time between crude gas component and the additive powder injected upstream evaporative cooler
- Excellent reaction conditions in the cloud of water droplets within evaporative cooler
- Redundant additive powder injection possible
- No limitation of additive powder injection quantity, as given in case of the spray sorption by the max. lime slurry concentration
- Low maintenance
- Increased formation of CaCO₃ is not expected

So far, the only disadvantage may be, that depending on the overall concept, partly long pneumatic conveying lines will have to be realised, ready for continuous operation.

The proof of efficiency of this type of concept has to be provided in the next time.

2.2.3 Injection of NaOH within evaporative cooler

Analogous to the lime slurry injection, this variant can only be realised if the evaporative cooler will be sufficiently dimensioned right from the beginning. The first studies of plant operator at the conditioned dry sorption system installed at the MHKW Ludwigshafen impressively proved that crude gas component peaks can effectively be reduced. Results are shown in illustration 8. An above average injection of Ca(OH)₂ for the observance of the emission limit valves could be avoided during these operating situations.

The disadvantage of this variant is the handling of NaOH.



III. 8: Operating experiences with reduction of HCI peaks with injection of NaOH (Source: R. Wradatsch/TWL-MHKW Ludwigshafen)

2.2.4 Injection of NaHCO₃ upstream evaporative cooler

From the author's point of view, this concept will so far only be used for projects, for which HCl values of > 2,500 mg/m³ have to be expected in continuous operation. Due to the definitely sub-stoichiometric injection of NaHCO₃ and the fact that NaHCO₃ will only be discharged after a multiple particle re-circulation, a nearly 100 percent utilisation of the NaHCO₃ has to be expected.

2.3 Multi-stage conditioned dry sorption

Provided that 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. corresponding 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, a well 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 type of process technology, i.a. also for thermal waste disposal plants.



III. 9: Prokon Nord / Steam power plant Weener



III. 10: Process scheme: Steam power plant Weener

Illustrations 9 and 10 exemplary show the gas cleaning system of the steam power plant Weener. With regard to the separation of HCl and SO_x , this plant has been realised in three stages.

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 11).



III. 11: 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.

Further advantages are:

- Fluctuations of crude gas contents within the gas downstream boiler will be compensated without increase in stoichiometry
- As a result of the additive powder injection upstream economiser and due to the reduction of acid dew point temperature close to the water dew point, the boiler outlet temperature can be reduced to approx. 150°C. Disadvantages regarding the heat transfer resulting from the additive powder injection upstream economiser could not be noticed

The disadvantage of the chosen procedure is the utilisation of two fabric filters, installed in series. The higher operating costs related to the power consumption and the filter fabric have to be taken into consideration when calculating the profitability. However, such type of procedure can be compared to e.g. the combination of spray dryer – fabric filter – two-stage scrubber.

The two-stage conditioned dry sorption process can in different variants be adapted to the corresponding application, e.g. by means of injection of the partly saturated additive powder upstream first reactor – filter stage instead of upstream economiser with at the same time injection of activated coke / carbon upstream fine cleaning stage. With regard to the dioxin / furan separation and the reduction of mercury compounds, a two-stage process can then be achieved.

Concepts for low emission limit values considering NO_x 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 intoxication by means of upstream installed cleaning stages. Furthermore, an adequate SO₂ 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 SO₂ concentration lies in a range of max. 25 mg/Nm³ dry. Up to SO₂ contents in the crude gas downstream boiler of 1,000 mg/Nm³ dry and longer lasting peaks of up to max. 1,500 mg/Nm³ dry this can be realised economically by means of an upstream installed single stage, dry procedures with utilisation of NaHCO₃ 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 SO₂ concentration on the crude gas side, either a multi-stage process technology has to grant the reliable observance of the max. admissible SO₂ concentrations or, as alternative, the operating temperature of catalyst has to be increased.

Illustrations 12 and 13 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 specified in the 17 BlmSchV. The emission limit value for NO_x totals to 70 mg/Nm³ dry with a max. NH₃ 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.



III. 12: Gas cleaning with integrated catalyst downstream RDF incineration



III. 13: Plant scheme of a 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 addition it should be mentioned again that there is no most suited process for each type of application. In fact, you always have to choose an adequate and optimised procedure, based on the key aspects and basic conditions of the corresponding application.

3.2 SNCR with NH₃ separation

Operating results gathered from modern incineration plants with SNCR process for the reduction of NO_x showed that in most of the cases the reliable observance of the currently discussed, tightened NO_x limit value of 100 mg/m³ will be possible. However, it will possibly be necessary to extend the concept by integration of another separation stage for NH₃.

Illustration 14 exemplary shows a gas cleaning system downstream circulating vortex bed for biomass combustion in the Netherlands. For the observance of the requested NO_x limit value, the constructor of boiler installed a SNCR plant.

In addition, the illustration shows a table with the requested emission limit values to be observed by means of the downstream installed gas cleaning system.

Emis	ssion limit values		DAV	нау	AAV
Parti	icle content, total	mg/Nm³ dry	3	15	1
НСІ	content	mg/Nm³ dry	5	60	3
, HF c	ontent	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 c	ontent	mg/Nm³ dry	0,03		0,005
	ontent	mg/Nm³ dry			0,005
	ontent	mg/Nm³ dry			0,005
Cd a	nd TI content	mg/Nm³ dry	0,05 ¹⁾		0,01
Sb -	Sn ²⁾ content, total	mg/Nm³ dry	0,25 ¹⁾		0,05
Diox	in/Furan content TEQ	ng/Nm³ dry	0,05 ¹⁾		0,02
^{•)} Ave •) Sur	erage value over sample ta n Sb - Sn : Sb + As + Pb +	king period ∙ Cr + Co + Cu + Mn	+ Ni + V + Sn		
• Volu	ume flow: 000 Nm³/b bumid				

III. 14: Gas cleaning system for biomass combustion HVC in Alkmaar

As a result of the requested, extremely low limit values especially with regard to the annual average values as well as the additionally necessary NH_3 separation from max. approx. 15 mg/m³ to < 5 mg/m³, the following concept had been chosen fort the gas cleaning system:

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

The design of plant is shown in illustration 15 by means of the scheme taken from the process control system. The wet stage, located downstream of conditioned dry sorption, ensures the reliable undercut of all requested emission limit values.



III. 15: Schematic view of biomass combustion HVC Alkmaar

The separation of NH_3 takes place in the acid scrubbing stage (illustration 16) located upstream of wet ESP. The pH-value in this stage is set to approx. 5.7. To ensure a sufficient SO_2 separation, a ph-value of 6.3 was chosen for the second scrubbing stage.



III. 16: Schematic view of wet ESP with integrated two-stage scrubbing

The waste water from the basic scrubbing stage is used 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 to a local, central water-recycling plant.

4 Selection of process technology

In addition to the presented concept variants concerning the conditioned dry sorption, there is surely a large number of other process technologies available for the gas cleaning downstream incineration plants for waste and RDF. 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 from case to case 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

The process selection can in addition be influenced by the requirements on increased emission limit values for NO_x in connection with a limitation of the NH_3 slippage. If due to these reasons the application of a catalyst will be necessary, the utilisation of NaHCO₃ compared to procedures based on Ca(OH)₂ / CaO may offer advantages. This is due to the higher, optimum reaction temperature when using NaHCO₃.

The fabric filter with NaHCO₃ injection will then be operated at 200 up to 240°C. At extensive separation of acid crude gases, especially of SO₂, the catalyst can be installed downstream of filter without heating device. However, 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 further heavy metals has to be installed downstream of catalyst at low temperature.



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