LUEHR FILTER

TwinSorp – a simple process for increased requirements on the emission limit values i.a. for waste and RDF incinerators, considering the energy efficiency command

Author:
Dipl. - Ing. Rüdiger Margraf

HDT symposium

Dry flue gas cleaning for firing installations and other thermal processes

Summary

1 Introduction

In the course of the past years semi-dry and/or conditioned dry procedures with utilisation of Ca-based additive powders for the gas cleaning downstream waste and RDF incinerators gained outstanding importance especially in Germany. This technology with simple design allows the simultaneous separation of particles, acid crude gas components such as HF, HCl and SO_x, mercury and other heavy metals as well as dioxins/furans in one stage. The requested emission levels, e.g. in accordance with 17 BImSchV or EU Directive 2000/76/EC, with the typical inlet concentrations of components to be separated are reliably observed with acceptable operating costs.

However, due to the discussion about the tightened emission limit values i.a. for NO_x with consideration of a sufficiently low NH_3 slippage, this process has increasingly been put into question lately. Even for other components such as e.g. the acid crude gases or heavy metals, higher degrees of separation have been requested for many times.

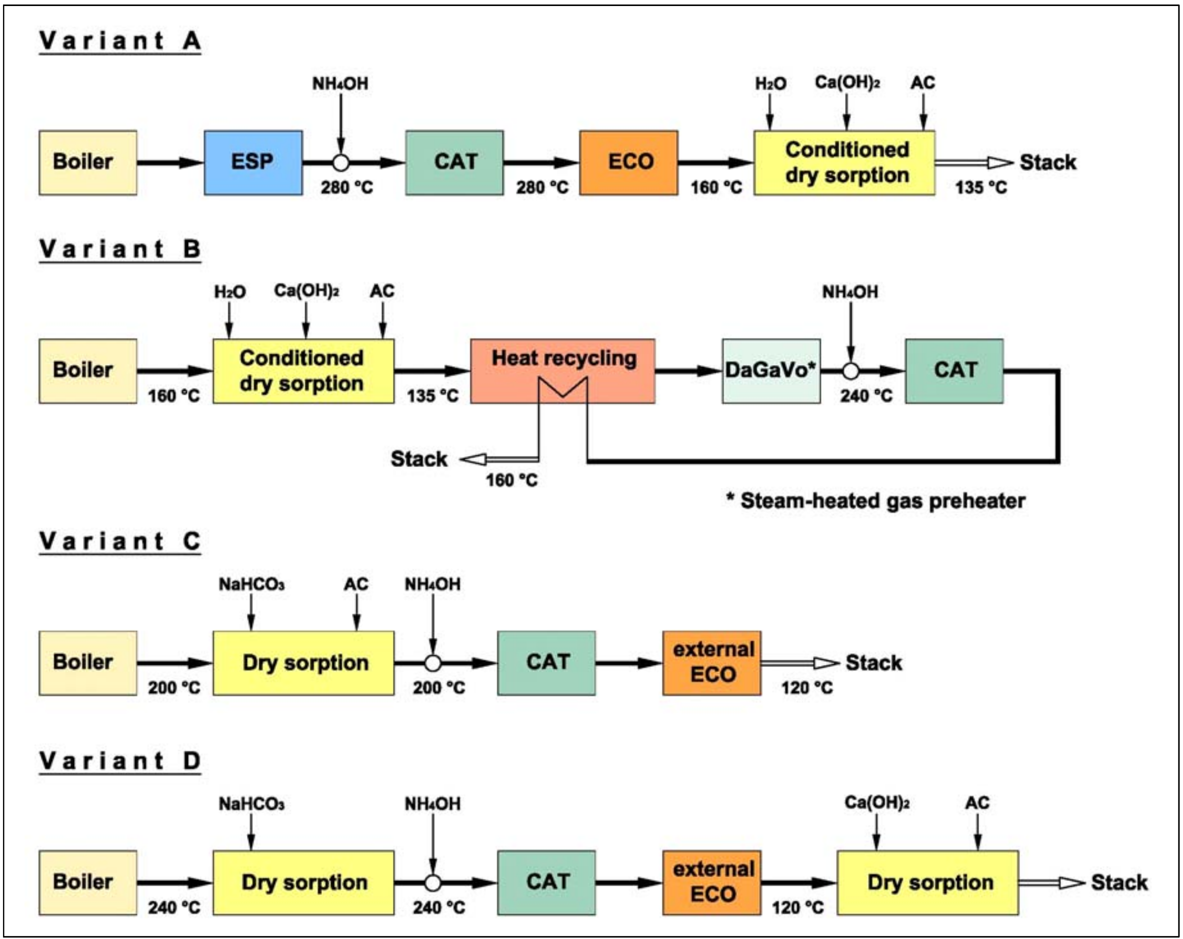
In the scope of this lecture, some process examples, considering in particular the reduced emission limit values for NO_x and NH_3, will be discussed with listing of advantages and disadvantages. Following to this, a two-stage technology with integration of the conditioned dry sorption as main cleaning stage will be explained and an application example for this procedure will be introduced.

2 Examples for process variants with integration of a catalyst for the NO_x reduction

The integration of a catalyst in the crude gas cleaning system can be realised with a multitude of variants. Illustration 1 shows some examples.

Variant A in illustration 1 shows the arrangement of SCR plant for the reduction of nitrogen oxide downstream boiler at 280°C in order to avoid a complex reheating of gas. To avoid a clogging of catalyst with fly ash, an ESP has been installed upstream catalyst. Due to the operating temperature of catalyst of approx. 280°C, a sulphation of catalyst will be avoided.

Subsequently the gas is cooled down to approx. 160°C by means of an additional economiser. The separation of remaining crude gas components takes place in a conditioned dry sorption plant with hydrated lime and activated coke as additive powders.



Ill. 1: Flue gas cleaning concepts with catalyst for NO_x reduction

The advantages of this technology are:

- no reheating of gas necessary for a safe operation of catalyst
- well-proven and economical gas cleaning system for the acid crude gases, mercury, heavy metals and dioxins/furans

The disadvantages are:

- high investment costs
- risk of clogging of catalyst due to limited particle separation in the ESP

In case of variant B, the catalyst will be installed downstream of conditioned dry sorption. The essential disadvantage is surely the reheating of gas from approx. 130°C to 240°C, necessary to avoid a sulphation of catalyst. Another condition is the reliable observance of a max. SO_2 content upstream catalyst of < 25 mg/Nm³ dry.
The use of $NaHCO_3$ as additive powder for the separation of acid crude gas offers the possibility to run the sorption stage with higher gas temperatures, e.g. 200°C (variant C). This variant is characterised by the fact, that the complete separation of crude gas,

except for NO_x, takes place in a single stage dry sorption process with utilisation of $NaHCO_3$ as additive powder. After outlet of flue gas from boiler, sodium bicarbonate and activated coke are injected at a temperature of approx. 200°C. The SCR plant is directly installed downstream fabric filter. To improve the efficiency of overall plant, the gas can subsequently be cooled down from 200°C to e.g. approx. 120°C by means of an external economiser.

The advantages of this technology are among other things:

- a simple plant design
- a high energy efficiency

The facing disadvantages are:

- high operating costs for additive powders
- risk of an at least partly insufficient mercury separation due to the comparatively high dry temperature in the sorption stage

To improve the separation of heavy metals, mercury and dioxins/furans, a further separation stage can be installed downstream catalyst (variant D). However, there is still the disadvantage of high purchase costs for $NaHCO_3$. The acid crude gases still have to be separated nearly completely in the sorption stage upstream catalyst in order to avoid a sulphation of catalyst. In case of an operating temperature of catalyst of e.g. 240°C, the SO_2 concentration has to be < 25 mg/Nm³ dry.

Due to the fact that all introduced variants show aggravating disadvantages, it was obvious, to look for alternative procedures. The essential criteria for the considerations are:

- preferable use of an SNCR - technology
- use of Ca-based procedures for the separation of acid crude gases
- high energy utilisation
- waste water-free operation
- on request, observance of low emission limit values for acid crude gases, mercury and other heavy metals, particles, dioxins/furans

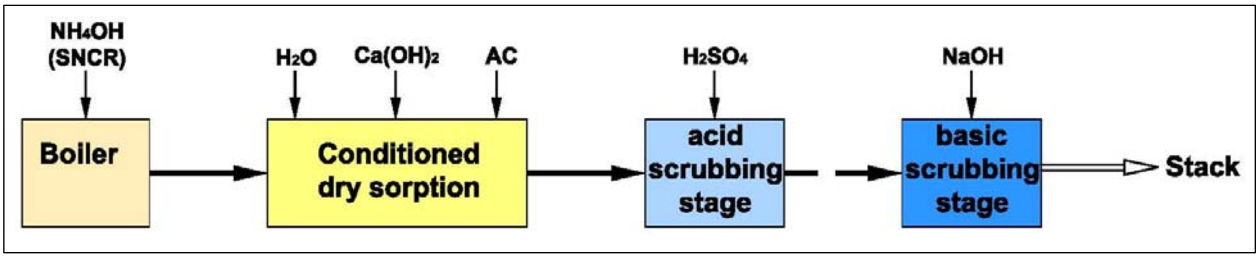
The TwinSorp process developed by LUEHR FILTER is able to fulfil the above-mentioned requirements.

3 TwinSorp process

3.1 Preliminary remark and general design

The combination of SNCR with conditioned dry sorption proved to be successful with regard to the requirements accord. to 17 BImSchV or EU Directive 2000/76/EC. The procedure is simple, reliable and economical. The emission limit values accord. to 17 BImSchV are reliably observed. Furthermore, the SNCR - technology is nowadays able to observe also NO_x contents, definitely < 100 mg/Nm³ dry, however with an increased NH_3 slippage.

Following to this, in case of request for lower emission values for NO_x, this well-proven process has only to be extended by one stage for the separation of NH_3. This can be achieved by the installation of a wet fine cleaning stage downstream conditioned dry sorption.



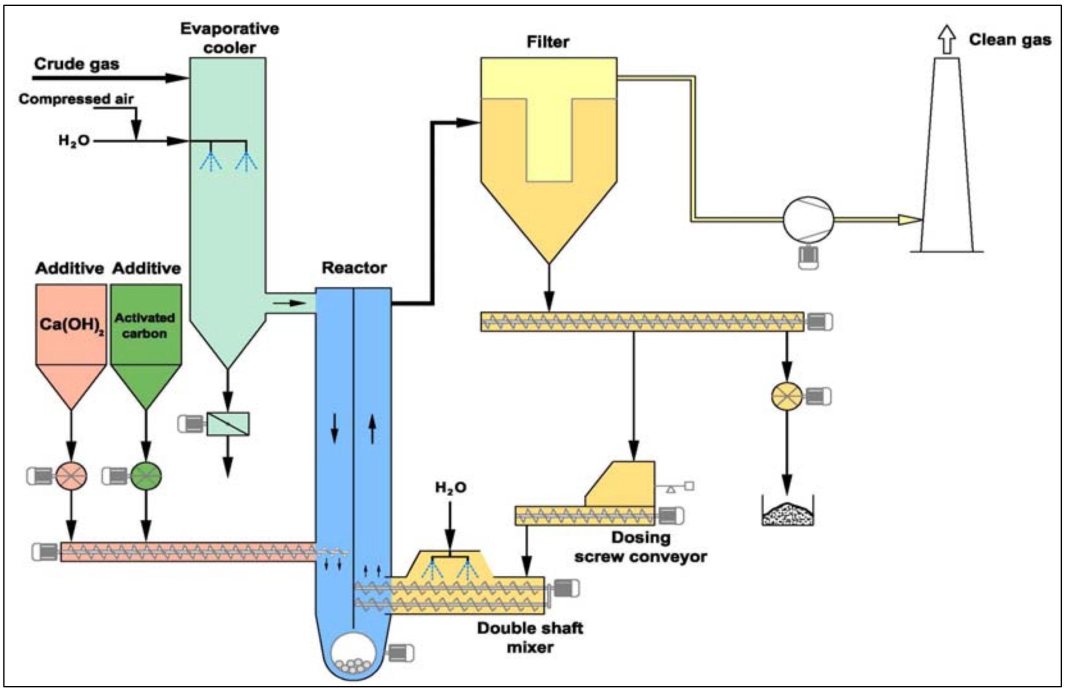
Ill. 2: Scheme TwinSorp process

The basic scheme of TwinSorp process is shown in illustration 2. The two process stages conditioned dry sorption and wet fine cleaning stage will be explained in the following. A discussion of the SNCR – technology is not included in this lecture.

3.2 Chemisorption with gas and particle conditioning

Illustration 3 shows a schematic view of this technology which has been introduced and successfully installed since many years downstream waste incinerators for the reliable observance of the emission limit values accord. to 17 BImSchV. It mainly comprises the unit 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 for an optimisation of separation efficiency and additive powder utilisation. Due to the fact that especially in case of alternative fuel incinerators and as a result of the fuel composition and pre-treatment the gas humidity is often lower than the one of e.g. domestic waste incinerators, the possibility of adjusting an optimum gas temperature gains special importance.



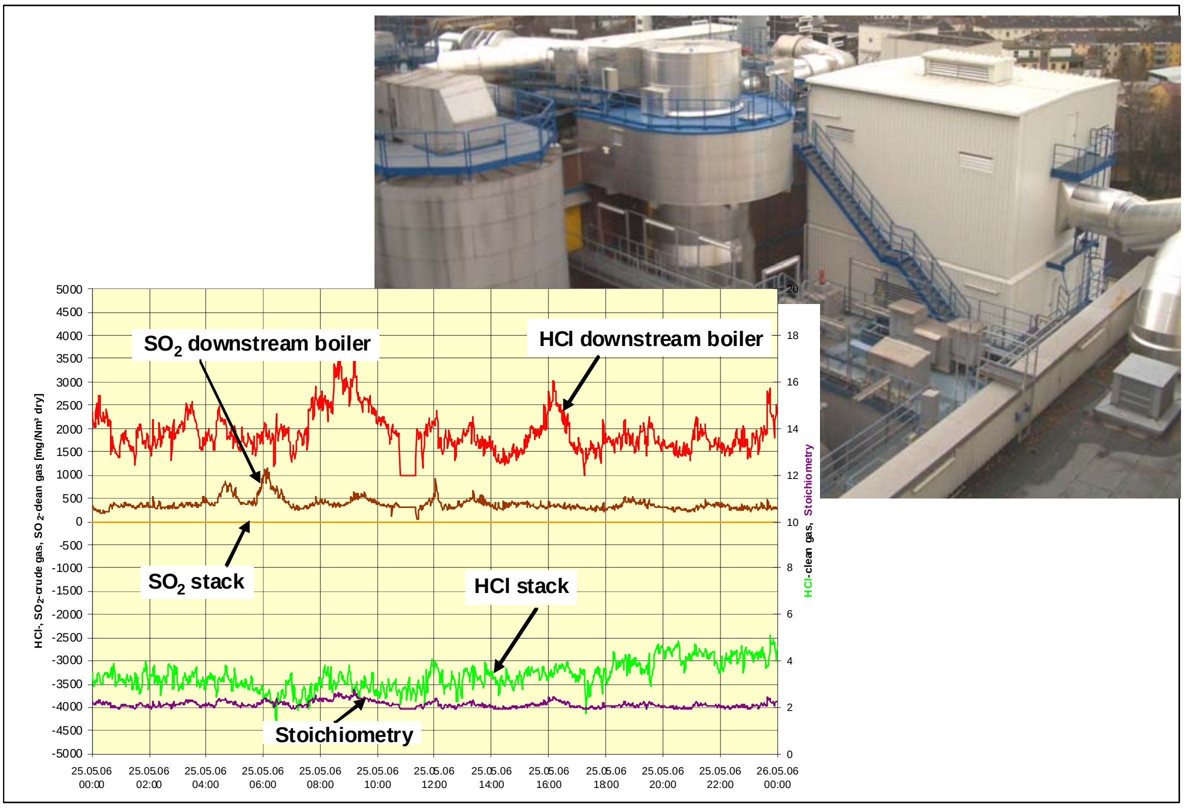
Ill. 3: Chemisorption with gas and particle conditioning

The crude gas sorption and separation of all other relevant components which are not reduced near the boiler and the combustion, takes place in the reactor – filter combination with injection of $Ca(OH)_2$ and multiple particle re-circulation, including conditioning of re-circulated particulate. Excepted from this is the separation of NH_3.

The objectives of this stage are:

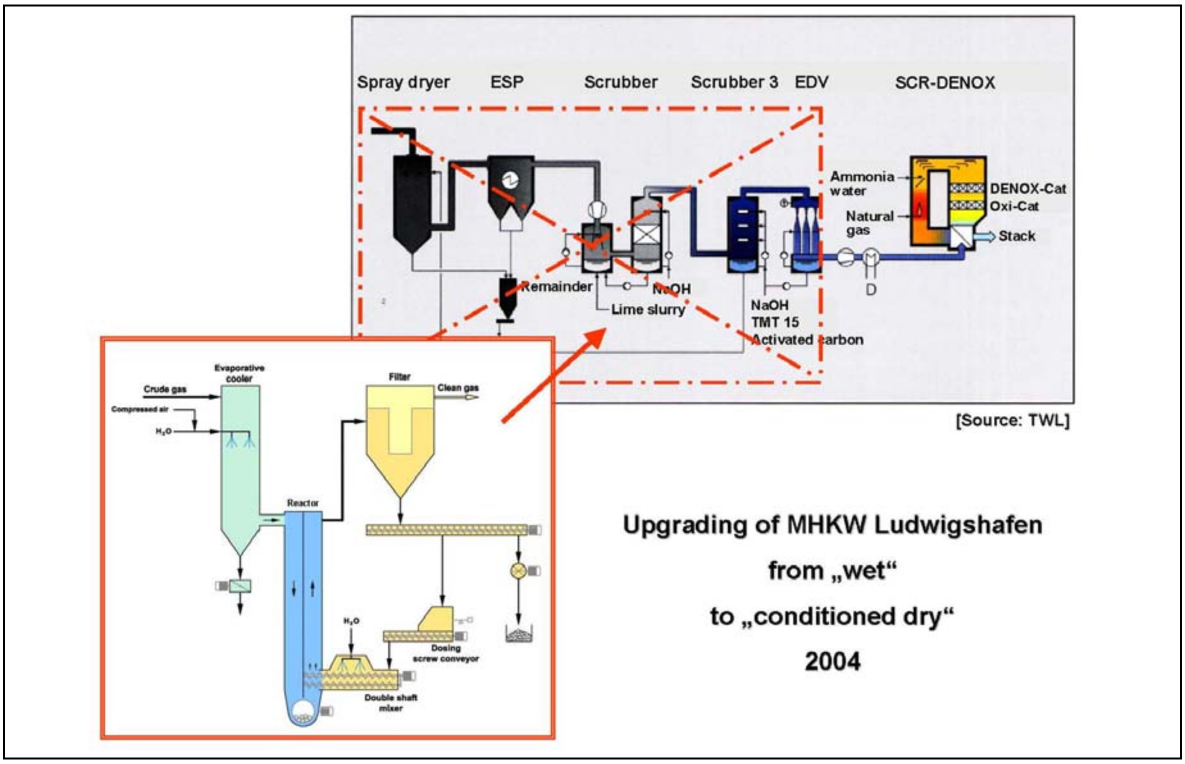
- Creation of good reaction conditions by means of particle re-circulation up to n x 100 g/Nm³
- Optimisation particularly of SO_2 separation by means of moistening of re-circulated particulate.
- Further, even though minor reduction of gas temperature

The efficiency of the above-described basic variant for the observance of the limit values accord. to 17 BImSchV with crude gas contents of up to approx. 2,000 mg/Nm³ dry for HCl and up to 1,000 mg/Nm³ dry for SO_2 is demonstrated by the waste heat generation station MHKW Ludwigshafen (illustration 4).



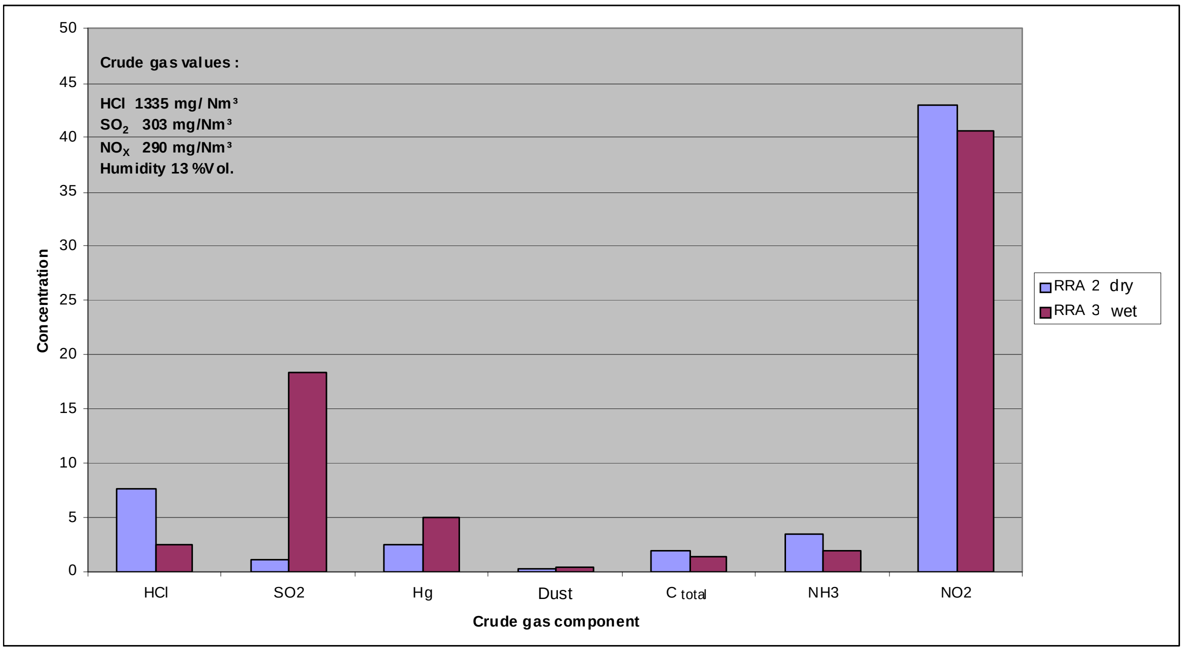
Ill. 4: Conditioned dry sorption in MHKW Ludwigshafen

The conditioned dry gas cleaning system was installed in 2004 and replaced a definitely more complex, wet system, consisting of spray dryer, ESP, multi-stage scrubber and aerosol separator (illustration 5).



Ill. 5: Upgrading of MHKW Ludwigshafen from „wet“ to „conditioned dry”

Up to the year 2008, another wet flue gas treatment system had been operated in parallel with the conditioned dry gas cleaning at the MHKW Ludwigshafen until its conversion in 2008, thus allowing a direct comparison of both installed variants. Illustration 6 shows the average values of the year 2005 for selected substances.



Ill 6: 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 SO_x separation combined with a nearly 100% SO_3 sorption by means of the conditioned dry sorption process allowed a reduction in operating temperature of the downstream installed SCR plant in the MHKW Ludwigshafen from 300°C to 230°C. An additional advantage for 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 regarding SO_2. This is especially important in case of downstream installation of SCR plants

3.3 Wet fine cleaning stage

3.3.1 General design

The conditioned dry sorption of this process variant is operated in that way, that the crude gas downstream this stage will as far as possible comply with the requirements of e.g. 17 BImSchV or EU Directive 2000/76/EC. Depending on the application in question, the downstream installed fine cleaning stage serves for the

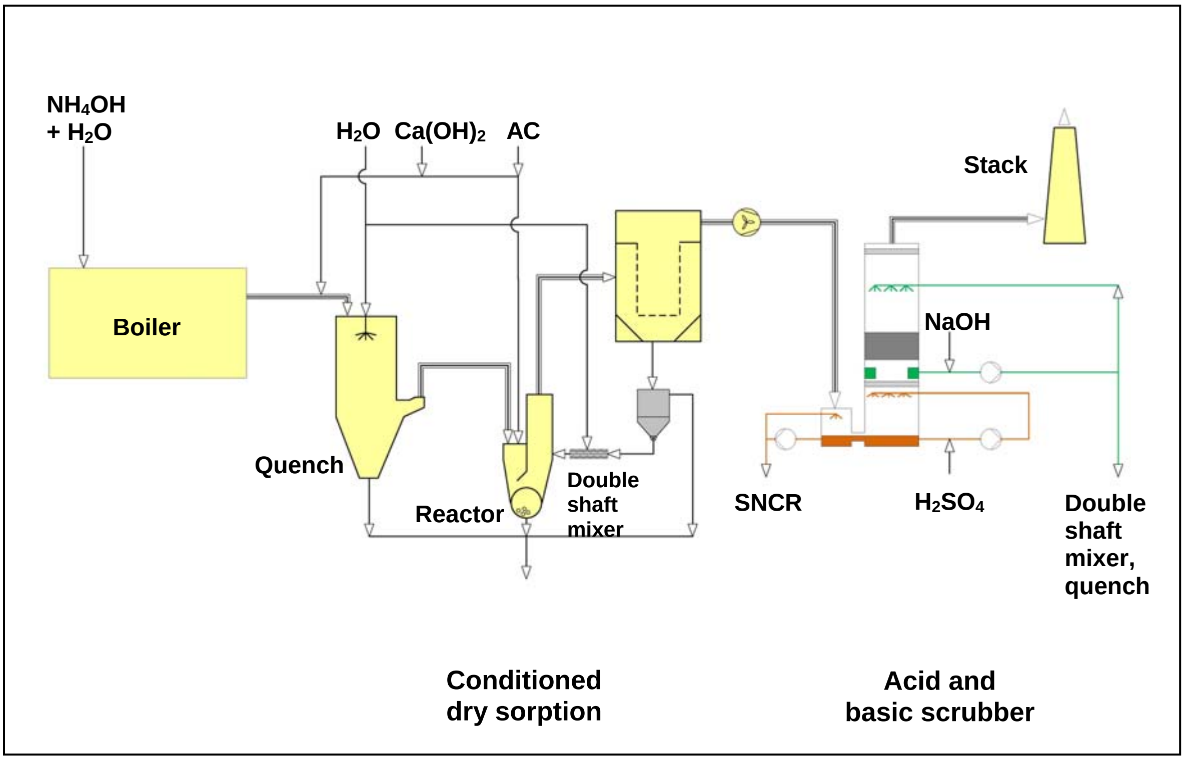
- separation of NH_3
- progressing reduction in emission values e.g. for the acid crude gas components
- heat recovery

Depending on the requirements, the wet stage of TwinSorp process can be realised as:

- single-stage acid scrubber
- scrubber with acid and basic stage
- acid and basic stage with wet ESP
- measures for heat recovery
    - o heat exchanger between conditioned dry sorption and wet stage
    - o use of heat of condensation inside of scrubber

Below follows a discussion of the separate types of design.

3.3.2 Acid scrubbing stage



Ill. 7: TwinSorp process: Variant I: Combination of conditioned dry sorption – acid scrubbing

The acid scrubbing stage in combination with a conditioned dry sorption is shown in the schematic view in illustration 7. It serves for the separation of NH_3, HCl and partly of SO_2. To allow this, the gas is cooled down to the saturation temperature by injecting scrubbing water.

In order to ensure a sufficient NH_3 separation, the ph-value in the scrubbing water of the acid stage has to be sufficiently low. Only in case of a definitely acid operating mode, an efficient separation of NH_3 can be achieved. In this respect, the ph-value will be measured and possibly adjusted by injection of H_2SO_4. An example for this is a realised plant that allows a reliable NH_3 reduction in continuous operation of approx. 15 mg/Nm³ dry to < 5 mg/Nm³ dry at a ph-value of < 5.6. Depending on the NH_3- and HCl concentration, a sufficiently low ph-value will temporarily be reached in the water, even without injecting other chemicals.

A high-capacity droplet separator is installed downstream of acid scrubbing stage. This is also of great importance for the variant with additionally installed basic stage, in order to achieve a clear separation between the acid and the basic stage, thus allowing a separate reuse of waste water from both stages. In case of a necessary NH_3 separation, a direct injection of purge water from the acid stage into the quench of the conditioned dry sorption or the humidifying mixer of this stage will not be possible. Without a discharge of NH_3, this will be released again after contact with the basic additive powders in connection with water. With regard to this discharge way, an additional NH_3-stripper has to be installed. This additional unit is complex and energy-intensive in operation.

Due to the fact that the acid scrubber only serves as a fine cleaning stage for the reduction of HCl beside the separation of $NH_{3,}$ the waste water quantity can be kept on a low level. With regard to this small amount of water, a much simpler and cost-effective alternative of use is available. During the SNCR process, the NH_4OH solution is normally further diluted, to achieve a homogeneous dispersion of reduction agent over the whole distribution section within boiler. This dilution water can either partly or in total be replaced by the waste water of the acid stage. The NH_3 in the water is used for the reduction of NO_x. Referred to the HCl mass flow from the fuel, the inlet of HCl is very low. Negative influences on the process, e.g. due to a rise in the HCl concentration upstream crude gas cleaning, have to be excluded.

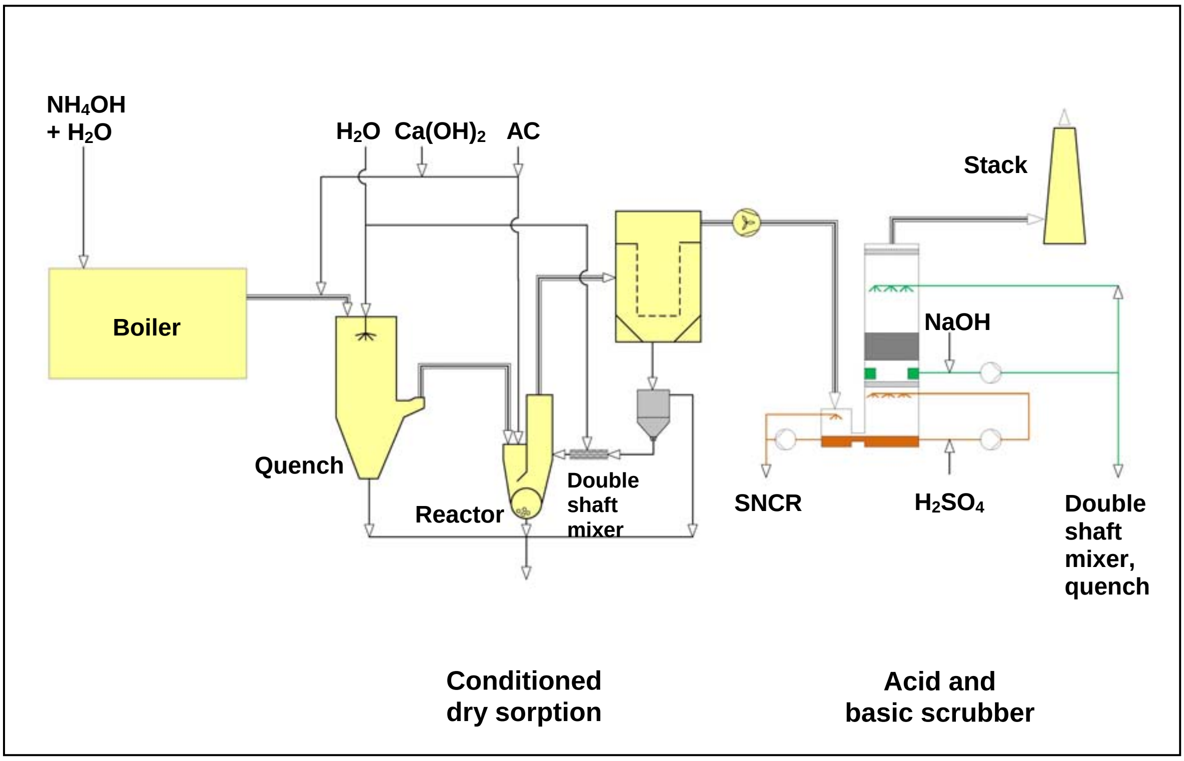
3.3.3 Basic scrubbing stage

The additional integration of a basic stage will be necessary if

- a progressing SO_2 separation will be necessary
- the heat of condensation has to be used

3.3.3.1 SO_2 separation

The process scheme with acid and basic stage is shown in illustration 8.



Ill. 8: TwinSorp process: Variant II: Combination conditioned dry sorption – acid and basic scrubbing

With regard to the SO_2 separation, a ph-value of > 6 has to be adjusted. In this connection and depending on the requirements, a corresponding amount of NaOH will be injected into the scrubbing water. Even in this case a droplet separator is installed downstream of stage.

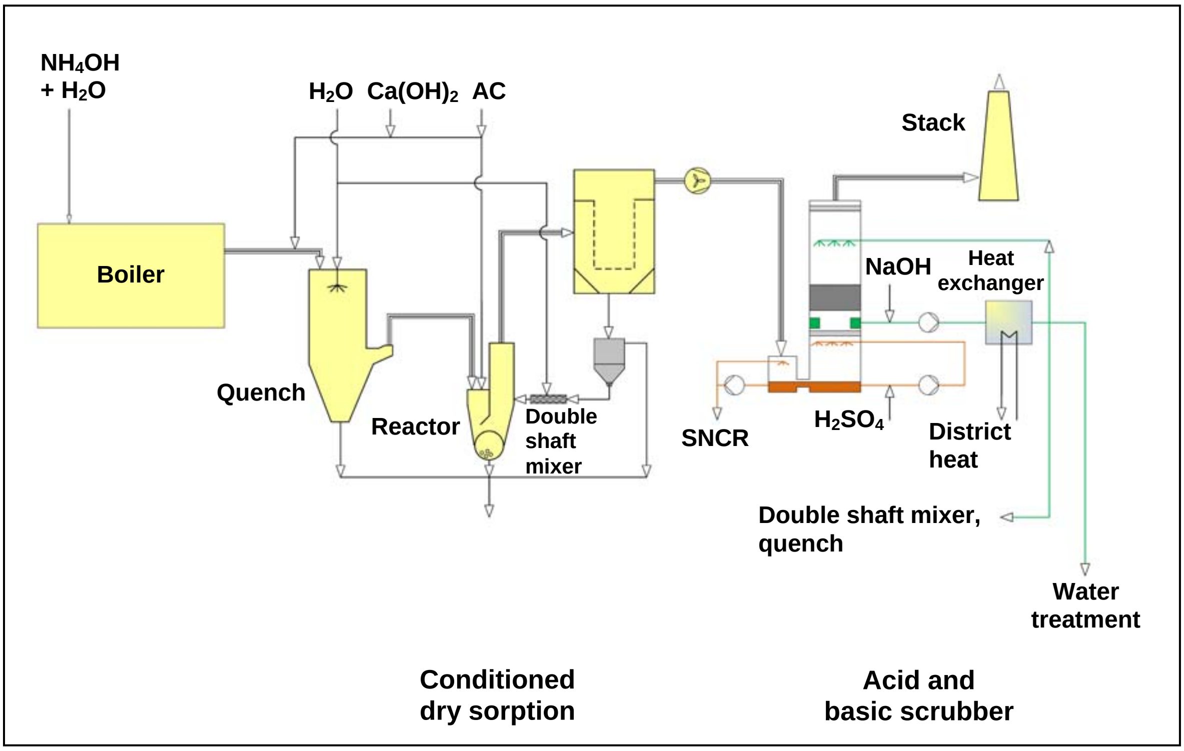
A small amount of waste water has continuously to be extracted. As far as no heat distribution is integrated in this stage, the purge volume can be kept at such a low level that this water in the evaporative cooler of conditioned dry sorption or also in the humidifying mixer of this stage can be used for the cooling of gas downstream boiler and/or for the conditioning of recycled particulate without any further treatment. Condition for this is of course that the acid crude gases are basically separated in the conditioned dry sorption stage and that the scrubber is operated as fine cleaning stage.

To achieve a progressing separation of particles, heavy metals and/or aerosols, the droplet separator of this stage can be replaced by a high-capacity wet ESP. An emission of sal ammoniac aerosols can reliably be excluded in case of using a wet ESP.

3.3.3.2 Utilisation of heat of condensation

Especially in Northern Europe, the heat of condensation contained in a wet stage is often used as energy input in a district heating network. The heat amounts to be supplied in this connection are not unimportant. Based on the typical general conditions of a waste incinerator, the specific heat amounts can lie in a range of approx. 800 up to 850 kW for a crude gas volume of 10,000 Nm³ humid.

The basic scrubbing stage is in this case realised as packed bed scrubber (illustration 9). The scrubbing water is dispersed on the packed bed by means of nozzles. While trickling through the packed bed, the waste water is heated and at the same time the saturated off-gas is cooled down during passage through the packed bed from the bottom to the top. The heated water is directed to an external plate heat exchanger in which the heat is partly transferred to the liquid of district heating network. After that the waste water is re-injected into the scrubber above packed bed. A droplet separator is installed downstream of basic scrubber.



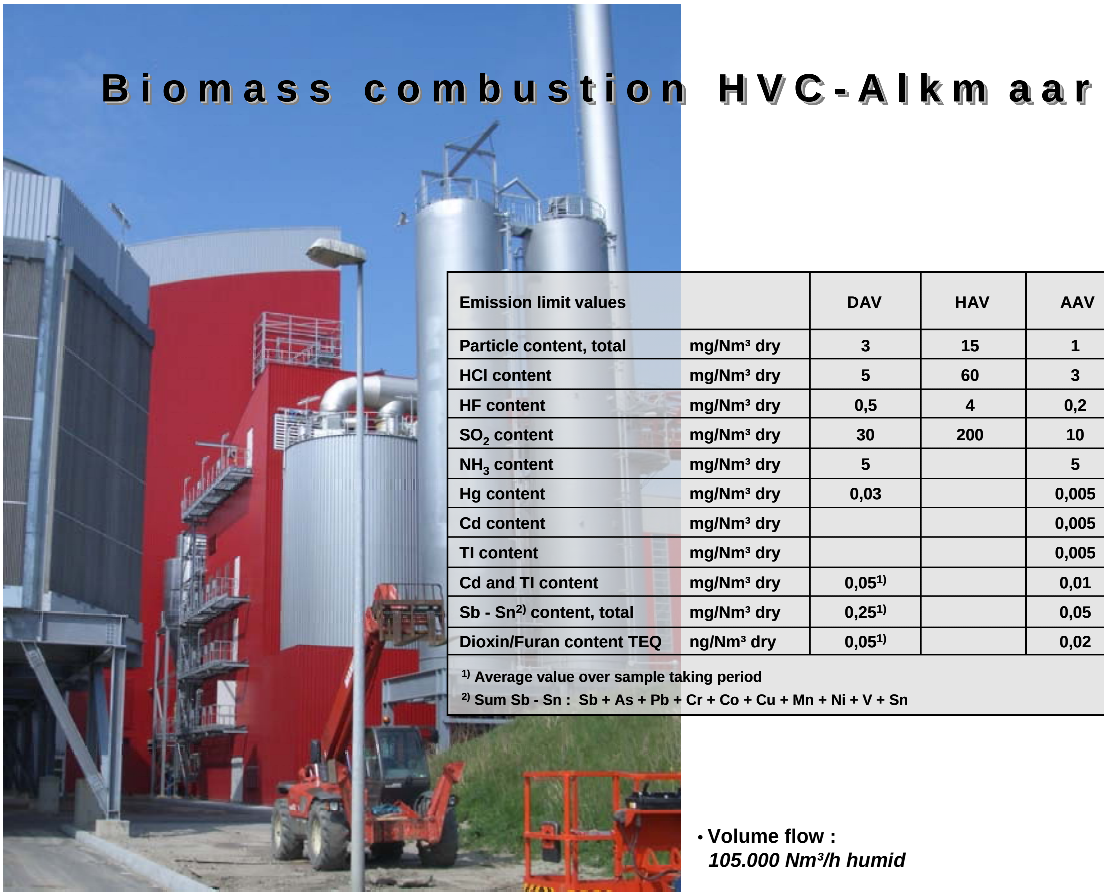
Ill. 9: Concept for the utilisation of heat of condensation

The waste water quantities arising for this application are of course considerably higher and are determined by the cooling down of gas. A use in the conditioned dry sorption is only possible for a small part. In any case, a waste water treatment has to be installed in accordance with the requirements of location. Due to the separate discharge of water from the acid stage, the use of an NH_3 stripping can in any case be omitted.

This lecture will not go into the design and the possibilities of realisation of such a waste water treatment. However, it may be mentioned that such type of plant will always be connected with comparatively high costs and expenditure.

4 Application examples for the TwinSorp process

As an example for a realised plant according to the TwinSorp process, illustration 10 shows a gas cleaning system downstream fluidised bed combustion for biomass in the Netherlands. In order to observe the requested NO_x limit value of 70 mg/m³, the boiler manufacturer installed an SNCR plant. The NH_3 slippage downstream boiler is limited to max. 15 mg/m³ Illustration 10 also shows a listing of the requested emission limit values to be observed by means of the gas cleaning system installed downstream of boiler.



Emission limit values		DAV	HAV	AAV
Particle 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	ng/Nm³ 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. 10: Gas cleaning downstream biomass combustion at HVC in Alkmaar

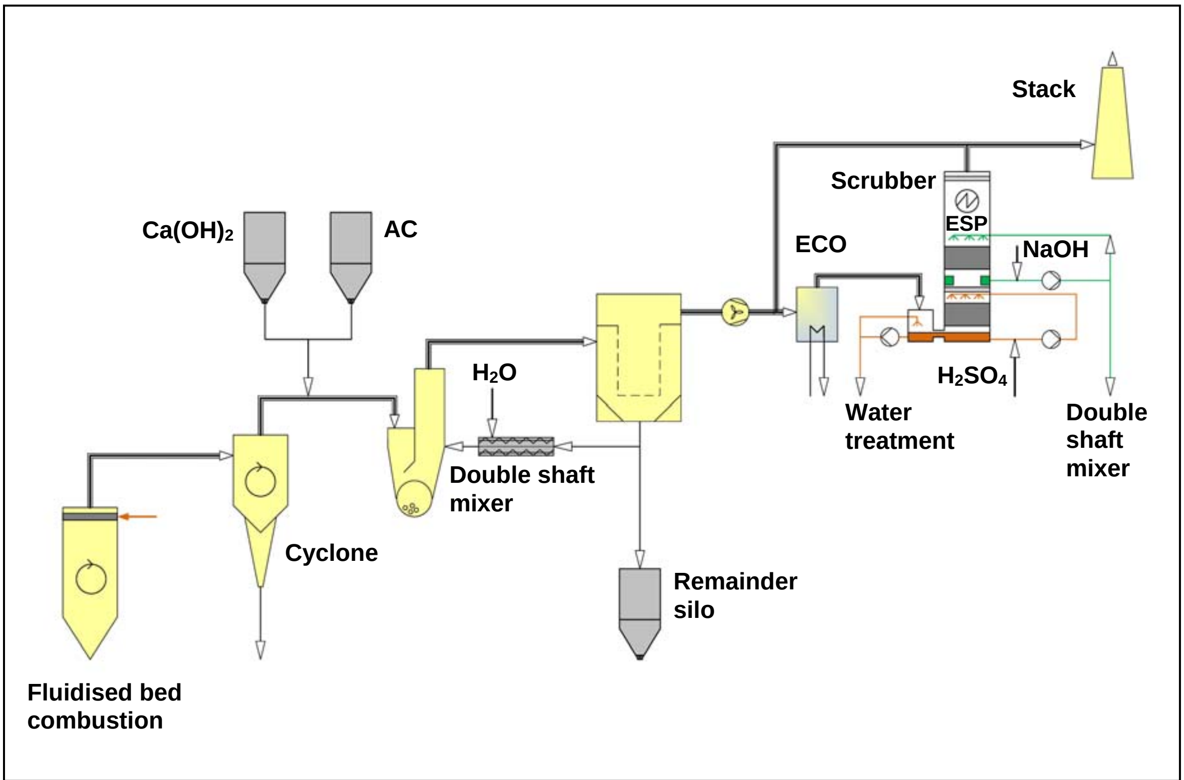
The requested, extremely low emission limit values especially for the annual average values, make clear that the gas cleaning system - besides a main stage for the observance of the emission limit values in a range of e.g. the EU Directive 200/76/EC -

has to be provided with an additional fine cleaning stage, allowing a progressing separation of nearly all requested emission limit values.

The following concept has been chosen for this gas cleaning system:

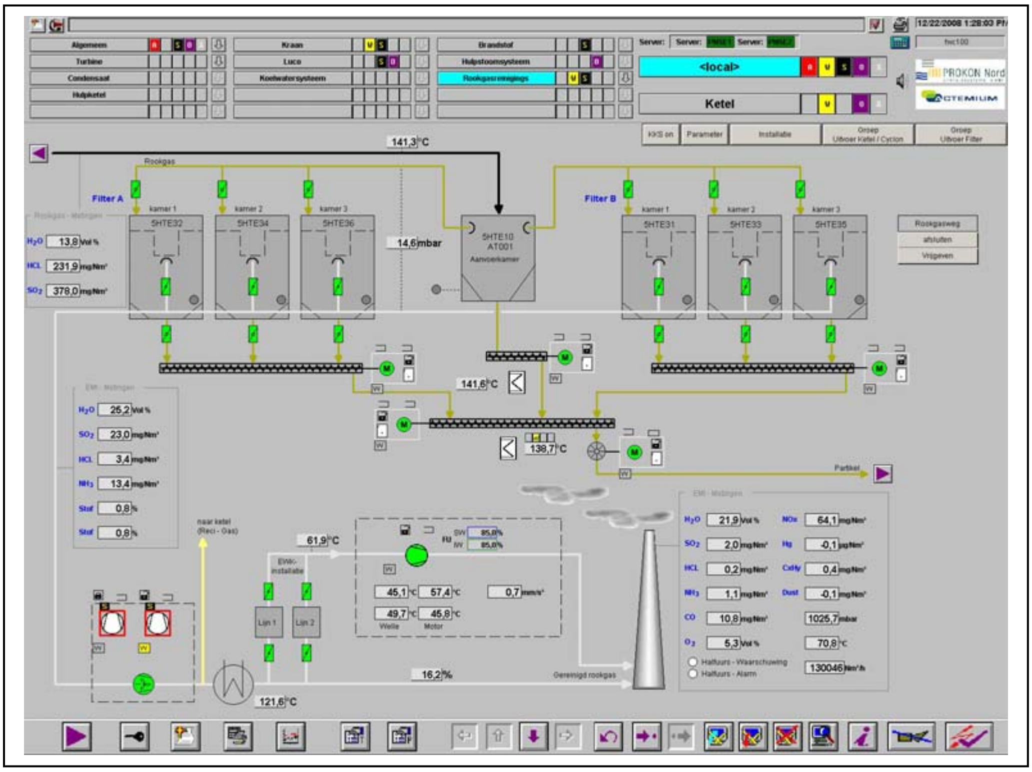
- cyclones for separate fly ash separation
- conditioned dry sorption at approx. 150°C
- heat exchanger for cooling down of gas to approx. 100°C
- wet ESP with integrated acid and basic stage

Besides an integrated NH_3 separation, this concept offers the reliable observance of extremely low emission limit values for all further components in an economical way. As a result of the requested high degrees of separation for particles and heavy metals, the wet ESP had been installed in addition instead of the second droplet separator. The design of gas cleaning system is shown in the rough scheme in illustration 11.



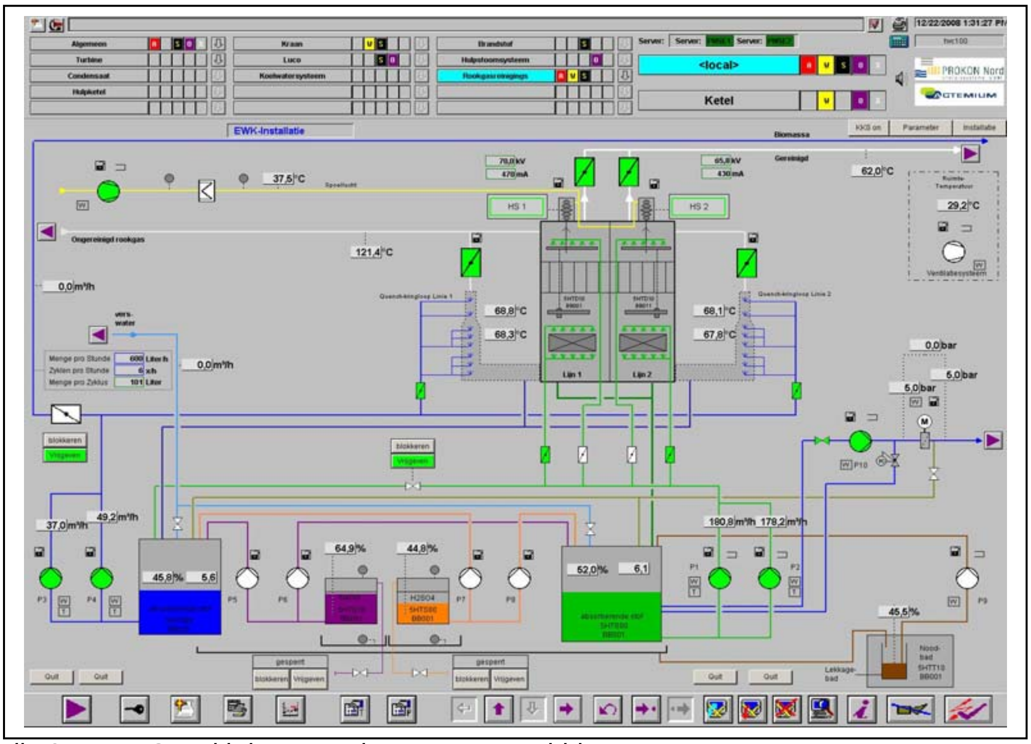
Ill. 11: Process concept for gas cleaning system at HVC Alkmaar

This plant has been in operation for more than 2 years. It allows the reliable observance of all relevant emission limit values in continuous operation without any restrictions. In this respect, illustration 12 exemplary shows continuously measured emission values at stack as instantaneous values as well as in addition for some components the concentrations in the intermediate gas downstream conditioned dry sorption and/or upstream wet fine cleaning stage.



Ill. 12: Emission values at HVC Alkmaar

The NH_3 separation takes place in the acid scrubbing stage (illustration 13) which is installed upstream wet ESP. The ph-value in this stage is adjusted to approx. 5.6.



Ill 13: Wet ESP with integrated two-stage scrubbing

To ensure a sufficient SO_2 separation, a ph-value of 6.1 has been chosen for the basic scrubbing stage.

The waste water of 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 into a central water treatment plant of location.

5 Summary of process advantages

As a result of the increasing requirements on the degrees of separation for gas cleaning systems downstream incinerators for waste and RDF, a further development and/or completion of the nowadays available, well-proven process technologies became necessary. In addition to the reliable observance of the requested emission limit values, low investment and operating costs have also to be considered, taking into account the heat distribution command.

The introduced process TwinSorp concept offers a comparatively simple, high-flexible variant, adjustable to the corresponding application. The main advantages are:

- Even in case of emission limit values definitely below 100 mg/Nm³ dry, a simple SNCR process can still be used for the NO_x separation.
- The use of reasonably priced Ca-based additive powder qualities for the separation of acid crude gas components in the main separation stage remains possible even in case of higher requirements on the NO_x reduction and without energetic disadvantages when using a catalyst.
- HCl- and/or SO_2 peaks in the off-gas downstream boiler do not have to be compensated by means of a disproportionally high additive powder injection. The reliable observance of the clean gas values is the objective of the wet stage. Resulting from this, the available additive powder quantity in the conditioned dry sorption can be reduced in total. Due to the associated low stoichiometry, savings regarding procurement and disposal costs will result.
- Flexible adjustment of process to the corresponding requirements of an application by means of variation of wet pre-scrubbing stage.
- Cost-efficient and reliable observance of low emission limit values in continuous operation.
- The process works without waste water and without a complex NH_3 stripping.
- Measures for a progressing heat distribution can be integrated.

LUEHR FILTER
Air Pollution Control Technology

Enzer Straße 26
31655 Stadthagen
GERMANY

Phone: +49 5721 708 - 200
Fax: +49 5721 708 – 154
E-Mail: info@luehr-filter.com

Internet: www.luehr-filter.com