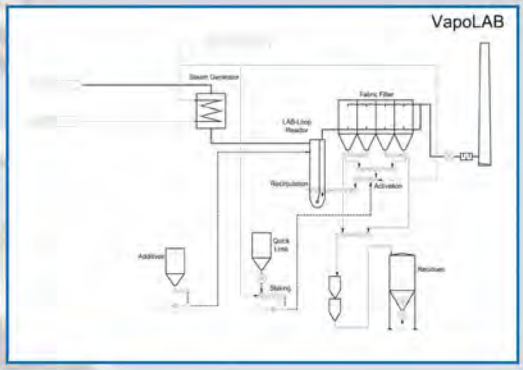
LAB.....Leader in Flue Gas Cleaning

As one of the first companies, **LAB** dedicated itself to the development of turn-key flue gas cleaning installations, in particular in the thermal waste management industry and quickly gained a good reputation due to its innovative technology and reliable components. Founded as a plant manufacturer for flue gas cleaning in 1953, the company with headquarters in Lyon, Stuttgart and La Seyne sur Mer, has been designing and manufacturing for more than 50 years components for flue gas cleaning and is in that area with over 300 reference plants one of the market leaders in Europe and worldwide. Today, **LAB** is a company of the Groupe CNIM with headquarters in Paris; in addition there are worldwide branch offices and affiliates.



LAB has a complete portfolio of own processes and offers for each individual project the relevant parameters adjusted to the most reasonable technology for the respective requirement, considering dry sorption with hydrated lime or bicarbonate as well as semi dry, wet type, multi stage or combined processes for the acid gas separation. Likewise, catalytic denitrification methods are designed and carried out. Principally, all processes are developed in our company and most of them are also patented, as, for example, the new **VapoLAB** process which significantly increases once more the performance, profitability and energy efficiency of dry sorption technology.

Our range of products and services comprises conception, designing and realisation of plants for flue gas cleaning of domestic waste incineration plants and for the desulphurization of power plants as well as service, maintenance and repair.

LAB offers you from one single source qualified counselling, designing of individual components of flue gas cleaning, turn-key delivery and assembly, commissioning, documentation according to your instructions and training for your future operating staff.

An excerpt from **LAB**'s current references:

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GROUPE CNIM

Variations of Flue Gas Cleaning Systems in Waste to Energy Plants

Christian Fuchs

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1. Motivation

This is a presentation and comparism of the available technologies to clean flue gas from incineration of waste or RDF.

All of these technologies have been developed, installed and tested during the recent years in Germany and Europe and have proven to be reliable and efficient in most cases. All fulfill the legal emission standards of today.

Nevertheless, there are differences: Some systems are more efficient, some are more economic, some treat particular pollutants better than other pollutants etc.

We want to describe the different Flue Gas Cleaning technologies available nowadays with the benefits they offer, but also show possible limitations in their application.

It is not target of this presentation to make detailed recommendations to define the best technology. To our understanding all mentioned technologies are reasonable under certain conditions.

It is our target to promote the understanding that every individual project requires a very careful analysis of all circumstances and conditions to be able to select the best technology for this individual project.

2. Available Flue Gas Cleaning Technologies

In this presentation we will concentrate on the cleaning of Acid Gas Components like SO_x, HCl and HF of the flue gas only. Other pollutants like Heavy Metals, Dioxins/Furans or NO_x require different technologies, which have to be combined with the Acid Gas Cleaning or which have to be added as an additional cleaning stage.

Acid Gas Components are treated usually by adding caustic sorbents to the gas flow. There is a principal difference in Cleaning Technologies for Flue Gas differentiated into dry, semidry or wet procedures. In between is a significant number of *Hybrid*-Technologies, which combine these procedures to multistage cleaning systems. Multistage cleaning combines advantages of individual technologies to achieve an improved efficiency or economy.

As reactive sorbents available are different depending on the cleaning process:

- Dry systems use either hydrated lime or sodium bicarbonate (actually sodium hydrogen carbonate)
- Semidry systems use quicklime
- Wet systems use caustic soda, quicklime or limestone

3. Description of the different Technologies

3.1. The Dry Sorption Process

The Dry Sorption Process based on hydrated lime has the architecture as described below (following the flue gas flow):

- Optional an Evaporation Cooler for the required conditioning of the flue gas to reach the required reaction temperature and to increase the humidity of the gas or alternatively a heat exchanger package to cool down the gas as required and thereby produce a significant amount of low pressure steam, which may be utilized (VapoLAB Technology)
- A Reactor to intensively mix sorbents and gas
- A Fabric Filter to separate fly ash and sorbents from the flue gas flow
- Optional Recirculation of the filter residues to enhance efficiency of the system
- The ventilator to convey the flue gas from incineration to the stack
- The Stack
- Peripheral Installations to support the process like storage and preparation of the sorbents, residues storage, compressed air preparation

To treat acid components of flue gas additives as hydrated lime of sodium bicarbonate are injected into the flue gas and are thoroughly mixed by means of static or mechanical mixing devices, depending on the manufacturers technology. The efficiency of the reaction of sorbents with acid gas is strongly dependent of contact duration, sorbent distribution in the gas flow, reaction temperature and humidity. This is the reason why all variations of the Dry Sorption Technology aim to optimize above mentioned conditions as much as possible.

An Evaporation Cooler is adjusting the temperature to the optimum for the reaction of hydrated lime, which is approx. 140 °C and represents the best compromise between efficiency and safe distance to the acid dew point, which varies depending on the HCl content of the gas.

As a secondary effect the relative humidity of the flue gas is increased by evaporation of water, which also has a very positive effect on the efficiency of the process. The presence of water (e.g. steam) is essential for the chemical reaction of acid gas with hydrated lime.

Alternatively the flue gas may be cooled down to the reaction temperature using a heat exchanger to recover additional energy from the incineration to achieve a better thermal efficiency of the complete incineration system. The produced steam may be used in the boiler circuit, as city heating or utilized in the VapoLAB process, which is described later.

The influence of reaction time and particle distribution of additives in the flue gas is self-explaining. To reach better efficiencies there are various components used between injection of additives and the filter, which are Static Mixers, Turbulence Generators and mechanical Reactors.

Recirculation of the fly ash and reaction salts captured in the fabric filter has a major effect on the efficiency of the Dry Sorption Process. Not all injected sorbent had a chance to react in the time between its injection and the separation in the fabric filter. A certain amount of unused, still reactive sorbent is present in the filter ash. This unused amount of hydrated lime, in relation with the injected amount gives the stoichiometric ratio of the process. If all injected hydrated lime has reacted and there is no free lime in the residue, the stoichiometric ratio is 1. For dry systems the ratio is usually between 2 and 3, depending on whether there is recirculation or not and whether there is additional humidification (water injection) of the residues while recirculating or not. To our experience the best stoichiometric ratio can be achieved by steam injection to the residues while recirculating, which has been measured with approx. 1,4.

Recirculation also has an additional positive effect: Acid gas concentration resulting from a waste or RDF- incineration never is homogenous; there are always high concentration peaks possible. Recirculating offers the benefit that the sheer mass of active sorbents in the flue gas flow is increased by factors – therefore the stability of such a system against peaks is by far higher than without recirculation.

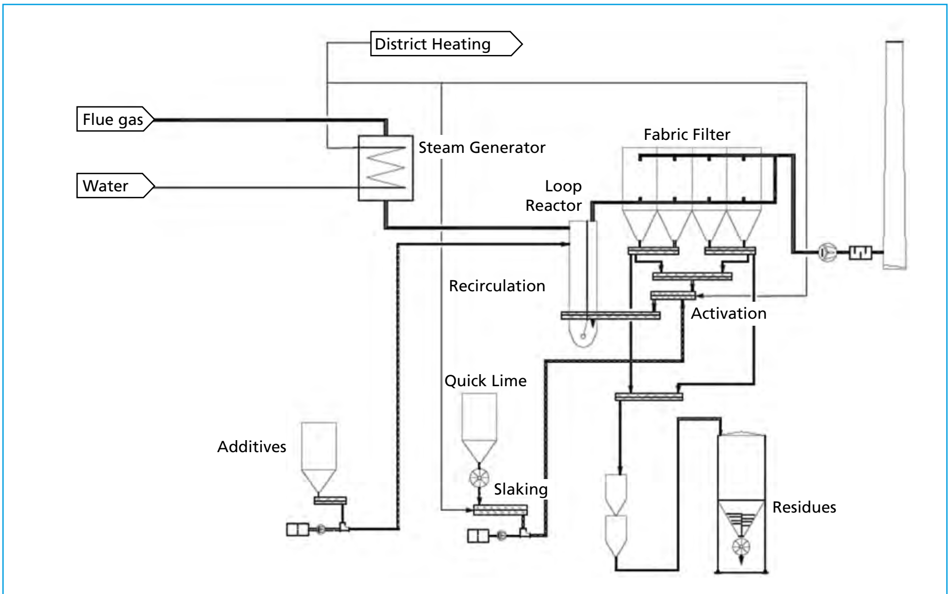


Figure 1: Process Diagram Dry Sorption, here: VapoLAB

In particular applications the use of sodium bicarbonate instead of hydrated lime as a sorbents may also be also advisable.

Here is also in most cases, in particular in existing incineration plants, a cooling system required to achieve a reaction temperature of approx. 170° to 180°. This requirement is not resulting from the use of sodium bicarbonate, but of other system requirements like the additional use of activated carbon, which limits the temperature to approx. 200 °C.

Sodium Bicarbonate is highly reactive, but requires in situ grinding of the granules to a very fine powder to achieve this high reactivity. Therefore grinding stations consisting of two or three special mills to be able to treat peaks and always have one mill available as being redundant for regular cleaning or unplanned downtimes.

When injecting the freshly ground powder into the hot flue gas actually the sodium bicarbonate is created out of sodium hydrogen carbonate by losing water. This explains that this technology produces less residues than the comparable process with hydrated lime.

3.2. The Semidry Process

The Semidry Process uses quicklime as sorbent, which is cheaper than the hydrated lime and also offer additional 30 % reactive material, because it does not contain water. The slaking may happen locally in an offline process to prepare lime milk, consisting of slaked lime and water.

The Semidry Sorption Process based on quicklime has the architecture as described below (following the flue gas flow):

- A Spray Drier Absorber to condition the flue gas to the optimum reaction temperature of approx. 140 °C and simultaneously inject lime milk to reduce the acid components of the flue gas in a first stage
- A Reactor to intensively mix sorbents and gas and add additional sorbents like PAC (pulverized activated carbon) and hydrated lime to reduce acid components in a second stage
- A Fabric Filter to separate fly ash and sorbents from the flue gas flow
- Optional Recirculation of the filter residues to enhance efficiency of the system
- The ventilator to convey the flue gas from incineration to the stack
- The Stack
- Peripheral Installations to support the process like storage and preparation of the sorbents, residues storage, compressed air preparation

All conditions for the reaction already described in the chapter *Dry Sorption* are fully valid for the Semidry Sorption as well. These conditions are residence time, temperature, humidity and recirculation.

The main difference between Dry Sorption and Semidry Sorption is the sorbent being a suspension instead of a powder, which evaporates by increasing the humidity of the flue gas. By evaporating the gas humidity at the particles is increased extremely. Molecular movements of acid gas to prepare the reaction with lime are enhanced in these conditions, reaction in particular with HF and HCl are improved. When completely dried the sorbents still reacts with acid components in a normal Dry Sorption. Generally Semidry Systems are more effective as Dry Systems because they have one additional reactor to allow for higher inlet concentrations of acid components.

Dimensioning of the Absorber allows for a complete drying of the suspension to form dry particles. Usually this is achieved with a residence time of approx. 20 seconds, which also is additional reaction time available.

The Absorber usually is operated at approx. 140 °C to ensure the safe distance to the acid dew point.

Volatile Heavy Metals and Dioxins/Furans are captured efficiently both at Dry and Semidry Systems by injecting PAC.

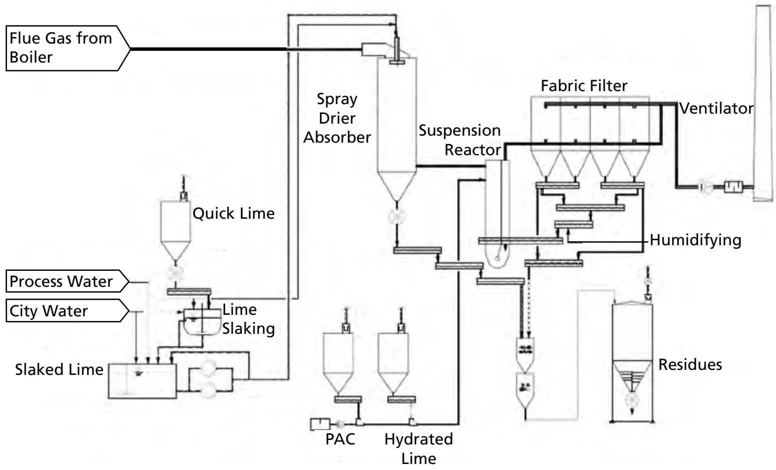


Figure 2: Process Diagram Semidry Sorption (SemiSecoLAB)

3.3. The Wet Process

The Wet Process uses quicklime, caustic soda or limestone as sorbent, depending on the application. Incinerations for waste and RDF usually operate with quicklime, since this re-agent is a good compromise between performance, additional effort to prepare the sorbent and price. Incinerations for hazardous waste or sewage sludge use caustic soda, because these plants require a high performance and they are usually quite small, which means the consumption of costly caustic soda is low. Power plants, which consume tons of sorbent per hour for desulphurization, use limestone only, because this is widely available at low costs.

The Wet Process has the architecture as described below (following the flue gas flow):

- Optional dust separation with Electrostatic Precipitation
- A Spray Drier to evaporate the reaction salt suspension of the scrubber bleed
- A Fabric Filter
- A Quench to condition the flue gas to saturation temperature, usually integrated in the Scrubber
- The first Scrubber, mainly operating to treat strong acid gas like HF and HCl
- Droplet Separators

- The second Scrubber, mainly operating to treat SO_2
- Droplet Separators
- Optional the Electrodynamic Venturi (EDV) to minimize the droplets passing the system
- The ventilator to convey the flue gas from incineration to the stack
- The Stack
- Peripheral Installations to support the process like storage and preparation of the sorbents, residue preparation, residues storage, compressed air preparation. In particular residue handling is involving extensive treatments like evaporation of scrubber bleed or waste water treatment
- Optional a Gas/Gas Heat Exchanger or a Heat Transfer System

The flue gas entering the flue gas cleaning installation are usually quenched to saturation temperature (approx. 60 °C) subsequent to a dedusting facility like an Electrostatic Precipitator or, in case the reaction salts are evaporated, a Spray Drier and a Fabric Filter.

The first Scrubber treats halogen acids and SO_3, and is operated at a low pH-value. The Droplet Separator ensures a hydraulic separation between the two Scrubbers. The second Scrubber is operated at a relatively neutral pH value to mainly catch SO_2. Finally follows a second Droplet Separator and, if required to reach very low particulate emissions, an additional EDV to minimize the droplets going to the Ventilator and Stack.

Both Scrubbers are controlled by monitoring and maintaining the pH value, if the value is decreasing, the continuous bleed is increased.

The bleed is either evaporated in a Spray Drier as part of the Flue Gas Cleaning installation or in an Evaporation Tower, which is extremely energy consuming. Alternatively a waste water treatment is possible with neutralization, separation of Heavy Metals and Mercury involving numerous pumps, pipings, measurements and vessels as well as a separate control system.

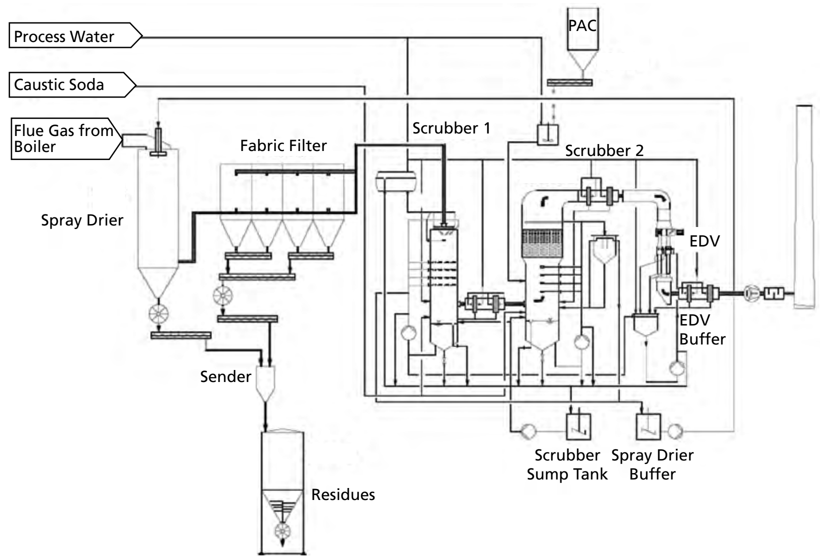


Figure 3: Process Diagram Wet Process

Separation of Heavy Metals, Mercury and Dioxins/Furans can be integrated in the scrubbing process and does not require additional process steps, just storage and injecting of an additional adsorbents, mainly PAC.

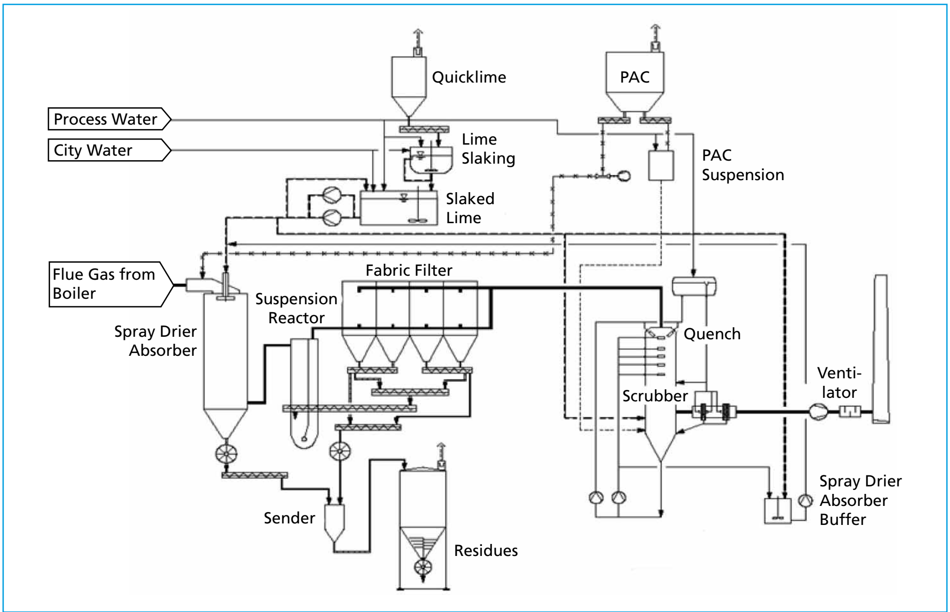
The Wet Process offers the benefit of a nearly complete chemical reaction of acid gas components and sorbents, stoichiometric ratio is nearly 1,0. This offers the most economic use of sorbents and also produces the minimum possible amount of residues.

3.4. The Hybrid Process

The Hybrid Process is mainly a combination of above technologies. Here we describe as an example the combination of Semidry and Wet Process.

This particular Hybrid Process has the architecture as described below (following the flue gas flow):

- A Spray Drier Absorber to condition the flue gas to the optimum reaction temperature of approx. 140 °C and simultaneously inject lime milk to reduce the acid components of the flue gas in a first stage. Also the Scrubber bleed is evaporated here
- Optional a Reactor to intensively mix sorbents and gas and add additional sorbents like PAC (pulverized activated carbon) and hydrated lime to reduce acid components in a second stage
- A Fabric Filter to separate fly ash and sorbents from the flue gas flow
- Optional Recirculation of the filter residues to enhance efficiency of the system
- A Quench to condition the flue gas to saturation temperature, usually integrated in the Scrubber
- The Scrubber as a third cleaning stage



Figue 4: Process Diagram Hybrid Process

- Droplet Separators
- The ventilator to convey the flue gas from incineration to the stack
- The Stack
- Peripheral Installations to support the process like storage and preparation of the sorbents, residue preparation, residues storage, compressed air preparation. In particular residue handling is involving extensive treatments like neutralization and evaporation of scrubber bleed

This particular Hybrid Process combines two powerful technologies to ensure very low emissions or to treat high concentrations of acid gas components.

Combining the powerful Semidry Process and the efficient Scrubber forms an economic compromise of high performance characteristics at economic operating costs.

4. Criteria to select Flue Gas Cleaning Technologies

Comparing and selecting Flue Gas Cleaning Technologies can only be complete under consideration of many conditions, which may be different at all possible locations. Principally every installation will be different, which explains also the variety of each technology.

For example, an existing installation with grown infrastructure, limited space available and an existing permit describing certain emissions will surely build different compared with a new installation on green field, which is under planning only. Also availability, investment costs and operating costs as well as residues have to be considered.

4.1. Technical Criteria

Performance

The different technologies differ in the performance to catch acid gas components.

Technically the simplest system, the Dry Sorption Process, is dedicated to moderate crude gas conditions, like biomass incineration, waste wood etc. Other applications like for household waste are also possible under certain conditions, e.g. low concentration of acid gas components, no peaks and, which is very important, emission limits not lower than the limits fixed by the Waste Incineration Directive.

Using certain high surface qualities of hydrated lime or sodium bicarbonate enhances the performance or reduces the consumption of sorbent. Most efficient here is sodium bicarbonate.

The Semidry System is capable of a higher performance due to longer residence time of sorbent in the flue gas and of high local humidity at the particles. Therefore the Semidry System recommends itself for high crude gas concentrations or emissions lower than the requirements of the Waste Incineration Directive.

In case of very high concentrations of acid gas components or uneven fuel resulting in many peaks, but also in case the emission limits are very low the preferred Flue Gas Cleaning Technology is the wet scrubbing process, which is, correctly designed, very stable against variations of flue gas flow and concentrations.

The Hybrid process as described before is a compromise with a performance between the Semidry System and the Wet Scrubbing Process.

Additives

The operation of a Flue Gas Cleaning System requires many different resources like water and various sorption additives. The range of Flue Gas Cleaning Technologies have different characteristics in specific consumption.

Dry Sorption Technologies use lime (hydrated lime with standard surface or high surface) or sodium bicarbonate to treat acid gas components. The lowest costs has the standard hydrate, but has the highest consumption. Lower consumption at a higher price has high surface hydrate, even more expensive is sodium bicarbonate. In this comparism standard hydrate is best.

The Semidry Process uses quicklime as sorbent, which is cheaper than the other lime products or sodium bicarbonate and therefore is the first choice for an additive.

The Wet Scrubbing Process uses limestone, quicklime or caustic soda as sorbent. Comparing these limestone is by far the cheapest additive, but has the lowest reactivity and also requires extensive preparation facilities, that it is virtually only used in Power Plants, where extremely high consumption puts the focus on additive costs. All other incineration plants use either quicklime or caustic soda. Since the consumption of additives at the wet technology is nearly stoichiometric, there can only be the price deciding element: Quicklime is by far cheaper than caustic soda.

All processes use more or less of the different additives to operate within the regulations of the Waste Incineration Directive. All of them use more than the minimum required amount according to the molar reaction.

Most efficient is the correctly designed Wet Scrubbing Process, which has a stoichiometric ratio of approx. 1,02 – 1,1. Here the minimum consumption of additive is realized. The Hybrid Process and the Semidry Process with a ratio of approx. 1,9 – 2,1 are both powerful and economic.

The Dry Sorption Process based on hydrated lime has a range of ratios between 1,9 up to 3,0, depending on the type of lime hydrat and the type of incineration. Using sodium bicarbonate reaches a ratio between 1,1 and 1,3. The new VapoLAB process offers the lowest consumption of lime hydrate at a stoichiometric ratio of approx. 1,4.

Residues

The stoichiometric ratio not only indicates the consumption of the individual additive, it logically has the same influence on the amount of residues.

Here again the Wet Process with the lowest consumption of additives has the lowest amount of residues.

Hybrid and Semidry Process offer reasonable residue amount, only the Dry Sorption Process creates a significant amount of residues at a stoichiometric ratio of up to 3,0. Exceptions are the VapoLAB process at a ratio of 1,4 and the sodium bicarbonate at a ratio of 1,1 to 1,3

Required space

In particular when upgrading existing installations with a new Flue Gas Cleaning Technology an important criterion is the required space to install the different components of that system. Also important is that the new installation shall not hinder the ongoing operation of the plant.

This criteria is won by the Dry Systems. The required components are relatively small, the number of components is limited, installation is comparably fast.

The other systems, be it wet or semidry, use components with larger dimensions and also several cleaning stages, so the amount of components to be installed is larger. Therefore the installation also takes longer.

Nevertheless, normally a solution is possible for any technology, if other criteria show advantages for this technology.

Availability

The most important criterion to assess the suitability of the different variants of Flue Gas Cleaning Technologies is the availability reached in real life operation.

Her clearly has to be stated, all different technologies can reach availabilities of more than 95 %, always under the condition of correct design and qualified maintenance.

Out of the experience of the recent years Wet Technology has advantages in availability, the reason may be given in less components for dry residue handling.

Maintenance

Deciding arguments for a Flue Gas Cleaning Technology are the annual expenses on costs and personnel for maintenance.

Principally it is true that the more components or the more the Flue Gas Cleaning System is complex the more is the effort for maintenance in frequency, duration, personnel and spare parts. Complex systems, which involve a high invest also are more consuming in maintenance.

On the contrary dry residue handling shows a tendency to require more attention in daily operation and in maintenance, so this effect is disadvantageous for the *simple* Dry Systems.

When correctly designed and installed, Dry Sorption Systems require in comparism a relatively low maintenance effort, both in personnel and in frequency/duration. Semidry and Hybrid Systems have a disadvantage here because of the complexity of the systems. The same is applicable for Wet Sorption Systems, but here we notice a slight benefit from the limited number of dry residue handling components.

Overall the Dry Sorption Systems require minimized maintenance in this comparism.

4.2. Commercial criteria

Investment

Unfortunately in the recent years investment cost have gained in importance for decisions for a certain Flue Gas Cleaning Technology.

A thorough evaluation of the relevant technical criteria, in particular consumption of additives, amount of residues and maintenance costs and an economic calculation for the next operation years show the small influence of the investment on the overall costs. The longer the depreciation period, the smaller is the impact of the invest to the overall cost and the stronger the influence of operating costs, availability, maintenance costs etc.

Simple Dry Sorption Systems have a very short process line, the only require storage and dosing of additives and conveying and storage of residues. From the invest point of view they are most advantageous.

A compromise again are the Semidry and the Hybrid Process. They are 10 % to 30 % more expensive compared with the Dry Sorption Process, depending on the additional peripheral components like lime slaking etc.

A multistage Wet Sorption Process is most expensive in this comparism, here mainly because of the extensive waste water treatment.

Operating costs

The operating costs follow the conversely order compared with the invest. Considering only cost of additives and cost of residue disposal clearly prefer the Wet Technology. Taking into account also maintenance frequency, duration and costs this technology still is advantageous.

Semidry and Hybrid Technology, due the higher stoichiometric ratio, have higher additive and residue disposal costs. Also maintenance costs are comparably high due to numerous components.

The Dry Sorption Process has the highest operation costs considering the additives, but makes ground when it comes to maintenance. The limited number of components require only minimum maintenance effort. In particular the VapoLAB process with the excellent stoichiometric ratio of approx. 1,4 has comparably low additive and residue costs , but still being a Dry Sorption Process with only limited components offering minimum maintenance requirements.

Size

Size matters. When planning and realizing a Flue Gas Cleaning System there is a division of scopes of services and supply. There is engineering, permission planning, supervision installation and commissioning and material cost.

Out of these different cost factors only a few vary with the size of the installation. Only material cost are directly influenced by the magnitude of the plant. Here is a linear dependency. But when it comes to installation, the same scope to be installed, only the components handled are bigger, there is a decreasing disproportionality. Engineering, permission planning and commissioning costs are identical, being it a big or a small installation.

The bigger the Flue Gas Cleaning installation, the more economical the price can be calculated.

5. Conclusion

The range of available Flue Gas Cleaning Systems spreads from *simple* systems like the Dry Sorption to complex multistage Wet Scrubbing Systems, which even may be combined to form Hybrides to fulfill very particular economic or technical conditions. Within the spectrum in principle every requirement can be fulfilled.

Before each planning has to be made an assessment with all relevant criteria for this particular project. This is the only way to choose the most advantageous technology for this project.

Taking into account only the invest or the additive consumption leaves too much room for uncertain assumptions concerning *weak* criteria, which may have an influence to the project. Just have in mind the acceptance of the population in the neighborhood and what harm a citizen initiative may do to a project during realization, if for example certain access roads are not possible due to the arrangement of components of the Flue Gas Cleaning System.

Within the comparism of the different systems the Dry Sorption Systems have gained in importance. They are attractive in invest cost, the performance has increased dramatically during the recent years and the process is economic with costly additives.