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COMPARISON OF ACID GAS CONTROL TECHNOLOGIES IN EFW FACILITIES

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ABSTRACT

As Energy-from-Waste (EfW) facilities make the leap into the twenty-first (21^{st}) century, so does the demand for cost efficient air pollution control technology. In an effort to meet this rising demand, companies have to develop concepts that remove acid gases in an efficient, sustainable, and reliable way. The current market trend to provide the best available control technology (BACT) leads people searching for technologies that are:

- Proven and have extensive records of success
- Highly efficient, resulting in low emission to the atmosphere, but requiring minimal investment
- Compact in design, simple, and low maintenance
- Offering high availability, low reagent consumption, and low residue levels.
- Resulting in either clean or suppressed liquid effluents.

This paper will specifically discuss the three main types of acid gas control technologies available in today's marketplace, which include dry, semi-dry, and wet scrubbers. It will first focus on the acid gas control technology most commonly used in the US, the spray dryer absorber, followed by a typical Ring Jet® wet scrubber with packed bed, and finally, the Turbosorp® system. For each of the above technologies, this paper will present the concepts, advantages and disadvantages, achievable emissions, and capital and operating costs. It will then look at how each of these technologies is utilized at existing EfW facilities operating throughout the world and provide information on how each facility has been operating. Lastly, it will look towards the future of acid gas control technologies and provide insight into what advances are being made to meet the most stringent air emission regulation all over the world.

INTRODUCTION

As the new regulations governing incineration of Municipal Solid Waste (MSW) in Energy-from-Waste (EfW) or Waste-to-Energy (WtE) facilities, as they are more commonly known, come into effect, the industry is trying to find ways to meet and exceed these regulations. One of the areas where the regulations have continued to tighten is stack emissions. Since the early-1980s, emission limits have continually become more stringent making the EfW industry one of the most highly regulated. If the existing and/or new facilities are going to either maintain or obtain their air permits, then considerable investments must be made into existing air pollution control technologies and developing new technologies.

The evolution of these ever tightening restrictions started with particulate and now includes nitrogen oxides and acid gases. This constant industry trend has led to the concept of having the best available control technology (BACT), because once a single plant installs a revolutionary system, then all the remaining facilities will have to install equipment to meet those new levels. This new philosophy, therefore, has caused competing companies to constantly improve the BACT levels, thereby eliminating their competition. This also has led to a situation where multiple control technologies have become available, each claiming to be more cost efficient.

This paper focuses on technologies that have been developed over the last few years to meet the ever increasing demand for lower acid gas emissions. It will also compare control technologies that have been available in the United States (US) for the last twenty plus (20+) years with those currently used in the European Union (EU). First, we will review the different concepts regarding the control of acid gas emissions through dry, semi-dry, or wet systems. Then we will review some of the products commercially proven in today's market place, such as the Spray Dryer Absorber (SDA), the Ring Jet® scrubber, and the Turbosorp® system. For each of these products we will provide the distinct advantages/disadvantages, achievable emissions, and capital and operating cost information.

This paper will then shift its focus towards the real world and take a look at some of the facilities that are operating throughout the world. In particular, we will focus on the AVS Zorbau plant located in Zorbau, Germany, the TRIDEL Lausanne plant located in Lausanne, Switzerland, and the

TREA Breisgau plant located in Breisgau, Germany. We will examine each of these plants' process train and determine what actual emissions we are able to achieve. Finally, we will have a look at where these types of technologies could be headed in the future. Since it is common belief that these emission standards will only become more stringent, companies develop innovative solutions, and conduct pilot tests all over the world trying to prove their technologies, such as the optimized wet scrubber, the optimized dry injection system with NO_x control, and putting multiple control systems in series.

ACID GAS CONTROL TECHNOLOGIES

Dry Acid Gas Control Technologies

The dry scrubber is any scrubber which uses zero water and creates zero waste water discharge. These systems are not commonly used on EfW facilities around the world, but are preferred for coal incinerators. The concept is that powdered additives, such as lime or sodium bicarbonate, often together with activated carbon or lignite coke, are injected into either a reactor or ductwork. The additives and flue gases mix and a reaction will occur between the acid gases and additives. Usually, the flue gas is then sent to a fabric filter where the remaining dust and additives with reacted pollutants are removed by getting trapped on the bag while the cleaned flue gases pass through.

Semi-dry Acid Gas Control Technologies

The semi-dry scrubber is any scrubber which uses water but does not create any waste water discharge. These systems are commonly used in EfW facilities around the world and are probably the most prevalent. However, there are two distinctly different types of semi-dry technologies: injection using slurry (commonly used in the US) and injection using powdered additives (commonly used in the EU).

The concept behind the slurry injection (US preference) is that a powdered additive, such as lime, is mixed with water to form a slurry mixture. The diluted slurry mixture is then injected into the reactor where it mixes with the flue gases. Once the water has been evaporated from the slurry mixture, a reaction will occur between the acid gases and additives. Usually the flue gas is then sent to a fabric filter (at this point activated carbon or lignite coke can be injected into the system) where the remaining dust, additives, and reacted pollutants are removed by getting trapped on the bag while the cleaned flue gases pass through.

On the other hand, the EU prefers using a system which injects powdered additives, such as hydrated lime, often together with activated carbon or lignite coke, directly into the reaction chamber with the flue gases. In the reactor, the additives and flue gases are mixed with water (for temperature control) and re-circulated fabric filter residues (for pressure control). The combination of these injections promotes the uniform mixing of the additives and flue gas, which react while the water is evaporating. The flue gas is then usually sent to a fabric filter where the remaining additive and pollutants are removed by getting trapped on the bag while the clean flue gas passes through.

Wet Acid Gas Control Technologies

The wet scrubber is any scrubber which typically uses liquids, such as water, lime slurry, and/or caustic soda solution to remove particulate and acid gases. These systems were commonly used on EfW facilities around the world, but are now typically not selected in the US or EU due to the effluent stream created from the process (however, they are still in use in EU installations). The concept is that liquid solutions are mixed with the flue gas at different stages in the tower. The water controls both the flue gas temperature and removal of particulate, while the lime slurry and/or caustic solution control the acid gases. Typically the exit temperature from a wet scrubber is much lower than either a dry or semi-dry system, which, therefore, causes a reduction in the condensable particulate and creates a visible stack plume.

SPRAY DRYER ABSORBER (SDA)

Concepts

The SDA is a semi-dry scrubber that deals with the raw flue gases from waste incineration by means of a specially designed reactor followed by a fabric filter. This technology uses as basis the creation a mist from a slurry mixture which cools the flue gases and then reacts with the acid gases. There are two different types of technologies in the market place right now: rotary atomizer and dual fluid nozzles; however, the majority of the equipment and process is still the same in either case.

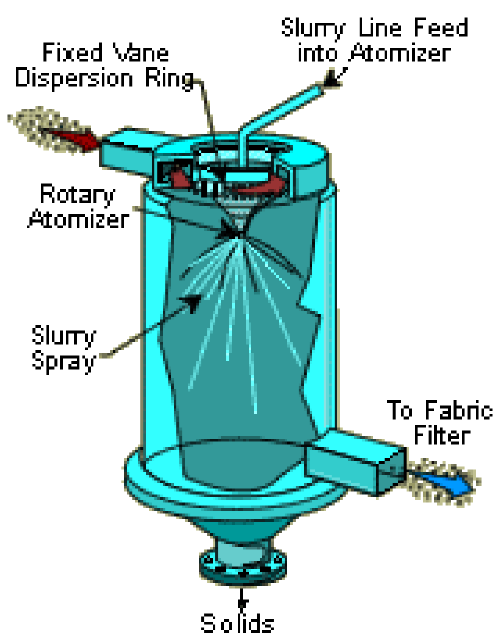

Figure 1 - Typical Rotary Atomizer Arrangement (US Environmental Protection Agency, 2010)

The SDA process is based on the raw flue gases from incineration being directly ducted to either the top or bottom of the vessel. As the flue gas moves through the system, it is mixed with the diluted slurry mist. The water portion of the slurry evaporates and decreases the temperature to between two hundred and ninety (290) and three hundred and ten (310) degrees Fahrenheit, which activates the additives for reaction with the acid gases. As the flue gas exits the reactor and enters the fabric filter, the additives and pollutants form a product that is captured on the bags while the cleaned flue gas exits the system and can be released to the atmosphere through the use of an induced draft fan and stack. Once the residues are trapped on the bag, they can be removed from the system and disposed of properly. The standard SDA consists of three (3) main pieces of equipment: the reactor, the fabric filter, and the rotary atomizer or dual fluid nozzle.

The reactor is a vertically oriented vessel typically constructed of carbon steel. The flue gas enters the bottom or top of the reactor, resides inside the reactor for around ten (10) to twelve (12) seconds and then exits through an opening on the opposite side of the reactor. The diluted slurry mixture is added at the flue gas entrance to provide maximum contact time for the reaction to occur. The amount of slurry injected into the system is dictated by the flue gas's sulfur dioxide level as measured by the downstream continuous emissions monitor system (CEMS), and the amount of water, which is mixed with the slurry, is dictated by the flue gas temperature.

The fabric filter for the SDA is similar to any other fabric filter used in an EfW facility. The fabric filter should be of a modular design with either a reverse air or pulse jet type cleaning system based on the facility's preference. The air to cloth ratio should be in the range of 3.0 to 4.0 $[ft^3/min]/[ft^2]$ and the bags can be any standard material which can resist the boiler exit temperature in case of failure of the diluted slurry spray. The fabric filter hoppers should be equipped with either a rotary or a double dump valve, isolation gates, vibrators, and hopper heaters. Lastly, a standard mechanical and/or pneumatic conveying system can handle the transportation of fly ash from the discharge of the fabric filter hoppers to the storage location.

The rotary atomizer type of SDA uses a mechanical disc to create the mist inside the reactor vessel. This mechanical disc is rotated by either the flue gas when it enters into the reaction chamber or is motor driven. As the disc spins, the diluted slurry mixture is dropped onto the disc and is pushed outwards and downwards to create the mist. The disc must be rotating quickly enough to create a fine enough mist for the water to evaporate. This is different from the dual fluid nozzle type of spray dryer, which uses a nozzle with compressed air to atomize the diluted slurry mixture into a mist. As the mixture is conveyed into the reaction vessel, it merges into a nozzle which uses compressed air and diluted slurry mixture to create the mist. The compressed air pressure and flow must be high enough to create a sufficienty fine mist for the water to evaporate.

Advantages/Disadvantages

There are three (3) main advantages to this type of system: the high reliability, the zero waste water discharge, and the proven track record. The SDA offers high reliability and availability for all the different loads because it controls many different variables. In addition, the minimal amount of moving/rotating mechanical parts also contributes to the minimization of operation and maintenance costs. Another main advantage is that the system does not create any waste water discharge; therefore eliminating the need to have any on site water treatment. Finally, the SDA is historically the most common technology in use today, so it has a proven track record on multiple EfW facilities throughout the US and EU.

There are three (3) main disadvantages to this type of system: the lime slurry mixture, the residues, and the wet bottom. The lime slurry mixture is difficult to deal with and causes multiple problems, such as clogs in lines due to poor slurry mixing, it is messy, and nozzles, hoses, valves, instruments, etc... have to be cleaned and/or replaced constantly. Another disadvantage is that the residues from a SDA tend to be difficult to transport, store, etc… The final, well documented disadvantage of the SDA is the formation of wet bottoms because the exit temperature is too low. If the system is unable to hold an exit temperature, then wet bottoms can form, which have to be manually unclogged.

Achievable Emissions

As mentioned above, one of the main advantages to the SDA is the high reliability for various load cases; therefore under all loads within the firing diagram, a SDA can typically achieve the emission values represented in table 1.

Key Pollutants	SDA Separation Efficiency	
	Normal	Maximum
Sulfur Oxides (SO_x)	85.0 - 95.0 %	95.0 %
Hydrogen Chloride (HCl)	90.0 – 95.0 %	98.0 %
Particulate	99.970 %	99.999 %

Table 1 - Typical SDA Emission Values (SPE-AMEREX / A-3, 2010)

As you will see later in this paper, the emission levels of the SDA, compared to etiher the Ring Jet® scrubber or Turbosorp® are typically higher. Since this is the most commonly used form of acid gas control in the US, it leaves room for improvement and hence the competition for the BACT.

Capital/Operating Costs

Finally, now that we have established the technical basis of a SDA we will need to take a step back and take a look at the cost implications of this type of system.

Costs (USD/ton MSW)	Normal	Range
Capital	2.14	1.87 – 2.49
Operating	13.41	8.37 – 21.62
Total	15.55	10.24 – 24.11

Table 2 – Typical SDA Costs (APC System – Dry, Semi-Dry, or Wet, 2010)

If we were to assume an interest rate of six (6) percent, amortization over fifteen (15) years, and constant additive and residue disposal rates, then we would get the costs associated with a SDA as shown in table 2. You will see later in this paper, that the total SDA costs compared to either the Ring Jet® scrubber or Turbosorp® the total costs are typically high. This leaves the question of why is it the most widely used technology while having the highest emissions and highest total cost?

RING JET® SCRUBBER

Concepts

The Von Roll Ring Jet® is a specially designed scrubber that deals with the raw flue gases from waste incineration by means of a multistage process. In this process, each of the different stages targets the reduction of different key pollutants, such as acid gases, particulate, heavy metals, etc… In the standard design, there are three independent stages, which can then have subsequent duplicate zones in cases where higher removal efficiencies are required.

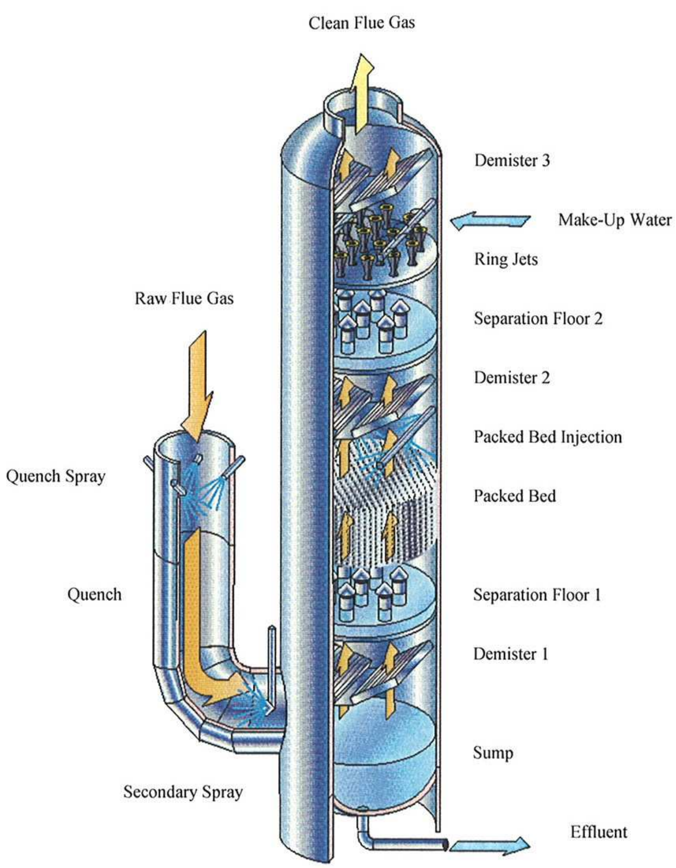

Figure 2 - Typical Ring Jet® Scrubber Arrangement (Flue Gas Scrubbing: The Multistage Route to Clean Air, 2002)

The first stage concentrates on the removal of particulate by the addition of water and is commonly known as the quench stage; if elected activated carbon or lignite coke can be injected into the raw flue gas stream prior to this stage. The flue gases then enter the stage, and quench water is sprayed in the flue gas stream, which causes the flue gases to cool to the adiabatic saturation temperature. Additionally, as the flue gas comes in contact with the water, the particulate matter is transfer into the excess water stream. The excess water is then put into the scrubbing tower sump and will leave as the water effluent stream, while the flue gas continues to the next stage of the system.

The second stage concentrates on the removal of acid gases by the addition of water, lime slurry, and/or caustic soda into a packed bed, which also sub-cools the flue gas. The packed bed creates a large surface area for the remaining pollutants to be efficiently absorbed, while the higher pH allows for them to react. The depth, quantity, and materials of the packed beds are dependent upon the flue gas composition and flow rates.

After the packed bed stage, the flue gases flow towards the third and final stage of the system which concentrates on the removal of particulate by the addition of water through the Ring Jets®. This stage consists of an array of Ring Jets® positioned so that the flue gas must pass through a jet of water as it flows upward. The controlled flow of water to each Ring Jet® allows the system to hold a constant pressure, and thus constant removal efficiency over a wide range of loads. After this final stage, the cleaned flue gas exits the system and can then be released to the atmosphere through the use of an induced draft fan and stack.

In between each of the different stages and at the exit of the scrubber, there are combinations of separation floors and/or demisters. The separation floors are used to collect the spent waste liquids in each stage so that they can be recycled back into the system after treatment. The demisters are used to prevent the carry-over of moisture entrained in the flue gas. The issue of water and waste water is critical to an efficiently designed wet scrubber, because if this is not done correctly, then the pollutant concentrations will be so great that equipment erosion and corrosion could occur. Typically, a recirculation loop for the liquids is used, which consists of make-up, blowdown, cooling tower, storage tank, etc… This loop is controlled by the combination of the temperature of the liquid and the concentration of pollutants in the liquids.

Advantages/Disadvantages

There are five (5) main advantages to this type of system: the simplicity, the small footprint, the ease to retrofit, the flexibility, and the high removal efficiencies. The simplicity of the system is that there are no moving parts, and it is a step by step process which eliminates different constituents in different stages. These different stages are typically stacked vertically and, therefore, tend not take much floor space in the facility. The small footprint also allows existing facilities with pre-defined spaces an easier time to retrofit their facilities with a wet scrubber. Additionally, the control of the Ring Jet® scrubber is designed such that the flue gas flow and loading of materials in the system can have a variability while still allowing the facilities to maintain emissions at all load cases. Lastly, the wet scrubber can be the technology with the highest removal efficiencies (dependent on the number of layers within each stage) of the main pollutants, and the cooling and condensing effect will also have a positive effect on the removal of the condensable matter.

There are multiple different reasons why people have expressed dislike for the wet scrubbing system; however, the general consensus leaves three (3) main disadvantages to this type of system: the pressure drop, the waste water, and the plume. The large amount of water and the small cross-sectional area of the Ring Jets® create a pressure drop in the area of thirty (30) inches of water column. This high pressure drop creates the need for a large induced draft fan. The next common dislike is that there is the creation of a waste water stream, which needs to be disposed of in safe and effective manner. The additional equipment to treat this water creates additional capital and operating expenses, which can be avoided with either a dry or semi-dry system. Lastly, the last common dislike is that there will be a visible plume exiting your stack unless additional heat exchangers are being added to the process train. For those reason most people nowadays tend to shy away from using wet scrubbers.

Achievable Emissions

So as mentioned above one of the main advantages to the Ring Jet® scrubber is that you can have the highest removal efficiencies, but these removal efficiencies are highly dependent upon the correct design of the unit. However, when designed correctly, the Ring Jet® scrubber can achieve the values represented in table 3.

Key Pollutants	Ring Jet® Separation Efficiency	
	Normal	Maximum
Sulfur Oxides (SO_x)	85.0 - 95.0 %	99.0 %
Hydrogen Chloride (HCl)	90.0 – 95.0 %	99.0 %
Particulate	99.970 %	99.999 %

Table 3 - Typical Ring Jet® Scrubber Emission Values (Flue Gas Scrubbing: The Multistage Route to Clean Air, 2002)

As you can tell from the comparison of the SDA and Ring Jet® scrubber, the normal removal efficiencies are similar, but with the wet scrubber you can maximize your reduction of pollutants even further.

Capital/Operating Costs

Finally, now that we have established the technical basis of a Ring Jet® scrubber, we will need to take a step back and take a look at the cost implications of this type of system.

Costs (USD/ton MSW)	Normal	Range
Capital	1.03	0.93 – 1.24
Operating	10.16	7.16 – 14.94
Total	11.19	8.09 – 16.18

Table 4 – Typical Ring Jet® Scrubber Costs (APC System – Dry, Semi-Dry, or Wet, 2010)

If we were to assume an interest rate of six (6) percent, amortization over fifteen (15) years, and constant additive and residue disposal rates, then we would get the costs associated with a Ring Jet® scrubber as shown in table 4. As you can tell from the comparison of the SDA and Ring Jet® scrubber, the total costs (if you neglect waste water treatment/disposal) are on a comparable level.

TURBOSORP®

Concepts

The Von Roll Turbosorp® is a semi-dry scrubber that deals with the raw flue gases from waste incineration by means of a specially designed reactor and fabric filter. This technology uses the basic principals of circulating fluid beds. The use of this technology has led to the successful demonstration of its simplified and efficient process which has led to higher availability and lower residue levels.

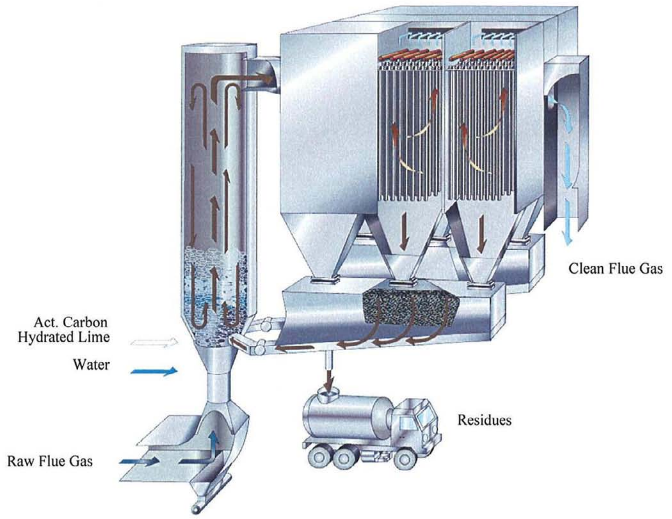

Figure 3 - Typical Turbosorp® Arrangement (Turbosorp® Flue Gas Purification, 2004)

The Turbosorp® process is based on the raw flue gases from incineration being directly ducted into the bottom of the reactor. As the flue gases move up the reactor vessel they are mixed with powdered additives (typically hydrated lime and activated carbon or lignite coke), high pressure water, and re-circulated fabric filter residues. The water acts to reduce the temperature to around three hundred (300) degrees Fahrenheit, which activates the additives for reaction with the acid gases present in the flue gas. As the flue gas exits the reactor and enters into the fabric filter, the additives and pollutants form a product that is captured on the bags while the cleaned flue gas exits the system and can then be released to the atmosphere through the use of an induced draft fan and stack. However, the residues captured on the fabric filter bags are then re-circulated back to the reactor via an air slide conveyor and re-introduced into the system (a blowdown of residues is taken from this stream prior to re-introduction into the reactor). This recirculation allows for the maximum utilization of all additives injected into the system. The standard Turbosorp® system consists of four (4) main pieces of equipment: the reactor, the fabric filter, the recirculation conveyor, and the high pressure water injection system.

The reactor is a vertically oriented vessel, typically constructed of carbon steel. The flue gases enter the bottom of the reactor and have a residence time of around two (2) to four (4) seconds and then exit through an opening in the side of the reactor. The powdered additives, high pressure water, and re-circulated fabric filter residues are injected in the area of the venturi. The two most commonly used additives are hydrated lime for acid gas and activated carbon for mercury control; however successful tests have been run with lignite coke, sodium bicarbonate, and caustic soda for acid gas control. The amount of additives injected into the system is being controlled by either hydrogen chloride or sulfur dioxide at the CEMS.

The fabric filter for the Turbosorp® is similar to any other fabric filter used in an EfW facility with just a few exceptions. The first key difference is that due to the high amounts of particulate in the reactor and fabric filter, the air to cloth ratio tends to be lower than a typical fabric filter (in the range of 2.6 to 2.8 [ft^3/min]/[ft^2]). Another key difference is that the fabric filter is typically located fifty (50) feet above grade. Another difference is that in order to promote the flow of residues, an air lock, such as rotary or double dump valve, between the fabric filter hopper and re-circulation conveyor is not necessary; however, an isolation slide gate for maintenance is still typical. Lastly, the inlet and outlet plenums must be arranged to minimize the height of the fabric filter penthouse or air pollution control building.

The fabric filter residue re-circulation conveyor is an air slide conveyor that is made to handle the difficult characteristics of transporting MSW fly ash. This conveyor is located directly beneath the fabric filter hopper (one conveyor per row of modules) and usually connected to it via flanges. As the fly ash drops off the fabric filter bags and into the conveyor, it lands on a fabric material. This material is designed to allow fluidization air, provided by blowers, to penetrate the fabric and fluidize the fly ash. Once the fly ash is in the fluidized state, gravity and negative pressure will pull the residues into the reactor. The amount of residues added to the reactor is controlled by installing a rotary dosing valve. The amount of residues extracted from the conveyor for disposal is controlled via a rotary valve. The ratio of amounts fed to the reactor versus disposal of is controlled by maintaining a constant pressure drop across the reactor.

A high pressure water injection system is used to inject water and/or waste water into the reactor to cool the flue gases. The system should be designed to get small enough droplet formation to promote uniform distribution in the reactor, which is achieved by the spill back nozzles. These nozzles allow the water pressure to remain constant and provide control of the temperature of the flue gas leaving the system. Additionally, these nozzles are also equipped with an automatic cleaning system to prevent the build-up of deposits on the tips. The system's pumps must also provide sufficiently high pressure in order to avoid a wet bottom, which could occur because the velocity would not carry the droplets in the flue gas. Additionally, if the pumps are sized too small, the flue gases will not be sufficiently cooled to the ideal reaction temperature. These pumps are usually fed from an intermediate storage tank for the water and/or waste water.

Advantages/Disadvantages

There are four (4) main advantages to this type of system: the high reliability, the zero waste water discharge, the compact design, and the low additive consumption. The Turbosorp® system has a high reliability and availability for all the different loads because it controls on many different variables, such as temperature, pressure, and emissions. In addition, the minimal amount of moving/rotating mechanical parts contributes to the minimization of operation and maintenance costs. Another of the main advantages is that the system does not create any waste water discharge; therefore removing the need to have any on-site water treatment. Not only does the system not create any waste water but, depending on the quality of different waste water streams in the facility, the Turbosorp® can actually use waste water as injection water, which could eliminate some other equipment. The next main advantage is that it has a compact design; because of the lower residence time requirement, the reaction chamber is typically smaller than other semi-dry scrubbers. Also, the elevated fabric filter provides abundant unused floor space for other equipment. The last main advantage of the Turbosorp® is the low reagent consumption because of the recirculation of fabric filter residues (the stoichiometric ratio in this system is typically in the order of 1.5 to 1.9). This not only leads to lower reagent cost, but will also decrease the residues produced and therefore, the residue disposal costs.

Since this is a newer technology there are not many people who have expressed dislikes with this type of system yet, but that does not keep some people from talking. The main item that people have against this system is that the technology is still young an unproven in the US market with MSW. However, this is changing, the new Frederick & Carroll Resource Recovery Facility located in Maryland, USA will be equipped with a Turbosorp®.

Achievable Emissions

As mentioned above one of the main advantages to the Turbosorp® is the reduction in additive usage, but some may wonder what effects this would have on the facilities emissions. The facilities emissions can either be controlled by the CEMS's sulfur dioxide signal or hydrogen chloride signal (this decision is made by the Von Roll during design). If sulfur dioxide is used to control, then the system can typically achieve the values represented in table 5; however, if hydrogen chloride is used to control, then the system can typically achieve the values represented in table 6. As you can tell from the comparison of tables 5 and 6 the control by hydrogen chloride will lead to an improvement in emissions.

Key Pollutants	Turbosorp® Separation Efficiency	
	Normal	Maximum

Sulfur Dioxide (SO_2)	85.0 – 92.5 %	98.0 %
Sulfur Trioxide (SO_3)	90.0 – 98.0 %	99.5 %
Hydrogen Chloride (HCl)	90.0 – 98.0 %	99.0 %
Hydrogen Fluoride (HF)	95.0 – 99.0 %	99.5 %
Particulate	99.970 %	99.999 %

Table 5 - Typical Turbosorp® System Emission Values Using SO_2 Control (Turbosorp® Flue Gas Purification, 2004)

Key Pollutants	Turbosorp® Separation Efficiency	
	Normal	Maximum
Sulfur Oxides (SO_x)	95.0 %	97.5 %
Hydrogen Chloride (HCl)	98.0 %	99.5 %
Hydrogen Fluoride (HF)	98.0 %	99.5 %
Particulate	99.970 %	99.999 %

Table 6 - Typical Turbosorp® System Emission Values Using HCl Control (Turbosorp® Flue Gas Purification, 2004)

So most people would ask why even use sulfur dioxide to control emissions then? Well, the reason sulfur dioxide is used is because the CEMS monitor is much more cost effective.

Capital/Operating Costs

Finally, now that we have established the technical basis of a Turbosorp® scrubber we will need to take a step back and take a look at the cost implications of this type of system. If we were to assume an interest rate of six (6) percent, amortization over fifteen (15) years, and constant additive and residue disposal rates, then we would get the costs associated with a Turbosopr® as shown in table 7.

Costs (USD/ton MSW)	Normal	Range
Capital	2.30	2.07 – 2.75
Operating	12.21	7.44 – 19.99
Total	14.51	9.51 – 22.74

Table 7 – Typical Turbosorp® System Costs (APC System – Dry, Semi-Dry, or Wet, 2010)

A comparison of the Turbosorp® with the SDA and Ring Jet® scrubber shows that although the initial capital cost is the highest, the lowest operating cost make the Turbosorp® system the most cost effective.

EXISTING FACILITIES

AVS Zorbau

The AVS Zorbau facility is a Von Roll designed facility that is owned and operated by SITA Abfallverwertung GmbH, Zorbau. The facility is located in Zorbau, Germany and was put into commercial operation in early 2005. It is composed of two (2) identical process trains, each using MSW and Commercial Waste (CW) as the primary fuel. The design capacity of the main fuel is for an annual throughput of approximately three hundred and thirty-one thousand (331,000) short tons, which produces approximately fifty-four (54) megawatts of thermal energy per train.

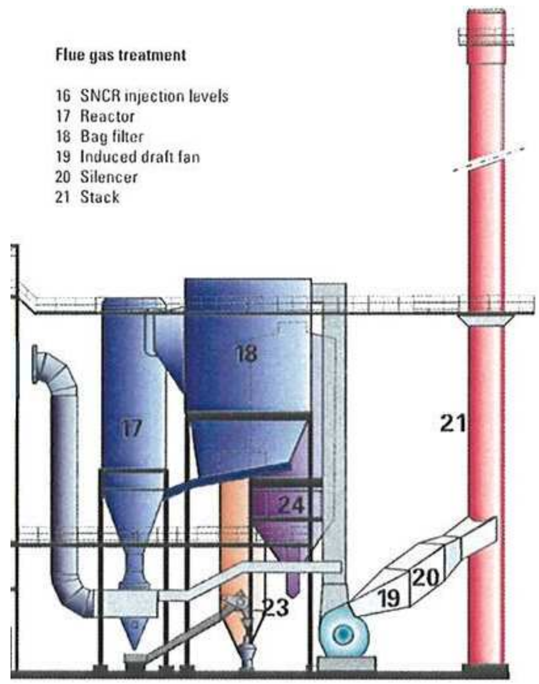

Figure 4 – AVS Zorbau Process Train (AVS Zorbau, 2005)

As seen in figure 4 the air pollution control equipment for this facility consists of Turbosorp® and selective non-catalytic reduction (SNCR) system. With this set of equipment Zorbau achieves the emissions shown in figure 5.

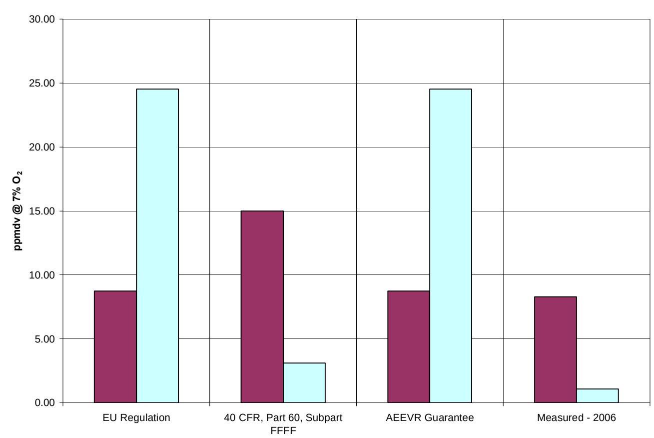

Figure 5 – AVS Zorbau Emissions (Turbosorp® - Semi-Dry Flue Gas Treatment, 2010)

The low emissions shown in figure 5, along with the high throughput capacity, makes the AVS Zorbau facility one of the largest facilities in Germany that is not only meeting but also exceeding the regulations imposed by the EU. It is also an example of what can be accomplished with the use of the Turbosorp® system to control acid gas emissions.

TRIDEL Lausanne

The TRIDEL Lausanne facility is a Von Roll designed facility that is owned and operated by TRIDEL SA. The facility is located in Lausanne, Switzerland and was put into commercial operation in early 2006. It is composed of two (2) identical process trains, each using MSW and CW as the primary fuel, but it also has the ability to burn hospital waste and sewage sludge in limited amounts. The design capacity of the main fuel is for an annual throughput of approximately three hundred and seventy-two thousand (172,000) short tons, which produces approximately forty (40) megawatts of thermal energy per train.

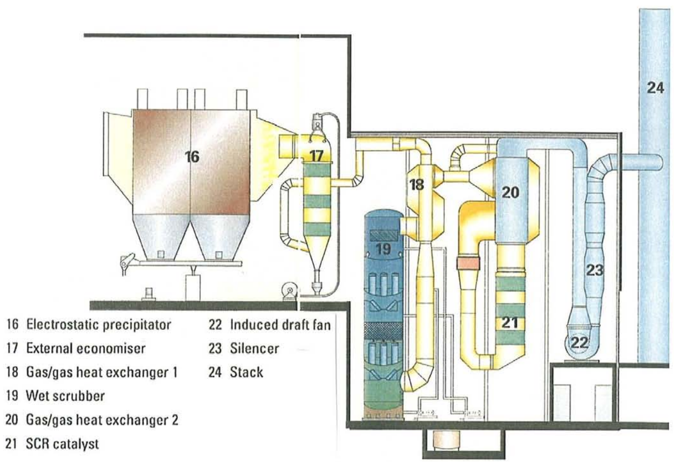

Figure 6 – TRIDEL Lausanne Process Train (TRIDEL Lausanne, 2006)

As seen in figure 6, the air pollution control equipment for this facility consists of an electrostatic precipitator, Ring Jet® scrubber, and selective catalytic reduction (SCR) system. With this set of equipment, Lausanne is achieving the emissions shown in figure 7.

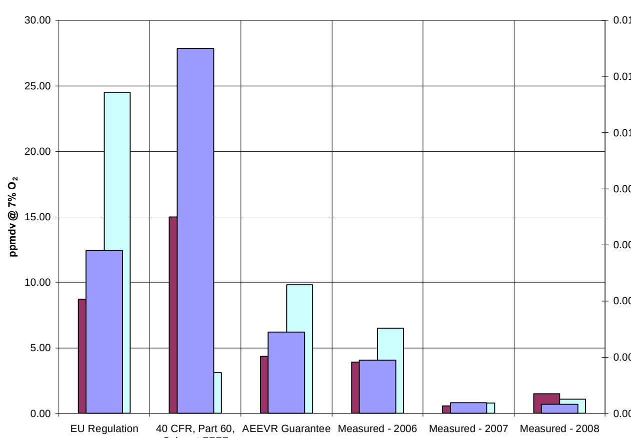

Figure 7 – TRIDEL Lausanne Emissions (TRIDEL SA, 2010)

The low emissions shown in figure 7 along with the high energy efficiency and virtually invisible plume make the TRIDEL Lausanne facility an example of what is accomplishable with the use of a Ring Jet® scrubber to control acid gas emissions.

TREA Breisgau

The TREA Breisgau facility is a Von Roll designed facility that is owned and operated by Gesellschaft Abfallwirtsschaft Freiburg i.Br. and SOTEC GmbH, Saarbrucken. The facility is located in Breisgau, Germany, and was put into commercial operation in 2005. It is composed of one (1) process train, which uses MSW, CW, and bulky goods as the primary fuel. The design capacity of the main fuel is for an annual throughput of approximately one hundred and sixty-five thousand (165,000) short tons, which produces approximately sixty-one (61) megawatts of thermal energy.

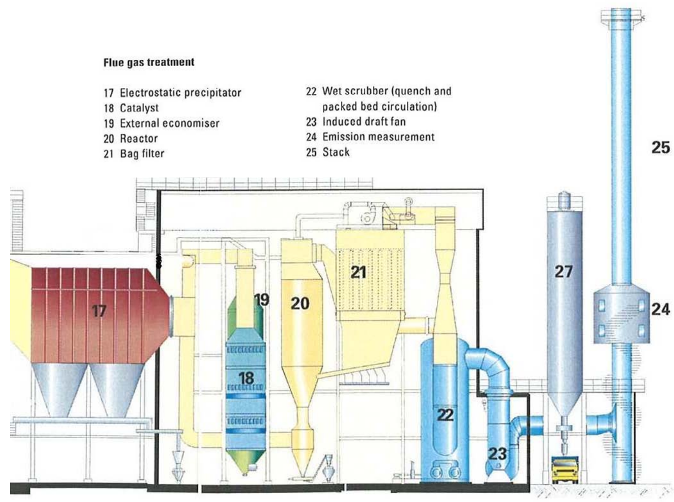

Figure 8 – TREA Breisgau Process Train (TREA Breisgau, 2005)

As seen in figure 8, the air pollution control equipment for this facility consists of an electrostatic precipitator, Ring Jet® scrubber, Turbosorp®, and SCR system. With this set of equipment Breisgau ise achieving the emissions shown in figure 9.

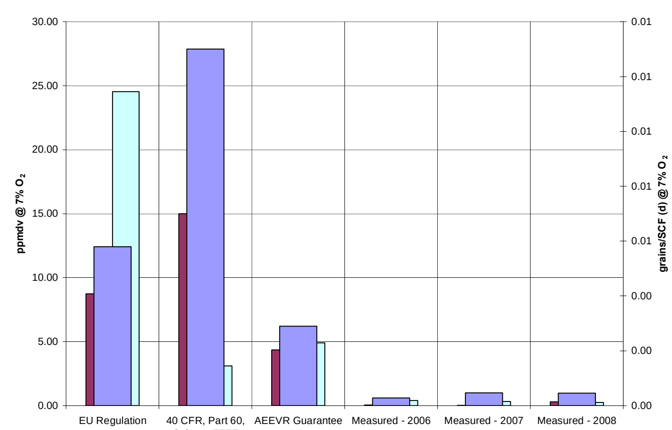

Figure 9 – TREA Breisgau Emissions (E.ON Energy from Waste AG, 2010)

The low emissions shown in figure 9 are achievable because of the multistage flue gas treatment which reduces emissions by some fifty (50) to eighty (80) percent below the limits set forth by the EU. It is also an example of what can be accomplished with the use of a Turbosorp® and Ring Jet® scrubber in series to control acid gas emissions.

FUTURE OF ACID GAS CONTROL TECHNOLOGIES

Optimized Wet Scrubber

The concept of the optimized wet scrubber is that you get the benefits of removal efficiencies from the wet scrubber and also eliminate the disadvantage of having the waste water stream. This is performed by putting both a Turbosorp® and Ring Jet® in series as shown at the TREA Breisgau facility. The flue gas would enter the semi-dry system first to remove the typical amount of acid gases and particulate, but then the flue gas would continue into the wet scrubber which would still maintain a high percent removal of the acid gases as if it were an independent system. Therefore when the flue gas finally heads for the stack, it has gone through two high efficiency removals. The key to making this system work is that instead of discharging the blowdown from the wet scrubber to a treatment plant, it is used as the injection water for the Turbosorp® reactor. There are some more design considerations that have to be taken into consideration when this system is used, but it provides the benefits of both the semi-dry and wet system, while eliminating some of the disadvantages.

Optimized Dry Injection System with NO_x Control

The concept of the optimized dry injection system with NO_x control is that you get the benefits of the dry system and also eliminate the need for a re-heat prior to the SCR system. This is performed by putting a dry scrubber, SCR, and Turbosorp® in series. So the flue gas would enter the dry system first and get the typical removal of acid gases and particulate, but then the flue gas would continue onto the SCR while maintaining the higher temperature. This would allow the higher removal efficiency of NO_x in the SCR system as opposed to a typical SNCR system. Finally the flue gas would continue onto the Turbosorp® prior to leaving the facility via the stack. The key to making this system work is to maintain the higher temperature through the dry scrubber so that the SCR can function efficiently. This type of system would provide the benefits of both the dry and semi-dry systems while reducing the emissions. This type of technology is just in the beginning stages and has not been proven commercial viable yet.

Multiple Control Systems in Series

The concept of having multiple control systems in series is utilized in both the optimized wet scrubber and the optimized dry injection system with NOx control. However this does not have to be limited to having different types of system in series, i.e. semi-dry and wet scrubber, dry and semi-dry scrubbers, etc… Instead it is perfectly acceptable and operational to put the same type of system in series in order to minimize emissions, i.e. wet and wet scrubber, etc… So the flue gas would leave the first Ring Jet® and then enter an additional Ring Jet® prior to exiting the facility via the stack. The efficiency of the second scrubber in this case is typically lower, but would lower the emission of some of the key pollutants. This type of technology has already been proven operation at a Von Roll designed EfW facility located in Uppsala, Sweden.

CONCLUSIONS

So some of you may be thinking right now that it is great to have all this information regarding these different types of technologies, but how do I know which is right for our facility? If cost is not an issue, then this can be solved by asking yourself five (5) simple questions:

- *Do I want to minimize the amount of waste water discharged from the facility?*
  If yes, then a wet scrubber alone is not the right technology for you (but you could still use it in some combination).
- *Do I have to maintain a low NOx value in addition to achieving the low acid gas values?*
  If yes, then a dry scrubber which prevents re-heating the flue gases for SCR is the right technology for you.
- *Do I want to have a virtually invisible plume?*
  If yes, then a wet scrubber is not the right technology for you.
- *Do I have abnormally high air pollution control fly ash residue discharge rates?*
  If yes, then a wet scrubber with some sort of residue treatment is the right technology for you.
- *Do I have to or want to achieve emission value much lower than the posted regulations?*
  If yes, then a combination of dry, semi-dry, and wet scrubbers in series is the right technology for you.

However, as most people know cost is always an issue, so it would become necessary to do a cost analysis for each of the different technologies that are suitable based on the questions above. Always keep in mind when doing that cost analysis that all of these technologies have been proven and will meet the current US regulations so do not go in with a pre-determined favorite, but instead keep your options open as long as possible.

All in all, as the government continues to tighten regulations in the EfW industry it becomes more and more important to find the right technology to meet the every growing need to reduce emissions. In order to meet the ever growing need it will become important to be open minded regarding new technologies to meet the decreasing emissions levels and to maintain the concept of BACT.

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