WESP (Wet precips) for CCS and Utility Market

Increasing Business Opportunities for Large Scale WESPs

Presented

By

Dr. Ing. Norbert Seyfert

at

ICESP XII

In NÜRNBERG 2011

CONTENT

B1CS Postfach 12 52 Weimarer Str. 9 **Tel.:** + 49 (0 27 61) 83 74 63

1 Introduction

The precip technology is an outstanding efficient process for the separation of aerosols. Nevertheless as per the authors perspective a not satisfactorily good reputated technology.

The aim of the ICESP-XII is to show and clarify some of the main topics of this technology as per today. Engineering and science come together.
This task is mandatory for the business and for the environment.
The lack of reputation and its consequences are illustrated below in a small exemplary statement.

For anyone involved in manufacturing the separation of mists from machining equipment WESPs is a well known standard.
As soon as the aspect starts to be focused on environmental issues the bag-filter shows much better reputation.
Historically the reason for this attitude, at least to some extent for central Europe is based on the traditionally good relation between ESP buyers and ESP sellers. For a long period of time it was standard to reach a level of 50 m/Nm³ dust outlet. This level was undergone for a reasonable portion of the market. Neither the buyers had any interest to push the sellers for smaller equipment, as safety was a higher priority subject than costs, neither where the sellers interested to start blooming marketing campaigns, due to the sufficient margins of the market for all participants.
The opposite happened when the bag-filter suppliers started to enter into the market.
The more the environmental issues got public, the more important was reputation by the public even for buyers of technical equipment. By this the aggressive marketing of the bag-filters, and their simple and easy understandable process (Vacuum cleaner) the market share of the precips deceased.
It is one of the purposes of this paper to show future market opportunities for precips and in special for WESPs.

2 Well Established WESP Applications

- Sulphuric acidTar
- Pyrite , sphalenite roasters
- Sinter belts for iron
- Sinter for, lead
- Sinter for zinc concentrates
- Copper converters
- Combustion of H_2S
- Calcining kiln for TiO_2
- Tar precipitators

As can be seen from the above examples there is plenty of experience for several processes. It can be stated, that WESPs are basically a well established technology.
It is nevertheless remarkable, that there are still only a few established companies keeping this technology fundus within a limited circle of suppliers.

3 Recent Industrial WESP Applications

3.1 Wood chip dryers

The wood chip drying process was for a rather long period of time under a strong evaluation process. The main factors influencing the process are:

- Risk of fire
- Reasonable large volume flows
- Low budgeting industry

It took nearly two decades to settle a top level standard, which is in this application the wet precip. There are still some plants working just by cyclones, and there are some plants using bag-filters, which is only applicable for the indirect drying.

For the majority one can summarize, that the best physically fitting technology finally gained the highest market share. The evaluation of this market segment even incorporated dry precips with fire suppression systems, Dry gravel-bed electrically enhanced moving-bed systems and as well special scrubbers.
It was the achievement of the recent market-leaders to bring the technology of wet precips into a sizing and standard that suits for the cost-driven industry.

3.2 Glass ovens

In this application there are numerous processes for fabrication different glass types. For the WESP the glass fibers are a common application.
Due to the toxicology of fibrous material you can find very low emission numbers for this application.
The gas flows are reasonable high and the cost is as well one of the major driving forces for the choice of separation equipment.

3.3 Waste to energy plants

Within the waste-to energy segment there are a variety of wet scrubbing processes available. Some of them are equipped with WESPs.

Due to the ph-level of the scrubbers you can find any corrosive atmosphere in this field of application.
The market in this area is mainly driven by very sensitive and low emission limits and not too stringent cost restrictions. Buyers are somehow linked to public acceptance of their plants, and thus they have to follow to a certain degree the public reputation of any technical solution

4 Focus on Utility Application

The temporary situation of the utility market can be characterized by the following topics:

- Increasing global demand for electricity
- Limited resources
- Greenhouse effects and air pollution control
- Restricted use of nuclear power

The last point seems to be evident in the moment, but the global number of stations under construction is still in order of 50 to 100, each having 800 MW in average. Even if the effects of 3-miles-island, Tschernobyl and Fukushima are not clearly to be predicted the role of nuclear power has only a secondary effect on the market opportunities of WESPS in the CCS content.

Taking into account the recent available and explored resources as well as the recent consumption you have from today the following time ranges for the main fuels:

Crude oil	40 – 50 years
Gas	50 – 70 years
Coal	150-250 years
Uranium	50 -80 years (no breeding technology)

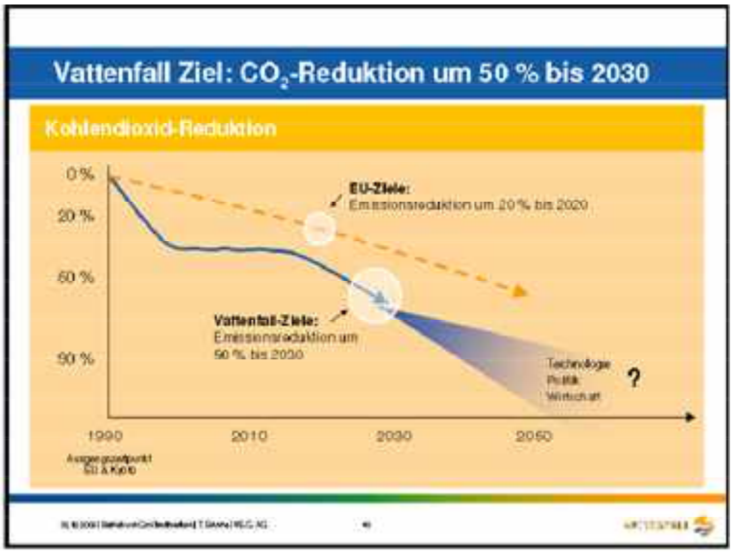
According to this distribution of available resources one can derive a high pressure on price for Crude-oil and gas as the most widely used fuels.

For the uranium one can derive, that the global capacity will stay about at the level of today with re-build of old stations and shift of production capacity from Japan and Europe to the second world states and China.

As coal is the only source with a satisfying time range it is easy to imagine, that the use of coal will increase and be a major contribution to utility market for a couple of decades from now on.

Coming from these findings you can easily state:

The stabilization of the atmospheric CO2 at a level of less than 450 ppm can only be achieved by the use of the CCS technologies.
Below find a published task of one of the leading European utility.



4.1 Coal Fired Systems

Within the coal fired boiler systems you have many applications for the precip technology. The vast majority is covered by the dry systems.
The utilization of dry ESP or Bag-Filter is decided by a number of factors, which are not only commercial or technical issues.
All the new stations of size 600 to 1100 MW in Germany are equipped with dry ESPs having the so called “world-wide-coal-range” as the design fuel. For the same application you will find in Italy very unlikely a precips but very likely a bag filter.
In terms of South-Africa Australia the choice for bag-filter is more driven by technical issues, as the local fuels are showing the worst conditions for dry precips.

B1CS Postfach 12 52 Weimarer Str. 9 **Tel.:** + 49 (0 27 61) 83 74 63

4.1.1 SO3

The separation of SO_2 is a standard for new power plants. The emission limits are as low as 200 mg/Nm³. There is as well a tendency to base the emission of sulphuric components as a SOx value. In this case any SO_3 in mg/m³ emission would contribute as 0,8 mg/Nm³ SO_2.
For a typical high caloric value coal the following table gives the SO_3 levels at different sulphur contents and different conversion rates.

B1CS Business First Consult-s — ***B11-011***

SO-3 Conversions and SOx contribution

Sulphur content of coal	Mass %	***0,25***	***0,50***	***1,00***	***2,00***	***4,00***	***8,00***
Caloric Value of coal	MJ/kg	**23,64**					
SO2	Vol %	0,02	0,05	0,10	0,19	0,38	0,74
SO2	mg/m³	**633**	**1264**	**2520**	**5013**	**9927**	**19414**
Scrubber with 90%	mg/m³	**63**	**126**	**252**	**501**	**993**	**1941**
Conversion rate		**0,40**					
SO3	Vppm	0,97	1,93	3,85	7,65	15,16	29,64
SO3	mg/m³	3,16	6,31	12,58	25,03	49,57	96,92
increase of SOx within SO3 scrubbing	**%**	**4,00**					
Conversion rate		**1,00**					
SO3	Vppm	2,41	4,82	9,62	19,13	37,89	74,10
SO3	mg/m³	7,90	15,77	31,45	62,56	123,90	242,31
increase of SOx within SO3 scrubbing	%	**10,00**					
Conversion rate		**2,00**					
SO3	Vppm	4,83	9,65	19,24	38,27	75,78	148,20
SO3	mg/m³	15,79	31,54	62,91	125,13	247,80	484,61
increase of SOx within SO3 scrubbing	%	**20,00**					

From these calculations you can see that the separation of SO_3 will increasingly get important for any systems with increased SO_3 conversion rates.
The conversion rate itself is a factor that might be not only influenced by the boiler but even by catalytic processes as the Denox systems. It is not clear in the moment whether high steam parameters, and by this high surface temperatures of the boiler tubes do not have increasing influence on the SO_3 conversion rate.
If we consider a 2%-sulphur coal with a conversion rate of 1% we have the following raw gas data: SO_2 = 5013 mg/m³ SO_3 = 62 mg/m³. Having a standard scrubbing system with 90 % percent efficiency for the SO_2 and practically no efficiency for the SO_3 this system would have to be enhanced by 4 % achieve the same SOx emission level. This calculation is done on a base of emission level of

B1CS Postfach 12 52 Weimarer Str. 9 **Tel.:** + 49 (0 27 61) 83 74 63

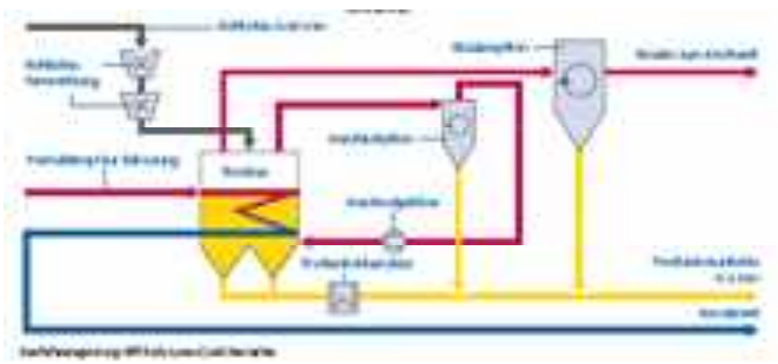
500 mg/m³ SO_2 or SO_x respectively.
Taking into account higher sulphur contents and even lower emission limits it gets clear that SO_3 separation is a mandative task.
Here we see one of the upcoming market opportunities for the WESP-Systems.

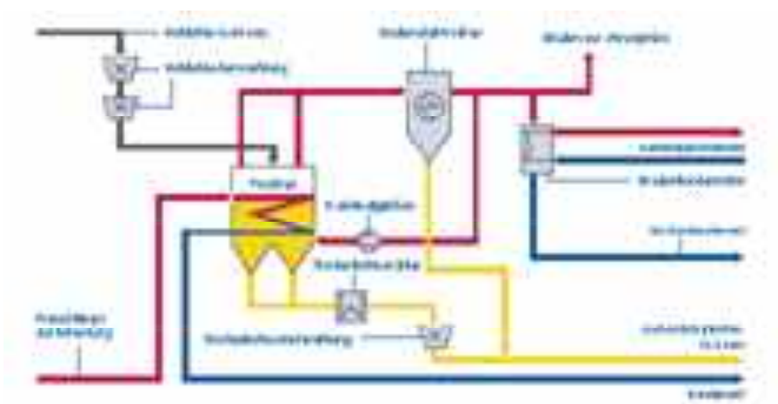
4.1.2 PM 2,5 (Hybrid)

The separation of ultra fine particles as PM2, 5 is effectively only done by a non gravimetric process. In this regard the precip technology is unique by separating particles or droplets out of any gas-flow without putting barriers into the gas flow.
There have been precips called Hybrid-precips, where the last field was a wet precip with 2 or 3 dry stages upstream. The technology was invented to a reasonable amount by the German LURGI and is used in sinter-belt-processes.
The physical properties of this DRY-WET-Precips are beyond any discussion as far as separation in discussed.

4.1.3 Coal drying (Dry precip in humid atmosphere)

For the use of post-combustion CC-Systems one has to consider a loss of over-all efficiency by the CO_2-scrubbing. For this reason it is more than evident, that all common potentials for efficiency increase of a boiler system have to be used. A traditional way of increasing the thermal efficiency is the drying of the coal. For this purpose the coal is dried with low pressure superheated steam to avoid water evaporation by energy input and downstream water condensation with no energy recoverment. The coal driers are common technique and the limit of commercial useful incorporation starts somewhere about 30% of water content in the as received coal.





The coal drying technology is based on a flow of water absorbing gas, which afterwards at least contains impurities of dried coal or as the common case the main mass-flow of dried coal. This coal has to be separated out of a nearly saturated gas flow.
The environment is very convenient for the physical process of ESPs, which gives small, cost effective plants. The precip- industry should take care of the special requirements of the coal drying and develop a technology as close as possible to the requirements of the drying process. This will open an interesting and prospective market opportunity.

B1CS Postfach 12 52 Weimarer Str. 9 **Tel.:** + 49 (0 27 61) 83 74 63

4.1.4 Mist (Low temp extraction)

For nearly all new Power stations in Germany you find the outlet of the flue gas within the cooling tower. There is basically no stack any more, and the off-gas is driven into the atmosphere together with the plume of the cooling tower.
Just for emotional reasons or because of lack of knowledge this plume in the media is often used for photographs underlining the negative influence of power stations to the environment. It is a matter of time, when the difficulties of emission monitoring in this mixed off-gases will create public resistance against any plumes.
There are examples from the wood-chip drying process of these phenomena. At some places where the dryers are located in touristic locations as you have in Switzerland and in Austria there was a demand for a “plume-free” operation. This ended up in a wet-precip, which was designed as a condensation system, using atmospheric air or a water cooling circle as the cooling media.

WESP conventional

WESP with condensing system

For the application of a wet Precip in the utility segment for the plume reduction a commercial beneficial use of the low temperature energy is essential. There have been a lot of approaches to this utilization ranging from heating of green-houses to farming of sweet-water water fish or even using heat pumps to convert the temperature level up to a range, where it can be used for house-heating.
From the authors knowledge this process seems to be to some extend useful. A prerequisite would be the location of the stations closer to the end-users. By this a new sizing philosophy would enter the utility market, as these stations would be of a 300 to 400 MW el size mainly.
This would as well open the investment market for even smaller entities than the known large utilities, and cities or industrial parks could execute this financial burden by themselves.

4.1.5 CC-Systems

The CC-technology is divided into three systems:
Pre-combustion, during combustion and after combustion. All the systems are under development recently and it might be stated that the Pre-combustion is always associated with coal-gasification. This technology is in use for decades, but always needed some extraordinary market conditions to get started or stay in commercial operation.
The During-combustion system is known as OXY-FUEL process and there are a number of pilot stations running on close to commercial scale.
The Post-combustion system is a scrubbing using new absorbents within a process having some similarities to the SO2-scrubbing.

4.1.5.1 Before combustion (gasification with water/gas-shift reactor and carbon dioxide scrubber)

This process was historically first used to process gas for urban lightning in the early 1800s before electrification. Till then this process was in use in several applications as producing fuel for vehicles which is still operated to a large scale at the Sasol refineries in RSA. More recent developments are even considering gasification of coal at the soil of mines to minimize handling of coal.
For the CC the gasification enables the use of physical absorption of CO2 rather than chemical absorption, because CO2 rich gas is on a high pressure level. Due to the ash content of the used fuel there is the problem of dust removal at high pressure and high temperatures. By these factors the author does not see a good short terms market opportunity for the electrostatic separation process.

4.1.5.2 During combustion (oxygen-combustion)

There are several pilot plants in operation for a reasonable period of time, and it is proven, that the electrostatic precipitator will find its place at the same process steps as for the air-fired boiler systems. The migration values for the dust removal at the dry separation of ash downstream the oxygen combustion are of comparable magnitudes as for the air-combustions.
The separation of SO2 runs with the Oxygen-combustion at much higher SO2 levels than with air-combustion, just due to the missing nitrogen in the flue gas. Basically the concentrations become 5 times higher, and by this the efficiency of the scrubbers have to be at highest levels. There is no evidence, that the conversion rate of SO2 to SO3 is less at the oxygen-combustion compared to the air-combustion in regard to the combustion process itself. In the conventional air-combustion we likely find reasonable conversion rates of SO2 to SO3 in the catalytic high-dust DENOX. This does not exist at the oxygen-combustion as there is no N2 in the flue-gas.
As the conventional scrubbers and even the two-stage scrubbers are not capable to remove essential parts of the SO3, we find the WESP to be the remaining technology for the problem.
There is the technology of dry scrubbing of SO2 by adsorption in a spray dryer or humidified flue gas, but this technology might have too low efficiency and by this two high consumption for the application in a oxygen-fuel combustion.

B1CS Postfach 12 52 Weimarer Str. 9 **Tel.:** + 49 (0 27 61) 83 74 63

4.1.5.3 Post combustion CO2 scrubbing

The best know process for this purpose is the MEA-scrubber. (Mono Ethanol Amin). The process was used widely on a small scale in the submarine technology.
Next are two layouts of a conventional station and a station with CO2 scrubbing.

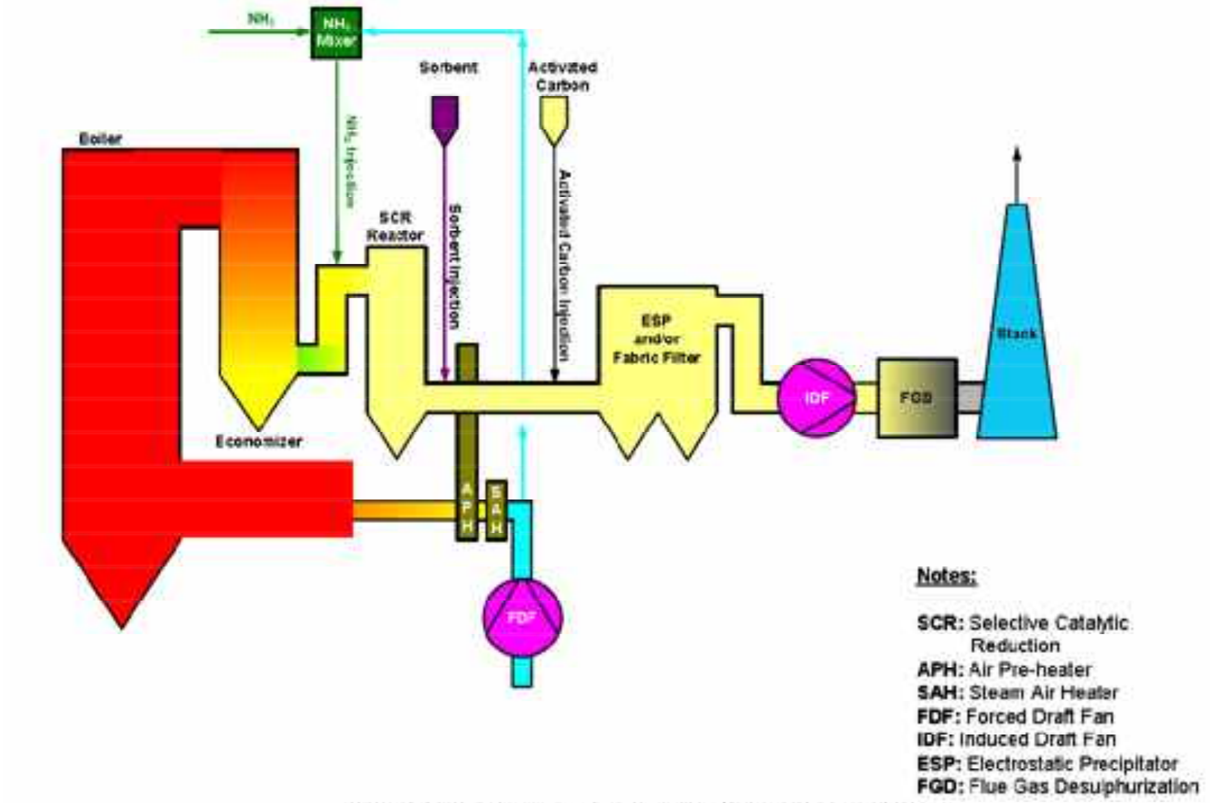


Figure 4: Power Plant without CO_2 Capture

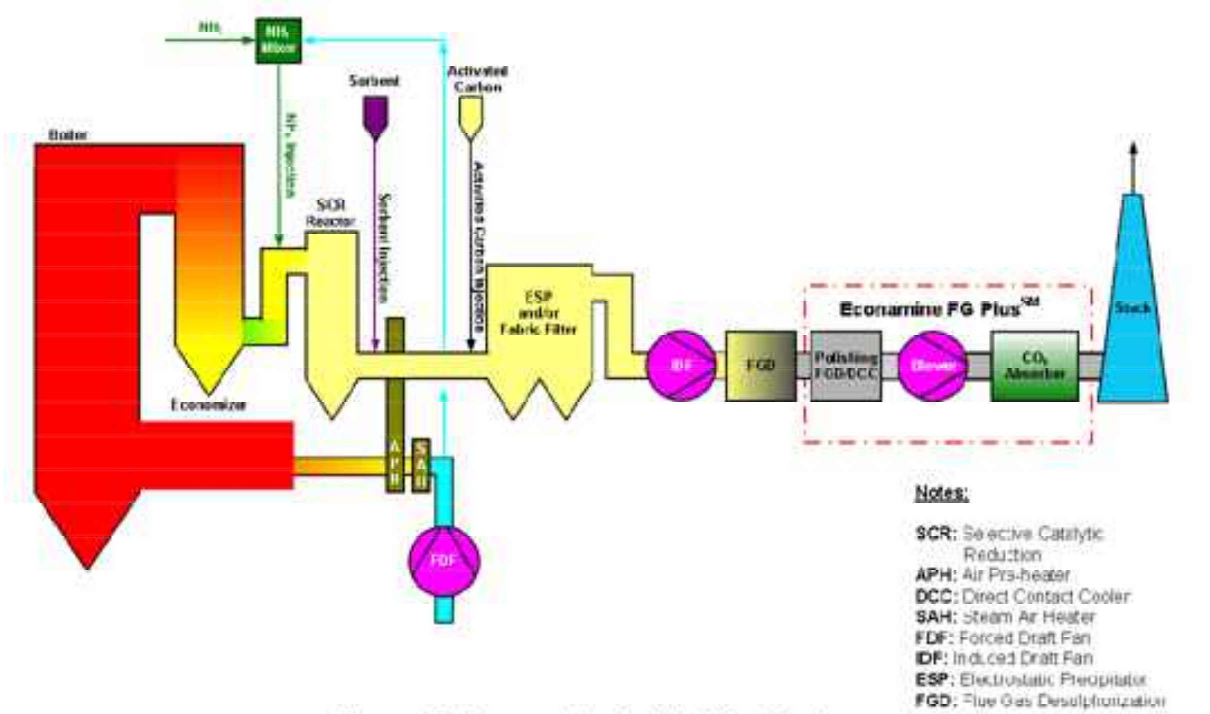


Figure 5: Power Plant with CO_2 Capture

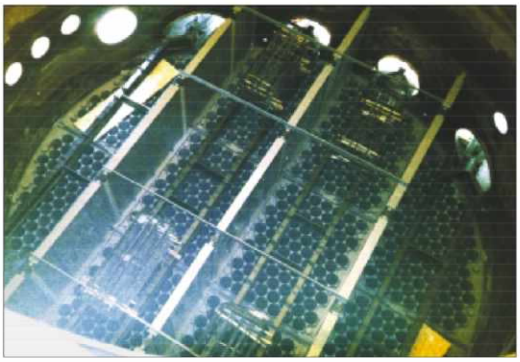
B1CS Postfach 12 52 Weimarer Str. 9 **Tel.:** + 49 (0 27 61) 83 74 63

In regard to precip market opportunity you may focus on the so called “Polishing FGD”. This is a further reduction of SO3 and PM as required by the regeneration process of the absorption.

There is evidence that CO2 scrubbing will require lowest achievable PM concentrations. Out of numerous findings we here just repeat a statement of Fluor Daniel:
“Regardless of whether SO2 is removed by wet or dry FGD, the carbon dioxide capture plant will be located downstream of the air quality control system. The flue gas will still have small quantities of particulate, SO2, ammonia, and other pollutant species that will need to be identified, quantified and considered in the design of the CO2 Capture unit. Ammonia based SO2 capture processes will also require a wet ESP to remove aerosols produced by ammonia the ammonia scrubbing process.”

As we have to tackle in the post-combustion CO2 scrubbing for utility purposes large volume flows the design of WESPs at this location is fundamental task.
It looks very encouraging to put a WESP on top of a scrubber, as it is done recently for SO3 removal within conventional FGD, and as it was done at HFO desulphurization in the past.

Tube bundles in a wet ESP designed for a gas volume of 535.000 m³/h.



Vertical integrated GEA-System at PCK Schwedt.

Horizontal MHI-System at Verbund-Kraftwerk Wernburg.

There will still be simple designs using horizontal WESP with additional ducting as the flow regime for the post-combustion CO2 scrubbing will be the leading factor for the lay-out.

4.2 Biomass systems and Blue Haze

As the use of biomass is considered to be CO2 neutral we just tackle the topic of blue haze in brief.
From the biomass boilers we know in some occasions the existence of what is called blue-haze.
This blue-haze stays visible for a long distance downstream the stack and consists of aerosols formed by condensation of unburnt components.
The simple way to avoid blue-haze is the optimization of the furnace and combustion, but it might still happen that in the course of the wider range of used biomasses, that some of them would still need the separation of the blue-haze.
In case you have to separate it is well known, that a WESP preferably with condensing is a very appropriate tool.

4.3 LFO / HFO systems

4.3.1 HFO

For the HFO systems the same findings as for the coal systems are valid in general.

4.3.2 LFO

This chapter is just inserted as there is a trend in the market to produce electricity by diesel engines in a scale up to 20 to 30 MW el.
Depending on the fuel-grade you may find precips as the solution for soot removal downstream the diesel engine. This might be valid preliminary only at touristic areas, where soot plumes are not accepted at all, but still any air-conditioning system is well accepted.

B1CS Postfach 12 52 Weimarer Str. 9 Tel.: + 49 (0 27 61) 83 74 63

5 Technical essentials

5.1 Material selection

5.1.1 SO3-precips

The application is mainly characterized by a gas condition at a level of pH 2 and below.

The materials which could be used are:

- Alloy
- Plastic
- Lead-lined steel

All alternatives do have the benefits and their obstacles.
For the alloy solution one has to use really high alloy grades for this environment. By this condition you are forced to use simple and double side used collecting surfaces.
The alloy solution yields practically a plate type WESP with either horizontal or vertical gas flow.

The plastic solution is very robust in terms of corrosion resistance, but has limited electrical and thermal properties. The use of this material is well experienced and there are two difficulties which have not always been solved to customer's satisfaction.
The earthing of a non conductive structure to an extend of clear and solid potentials adequate for modern WESP-control systems is a ongoing problem. There are many solutions and approaches for solution, but this item is still to be enhanced for utility purpose.
There is as well the problem of holes in the plastic tubes, which are burned in by permanent sparking onto the surface of the collecting electrodes.

The lead lined solution has a more historical background, and it would have to proven if the commercially interesting solution is totally resistance against corrosion attack at this permanent low pH-levels. The choice of skilled companies for lead-lining is also very limited, as least for the European market.

5.1.2 Boiler precip for Oxygen-combustion

Up till now there is no special requirement being observed for this application. It might be speculated, that the lack of nitrogen might catalyze any corrosive attack, as there is no diluting gas present compared to the air-combustion systems. The risk of SO3 condensation is to be expected higher.

5.1.3 Coal drying precip

The use of carbon steel will satisfy this application.

5.2 Redundancy

This is only a problem for the WESP on top or as intermediate part of a scrubber. You find very large diameters and for the separation one layer of WESP is normally good

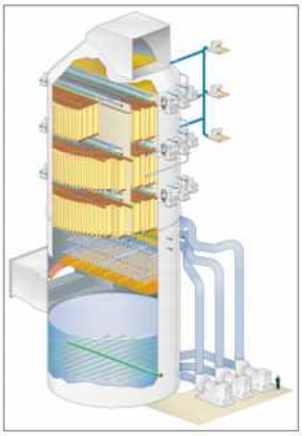


Figure 5 Upflow WESP integrated with WFGD.

enough for the separation of aerosols.
For the large diameters as experiences in utility purpose the load and the statically questions become a sever design task. In case of achieving good redundancy you would have to design a two stage WESP with all double support system for the high voltage components.

6 Summary and Outlook

6.1 Business Opportunities for Dry ESP for future coal fired boiler systems (Carbon Capture)

The precip technology will be implemented as the boiler-ash separation technology. As coal will remain one of the fundamental resources for the global utility market the precip suppliers will in future serve this market in continuation of the existing precip market for the conventional combustion systems.
As the oxygen-combustion and the post-combustion CO2 scrubbing have each additional energy requirements, the plant lay-out will ask for high efficiency processes, which will increase the use of coal drying. By this also the use of dry precips downstream the dryers will increase.

6.2 Business Opportunities for Wet ESP for future coal fired boiler systems

The WESP will gain market shares as all the CO2 srubbing systems are sensitive to incoming PM and gas pollutants.
The WESP will follow the FGD in non CC application where SOx emission limits will be established at reasonable low levels.
The WESP will gain some market in the plume abatement technology

6.3 Future developments for market penetration

From the marketing point of view we see the following topics as major tasks:

More active public relations work in terms of technical clearness

Spreading the spirit to serve the environment with most clever way to separate particulates and aerosols.

From the technical point of view we see the following topics as major tasks:

Making plastic components as reliable as steel components

Achieving better migration velocities at higher face-velocities

Revitalization of the Hybrid-system (Dry-Wet) for PM and SO3 separation.

Energy saving strategies for the WESPs to limit current flow in humid environment

7 Gratifications

We thank the following companies (by alphabetic order) for their assistance by photos, historical data and information:

Babcock & Wilcox	Barberton Ohio-	USA
Babcock Noell GmbH	Würzburg-	Germany
Beltran Technologies	Brooklyn	USA
Fisia	Gummersbach-	Germany
Fluor Daniel	Irving	USA
Scheuch GmbH	Aurolzmünster	Austria
Vattenfall Power Consult	Vetschau-	Germany

B1CS Postfach 12 52 Weimarer Str. 9 **Tel.:** + 49 (0 27 61) 83 74 63