ECOPURE CATALYTIC CANDLE FILTER
THE NEW ALTERNATIVE FOR FLUE GAS TREATMENT

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Abstract

Energy efficiency is an important issue not just for the glass furnace but for the whole glass melting system. Part of this system is the flue gas cleaning. For this two questiona arise. First, which type of system to install to cope with environmental limits and second, where and how to implement any heat recovery.

Classic systems for dedusting are electrostatic precipitators or the more modern bag filters. Both are not the best solution if you want to recover energy in a heat exchanger downstream the system. The ESP keeps the high input temperature and requires no cooling in advance, but reaches only poor emission values, which reduce the efficiency of any heat exchanger downstream the ESP. A fabric filter requires a cooling to stay below the temperature limits of the fabric, which reduces the available energy downstream.
So the best solution is to keep the temperature of the gases high and achieve lowest dust emissions. This could be achieved by using a ceramic candle filter, suitable for high temperatures. As these are also coated with a catalyst, it is also possible to reduce NOx emissions without adding a separate SCR for DeNOx.

In the presentation the technology will be shown in detail as well as examples of realized systems. For the energy recovery various solutions will be considered, even ORC solutions to create electricity.

1. Current situation

In Germany, the draft for the new air pollution control regulations (*Technische Anleitung zur Reinhaltung der Luft,* TA-Luft) is currently under discussion, and new emission limits are now being formulated as recommendations. It may seem that these are only marginal changes to the state of the art, but for many industries, the new limit values represent the starting point for thinking about acquiring additional equipment, or alternatively implementing completely new exhaust air purification systems. The glass industry now needs to review the long-term suitability of existing technologies such as electrostatic precipitators based on the reachable clean gas values for dust as well as the question if any new technology for the treatment of NOx is required.

2. Environmental requirements in glass industry

In 2013 the European Integrated Pollution Prevention and Control Bureau (EIPPCB) presented the BAT report (best available technology) according the implementation of the Industrial Emissions Directive (2010/75/EU) article 13 of the Directive for the Manufacture of Glass. All member states (Belgium, Bulgaria, Denmark, Germany, Ireland, Spain, France, Italy, Luxembourg, Hungary, Netherlands, Austria, Poland, Portugal, Romania, Finland, Sweden, United Kingdom), as well as industrial associations representing the European glass manufacturers (CPIV, FEVE, Glass for Europe, APFE, European Domestic Glass, ESGA, EURIMA, ECFIA, ANFFE) worked on this report. It is now the basis for all local legislations, which have already or will be adapted.

The main drivers for thinking about new technologies for air pollution control systems are the following main emission values, which are common in many countries :

Type of pollutant	Common limit	Comment
Dust or particulate matter	10 mg/m³	This low value is up to now only achieveable with bag filters or well designed electrostatic precipitators.
PM10	In dust emissions	This will only be a major issue in housing areas and be part of future limits
NO_x	500 mg/m³	Only reachable with additional secondary systems like SCR or CCF.

Table 1: Main critical pollutants

Whilst dust and NO_x emissions are already part of of legal limits, PM 10 is not regulated yet as an emission. PM10 will be the pollutant, the legislation will concentrate on in the future, as this is relevant for the air quality and resposible for many human health problems, especially in crowded areas and in Eastern Europe (see Fig.2).

There are already limits for the immission, as shown in figure 1, The current yearly average limit in Germany is for example at 40 µg/m³.

The figure shows also that total particulate emissions (total sum of particulates, TSP) have been reduced already successfully, but PM 10 is still on a high value, or even increases. The main sources are traffic, fire places and heating as well as power plants and huge consumers of fossil fuel.

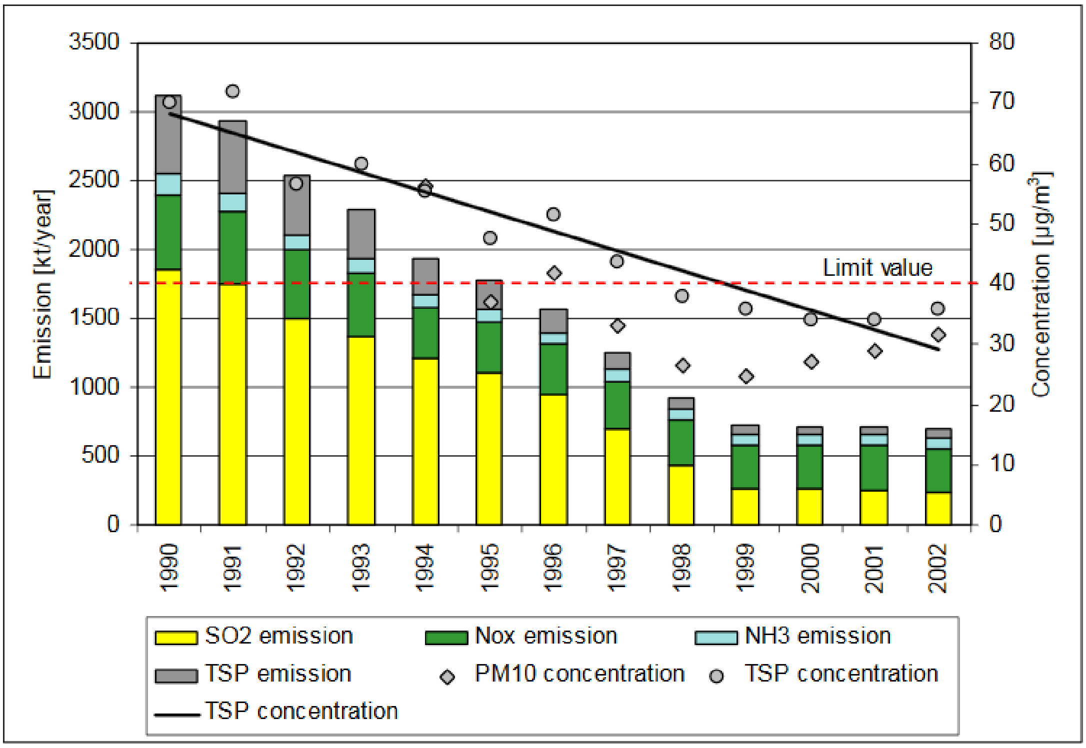

Fig 1: Trend of PM – emission and ambient air concentrations in the Czech Republic (source: Umweltamt Sachsen: Impact of particles on air quality in the region along the Czech/German border)

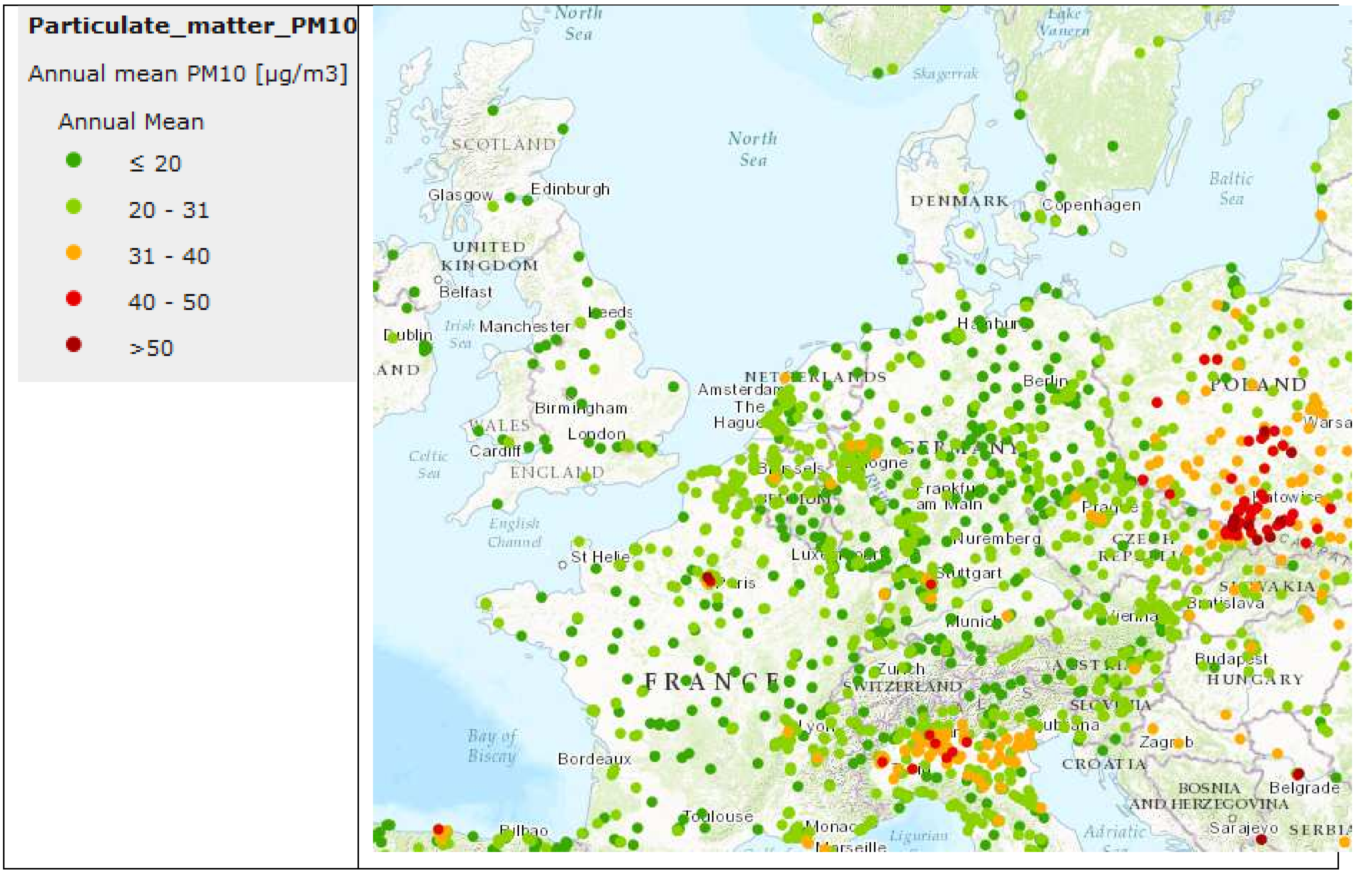

Fig. 2: Map of PM10 (source: http://www.eea.europa.eu/themes/air/interactive/pm10)

In case there will be future emission limits, this could also influence the glass industry.

3. Development of the technology

LTB and DÜRR have been active in many different fields of air pollution control. In the past years lots of SCR systems to control NOx emissions have been installed in various industries. At all these systems dust was a major concern as this would lead to a deactivation of the catalyst. So a pretreatment, realised as a filtering system , was included upstream to protect the SCR catalyst. But due to the filter material, suitable to realize lowest emissions, the temperature was limited to 220 - 250°C. As this temperature is not suitable for the SCR-catalyst the temperature has to be increased downstream by a heater or via a heat exchanger.

To improve such a system prefilters, suitable at higher temperatures, have been used. Filtering exhaust gases at high temperatures was already possible, using material, which could withstand temperatures more easy. Ceramic candle filters, made from aluminia silicates, were used already ten years ago in an exhaust air purification system at a hazardous waste incineration plant, which we supplied to German Army and also at a pyrolysis plant for electronic waste .

Fig. 3: Hazardous waste incineration plant with ceramic filters

So the first step to create a smarter solution was done, as we could keep the temperature at a higher level and the preheating is avoided.

The next step was then the combination of the ceramic candles with the SCR catalyst. The coating of the ceramic fibres with the catalyst was realized by the candle manufacturers.

Fig. 4: Catalyst particles on the surface of the ceramic filters

Fig. 5: Candle filter

The **Ecopure®** Catalytic Candle Filter (CCF) technology was optimized in our technolgical center in Bietigheim-Bissingen, where we could test the filters under realistic conditions and find the best fit of porosity and differential pressure.

On the other side, a solution using the conventional technology was considered. This consists of an electrostatic precipitator followed by a catalytic NOx abatement system employing a selective catalytic reduction (SCR) catalyst. While this SCR process would meet current limits, the used ESP would not meet the future stricter dust emission limit.

As another alternative for the use in glass plants was the usage of a bagfilter in combination with an **Ecopure®** SCR. Since this type of filter can only be operated at a maximum temperature of 220-250 °C owing to the filter media used, the raw gas, which usually has temperatures of more than 350 °C, has to be cooled.

For the subsequent DeNOx process, however, the optimum temperature is around 350 °C, which means the gas has to be heated again.

The high investment costs for the required heat exchangers and the operating costs of a heat transfer system, represented an excessive overall additional cost, and so this technology was rejected.

4. Solution

The **Ecopure®** Catalytic Candle Filter (CCF) technology makes it possible not only to comply with emission limits without additional cooling or heating processes, but actually keep emissions more than 50% below current limit values.
With this new technology, three pollutants are eliminated in one system, which translates into economic operating costs.

Dedusting

For the separation of dust the main focus is on the separation of very fine particles below a diameter of 10 micrometer, which could be seen as PM10.
This is the most important criteria for the design of the candles. Even it would work perfectly, the candles are not used as a deep filter technology, like classical HEPA filters. In these the fibers are in such a distance, that particles will be stopped in between. Considering that this would lead to a clogging of the filter our design is different. In Figure 4 it could be seen that the distance of the fibers could reach up to 20 µm. This would mean that smaller particles would go deep into the filter or even through it.
So there are two possible ways to cope with that. First we could adapt the distance of the fibers which would lead to much higher pressure drop of the candles. This would result in higher operating costs and would make the technology not economic.
Based on our experience in filter technology for paint shops, we use a precoating of the candles to coat the surface with a specific precoating material. The effect of such a precoating is similar to the production of water resistant clothings. Here also the basic fibre is coated with small particles to decrease the size of free openings and to reduce porosity. So particles or water droplets could not enter the fibre.
For the precoating, which is realised once during commissioning, we use a specific inert powder, which has a well defined particle diameter. So we coud ensure that the candles withhold fine particles and reach lowest emission values but the pressure drop will stay nearly constant for years.
Similar as in classical fabric or bag filters the cleaning of the candles is realised by compressed air, which is injected via the top of the candles from the clean gas side. This short impulse is stregthened via a venturi system. So the injected air volume is multiplied. The air flow is countercurrent to the flow of the flue gases and removes the sticking dust from the surface of the candle. Because the filter wall is much thicker in comparison to fabrics, these filters are rigid. This results in an extremely long service life, as the deformation during cleaning via a burst of compressed air, which causes wear in fabric filters, is eliminated. The filter’s rigidity means that a permanent filter cake forms on its surface. This contributes to

better filter performance and significantly lower cleaned gas values including for superfine particulates.

DeNOx

In the glass industry it is possible to reduce NOx emissions in various ways. Primary measures like Low NOx Melters or modifications in the firing system are possible to reduce NOx emissions. But in most cases these measures lead also to additional effects (f.e.. increased CO values) and limitations for the production process (f.e.. problems to reach a stoichiometric condition).

In secondary measures, like the established selective catalytic reduction (SCR) process, nitrogen oxides are removed via a reaction between injected urea or aqueous ammonia with NOx. Because of the catalyst, this reaction takes place at a relatively low temperature of 260 to 450 °C as shown in fig. 6.

Ecopure® CCF filters are coated with this catalyst material. The candles therefore perform the same function as the ceramic honeycomb in an **Ecopure®** SCR.

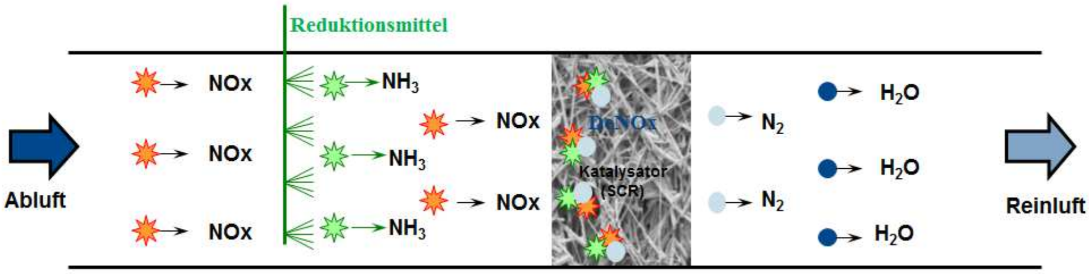

Fig. 6: NOx separation principle

The forced flow through the filter proves to be advantageous in this case. Unlike in conventional catalyst honeycombs, the mass transport processes of the reaction partners and products that occur help to improve the filter's performance.

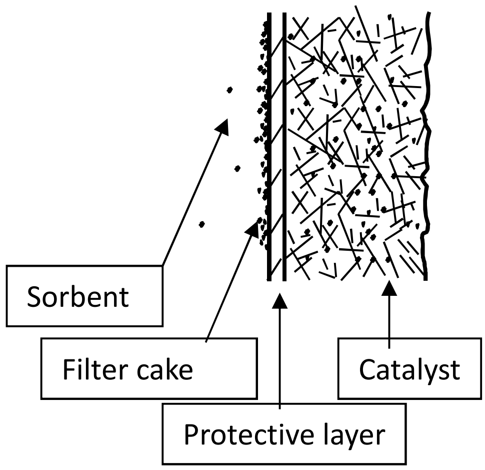

Fig. 7: Design of the catalyst, which is protected from dust

The catalyst is located on the inside of the filter wall (see fig. 7), protecting it from dust. This prevents the usual aging that occurs with other ceramic honeycomb elements due to the clogging of pores and reduction of the active surface area.

DeSOx and removal of acidic gases

Sulfur in many processes exists mainly as SO_2, which may be separated either wet or dry. With low pollutant concentrations, dry processes have become the preferred choice over highly efficient wet processes owing to their lower life-cycle costs. This technology is based on the reactivity of a sorbent such as calcium hydroxide $Ca(OH)_2$ with acidic constituents in the exhaust gas such as SO_2, HCl and HF. The reaction principle of SOx is showm in figure 8. Other sorbents like Sodium Bicarbonate (NaHCO3),also known as baking soda, could also be used in case lime products are not suitable for recirculation into the glass melting process.

In many applications, the technology described above has proven effective both with electrostatic precipitators and with fabric filters. For the desulfurization process to achieve good separation efficiency, a temperature of up to 180 °C and sufficient moisture are required. At higher temperatures, however, the reactivity of the calcium hydroxide decreases at first, before rising sharply again from about 300 °C upwards. This selective temperature-dependent behavior makes the use of calcium hydroxide particularly suitable for separating acidic compounds from exhaust gas in a temperature range that is favorable for the **Ecopure®** SCR DeNOx process mentioned earlier.

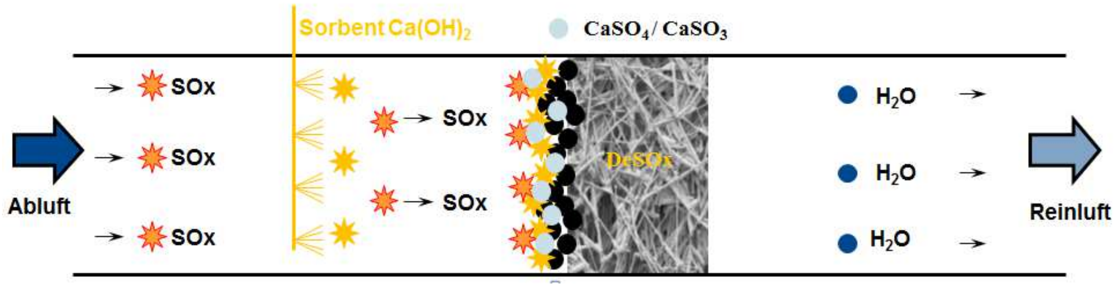

Fig. 8: Separation principle for acidic constituents in the gas, using SOx as an example

3-in-1 technology

As all three processes are combined in just one unit, the setup is very compact and allows space-saving installation within existing production facilities. The high efficiency of the individual processes delivers maximum separation efficiencies for all types of pollutant, meeting the latest requirements of the forthcoming German TA-Luft 2017 regulations particularly in respect of dust and nitrogen oxides. Integrating the three individual processes into the **Ecopure®** CCF system means lower maintenance costs and reduced space requirements. This results in lower operating costs.

The 3-in-1 technology has been well received especially in overseas markets, and is now available in Europe, where it has been included in the in the updated VDI 2578 standard as a best available technology.

5. Comparing technologies

Based on the requirement to treat various pollutants from a glass furnace there are currently three options available on the market. Existing electrostatic precipitators enable the use of a dedusting at high temperatures, but often have limited efficiency in terms of clean gas concentrations for dust. If these systems have not been upgraded by oversizing or higher electric fields, resulting in higher energy consumption, they usually reach clean gas concentrations of around 20 mg/m³. To ensure lower concentrations often bag filters have been used. The problem has been that for the use of a bag filter the temperature has to be reduced down to <250°C. This has been reached by adding ambient dilution air or by installation of a heat exchanger, either using the energy within the production or shifting it to the tail end to increase the temperature downstream the filter for using a SCR. The major disadvantage of such a heat exchanger is the poor efficiency due to the high dust load. These systems have to cope with the dust load of the furnace off gases, which created additional efforts for cleaning and maintenance.

Depending on the individual situation there are different criterias, shown in the following table 2, which should be considered when choosing a new solution for the flue gas treatment.

Type and criteria	ESP +SCR	Bag Filter & SCR	Ecopure® CCF
Required space	huge	medium	small
Dust emissions	medium	medium	best
Reduction of PM10	medium	medium	best
NOx emissions	medium	medium	best
Maintenance efforts	medium	high	best
Energy consumption	medium	high	best
Catalyst lifetime	medium	medium	long
Investment costs	low	high	medium
Recovery of energy downstream	medium	medium	best

Table 2 : selection criteria and effect for different flue gas treatment systems

6. References

Fig. 9: **Ecopure®** CCF

The first plant was realized in China for an American customer. They produce table wear in one glass tank. According to the authorities this is now the „cleanest table wear production in China“ as the emission values have been far below the project emission limits.

Pollutant	Project emission limits according to Chinese legislation	Upcoming expected TA-Luft limits in Germany
Dust	20 mg/m³	10 mg/m³
SOx	105 mg/m³	300 mg/m³
NOx	300 mg/m³	500mg/m³

Table 3: Air pollutant emission limits

In the meantime first plants have been built in Europe. These systems showed that the technology is usable also under critical conditions, for example at a plant with high Bor content of the glass. The dust emissions have been far below the limits and no plume was visible at the stack.

7. Energy efficiency

Besides the pressure drop of the system the most important factor is the usability of energy. Basically this is possible in all plants, as a heat exchanger could be installed in all kinds of flue gas treatment systems.

The most important question is the temperature level, which could be described best with an example. If we have an air flow at a temperature of 400°C compared to another one with 250°C the usable energy, considering a remaining temperature of 190 °C (due to risk of corrosion) will be 3.5 times higher. So it is worth wile to use a system, which could keep the temperature at the high level. The use of a heat exchanger downstream an **Ecopure®** CCF creates highest possible energy recovery.

Considering the long term efficiency of a heat exchanger the heat tranfer is depending on the conditions of the metall tubes. If these are clogged or coated with dust the heat transfer rate will decrease dramatically. The Ecopure® CCF ensures extremely low dust emissions, which enables the use of heat exchangers for a long time without cleaning or maintenance. The efficiency of this heat exchanger will be kept at highest possible rates and ensure a stable recovery of energy. This energy can be used for the extraction of thermal fluid, hot water or steam.

Another possible way is the production of electricity via an ORC process. By using a direct vaporisation of the heat transfer fluid thermal efficiencies of up to 20% could be reached.

Fig 10 DÜRR Cyplan ORC

8. Conclusions

To cope with future emission limits and to ensure a proper energy efficiency new ways for the treatment of flue gases are required. Lowest emission limits for NOx, particulate matter or dust as well as acid components like SOx, HCl and HF could be achieved with the 3 in 1 **Ecopure®** CCF catalytic candle filter. Due to the high usable temperatures and the low dust emissions a heat recovery could be easily installed and the whole system requires lowest maintenance efforts.

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