Reasons to Embrace "Next-Level" Control of Cement Air Emissions Using Ceramic Filtration

Ceramic filtration, both catalytic (UCF) and non-catalytic (UTF), is now a widely accepted solution for the control of stack emissions. The technology initially built-up extensive references throughout the glass industry, and has proven its versatility in meeting a variety of technical and regulatory drivers. Ceramic filter technologies are considered a Best Available Control Technology (BAT/BACT/BARCT/RACT) in industries across North America, Europe and Asia.

Ceramic filters are now a proven alternative to traditional technologies such as baghouses, ESPs and SCR systems to achieve high levels of NOx, SO2 and/or PM reduction at high temperatures, and are becoming increasingly cost-effective due to their high performance and lower operating costs when considered across the lifetime of the system.

The technology

Ceramic filtration technology originated from the desire to create a system with the efficiency of a fabric filter (with regard to PM removal), and the energy efficiency of an electrostatic precipitator (ESP).

In achieving high levels of NOx reduction, decades of experience in the coal-fired power industry have proven the longevity of Selective Catalytic Reduction (SCR) technology catalyst life in tail end downstream ceramic filters.

The major disadvantage when combining a baghouse with an SCR is the different flue gas temperatures required by both technologies. While most baghouses have a max temperature of 200 – 240˚C (400 – 450˚F), it is necessary to reheat the flue gas post baghouse to the desired operation temperature of the catalyst as shown in Figure 1. This is a major disadvantage, in light of efforts to limit CO_2 emissions.

With the ability to operate at temperatures up to 900˚C (1600˚F), ceramic filtration technology precludes the need for costly reheating requirements. This offers an advantage in combination with a waste heat recovery system; when installed downstream ceramic filters, heat exchangers for WHR have higher efficiency and lower operating costs.

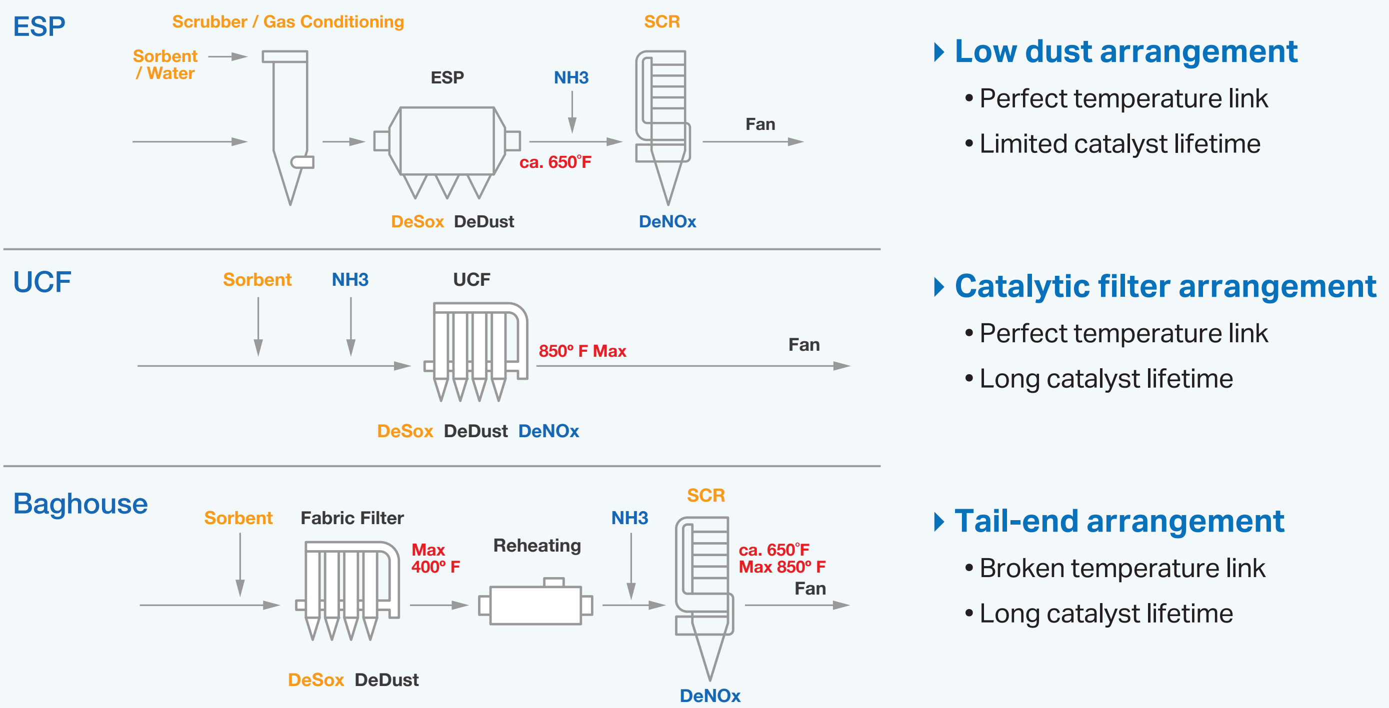


Figure 1. Comparison of temperature link and catalyst lifetime for ESP vs. UCF vs. fabric filter

Like the fabric (bag) filter, the ceramic filter has a tube-like shape ("candle") as shown in Figure 2 and works on the principle of barrier filtration. However, in contrast to fabric filter material, the ceramic fibers create a rigid filter wall, allowing the filter to build and maintain a residual layer, even during pulse jet cleaning, as shown in Figure 3.

This characteristic permanently moves the barrier filtration zone into the filter cake, preventing penetration of dust constituents into the filter wall. While this characteristic enables reduction of PM10 and PM2.5 to >99.99% levels, when catalytic filters are preferred, it fully protects the catalyst, which is finely dispersed on the ceramic fibers inside the filter wall, against plugging or poisoning. This ensures minimal degradation of the catalyst for the life of the ceramic filter, significantly minimizing costs associated with replacement or regeneration of catalysts within traditional SCR systems.

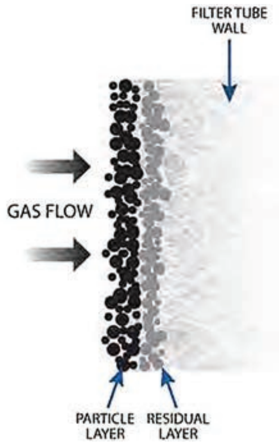


Figure 2 (left) Ceramic filter candles of different length.

Figure 3 (right) Principle of barrier filtration in the filter cake on residual layer.

The catalyst formulation used within ceramic filters can be tailored for different applications. Typical catalytic ceramic filters allow the control of organic hazardous air pollutants (O-HAPs), typically from the BTX aromatics group (benzene, toluene and xylene) and aldehydes, together with dioxins and furans by catalytic oxidation.

When injecting ammonia or urea, the catalyst will act like a typical SCR technology in controlling NOx with a high efficiency, as shown in Figure 4, according to the following chemical reactions:

$$NO + NO_2 + 2NH_3 \rightarrow N_2 + 3H_2O$$

(fast)

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$

(slow)

$$6NO_2 + 8NH_3 \rightarrow 7N_2 + 12H_2O$$

(slow)

The catalytic filtration process is completed with the addition of a dry sorbent for acid gas and aerosol control. At an elevated temperature, hydrated lime will typically be chosen for its excellent filtration properties and the ease of transporting reaction products, like calcium sulfate.

However, removal efficiency is not solely limited to the acid gas components like SO_2, SO_3, HCl or HF according to the below reactions, but also helps to control metal and heavy metal oxides as a precursor to Brønsted acids, like Se, Ar, Cr, Pb or Hg, and in combination with pulverised activated carbon (PAC) to a very low level.

$$Ca(OH)_2 + SO_3 \rightarrow CaSO_4 + H_2O$$

$$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$$

$$Ca(OH)_2 + 2HF \rightarrow CaF_2 + 2H_2O$$

The application: Adding functionality

Decades of experience with ceramic filtration for pollution control have driven significant advancements in the technology. One of the newest developments is within the ceramic filter (candle) itself, with filter lengths up to 6 m (20 ft).

This development has enabled the technology to be even more cost efficient when used on large gas volume flows, such as cement kiln exhaust. Additionally, these longer filter elements help with filter house design, reducing the footprint in constrained spaces. Although local regulations vary, there is a notable trend towards higher levels of reductions that exceed the capability of installed technologies.

Taking NOx regulations as an example, in areas of high industrial activity (and air pollution) regulations now require more stringent emission limits, as shown. In Germany, emission regulation changes have triggered the installation of 23 SCR-based systems since 2013, when new emission standards came into effect.

Depending on the design of the cement plant, different exhaust flows are leaving the cement kiln with a requirement for dust separation, like the main exhaust of the kiln (position 1 in Figure 5) to the stack, the chlorine bypass (position 2, Figure 5) and the clinker cooler (position 4, Figure 5).

Fabric filter baghouses have been the most common technology installed for efficient production and raw material recovery in the clinker cooler and main kiln exhaust. As described earlier, both gas streams have to be conditioned in order not to exceed the operational temperature limit of the fabric filter bags.

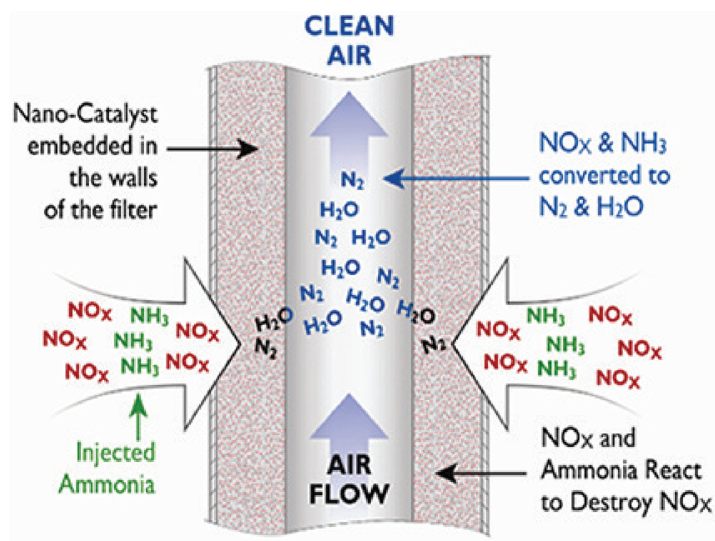
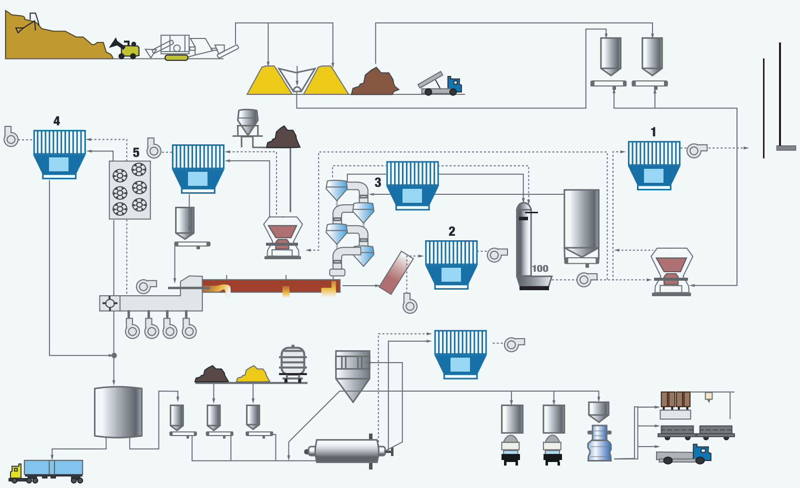


Figure 4. Chemical reaction between gas constituents while passing through the catalytic filter wall (example SCR DeNOx reaction).

Since the clinker, driven by product properties, has to be indirectly cooled by an air cooler (position 5 in Figure 5), utilising ceramic filters at increased filtration temperature instead of bag filters can be highly attractive, with a return of investment (ROI) from saving power through elimination of the cooler. Since the introduction of high temperature ceramic filtration technology in Europe in 2015 (Italcementi), the development of longer filter elements has resulted in a number of additional installations of 6 m non-catalytic ceramic filter elements for clinker recovery in Europe.

The bag filter in the kiln main exhaust (position 1 in Figure 5) is another location for raw material recovery where ceramic filtration can provide added benefit. Depending on the source of raw material, it has the potential to release organic trace compounds while heated. Most of these trace compounds fall into the class of organic hazardous air pollutants (O-HAPs), consisting of aldehydes and aromatics. The embedded catalyst within the ceramic filter wall has the capability to reduce the O-HAPs emission by 90% without further fuel consumption as necessary for alternative thermal oxidizers.



The ceramic filtration system can be:

- **Added upstream** of the exhaust gas cooler, maintaining the existing bag filter just upstream of the stack (position 3 in Figure 5) for dust emission control. This design has been realized in one US application

or

- **Retrofitted** within the existing baghouse, replacing the existing bag filter just upstream of the stack (position 1, Figure 5) for integrated O-HAPs and dust emission control.

Figure 5. Cement plant with typical installation location for dust separation equipment

Among other factors, the design will depend on the temperature rating of existing downstream equipment, like raw mill or ID-fans. The same design considerations will determine whether the addition of a NOx control based on the principle of SCR would be appropriate; this would require the addition of aqua ammonia storage, dosing and injection equipment.

The bag filter in the chlorine bypass (position 2, Figure 5) is another potential location to add NOx control functionality, especially when combined with other techniques for NOx reduction, such as SNCR, or when the control level of the required NOx reduction is moderate.

The best path forward depends on many considerations. An engineering study to assess existing equipment and site limitations and develop a cost/benefit model is highly useful. This will ensure that a solution is considered that uses existing equipment, thus reducing capital expenditure, and operational cost.

Conclusion

Ceramic filtration technology is a proven solution that has the experience and flexibility to address regulatory requirements for the cement industry. Where cement plant design allows, integration of ceramic filtration technology into existing equipment ensures enhanced performance, while preserving as much existing infrastructure as possible.

Experience shows that the filter elements can operate for more than 10 years without replacement or catalyst degradation.

In summary, certain industries have already adopted ceramic filtration technology to meet present emission control requirements, while allowing clients to upgrade their systems to meet future requirements with reduced effort and cost. The cement industry is at the starting line to embrace ceramic filtration technology as a tool to balance costs in a CO_2 neutral manner and achieve the next level of emissions control.

About the author

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