Ceramic FILTER Systems

➤ Controlling furnace emissions with low-density ceramic filters is a crucial part of glass manufacturing.

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Glass plants have used ceramic filter systems for the control of furnace emissions for almost four years. The companies that first adopted the technology on a commercial scale have elected to build additional systems, and other companies have followed. Ceramic filter systems are currently operating or under construction in Europe, Central America, the Middle East and the U.S. Systems using low-density rigid ceramic filters for other hot gas applications are found wherever there is a need to remove particulate matter (PM), SO$_x$ and NO$_x$ using a single pollution control device.

Testing and Initial Success

Low-density ceramic filters, often called “candles” because of their solid tube shape, have been used in pollution control to remove PM and acid gases since the late 1980s. The additional capability to reduce NO$_x$ became available in 2005, when Clear Edge Filtration embedded filter walls with micronized selective catalytic reduction (SCR) catalyst.

Test results for ceramic filters on glass were first reported by Gary Elliott and Andrew Startin. Test results for the pilot unit were given, and the authors came to this conclusion: “The employment of low-density ceramic filter elements for pollution control and product recovery applications is now well-established. The principal benefits of ceramic elements are high filtration efficiency and high temperature capability, now allied with a catalyst capable of removing NO$_x$. These benefits can most effectively be utilized to treat the gases associated with glass furnaces.”[1]

The status of the full-scale operational system was commented on by David Gambier of Maguin SAS and Guy Tackles of Saint-Gobain: “Based on ceramic filters, the technology allows the treatment of all pollutants in a single unit and at a range of temperature from 260°C to 400°C. It is particularly well-suited to the needs of the glass industry and has already been installed at two European plants. Performance achieved with particulates in this temperature range cannot be matched by other technologies. As for the neutralization of acid gases, reagent consumption is much lower with the CerCat filter than with electrostatic precipitation (ESP), to achieve the same set of results.”[2] Test results were published in 2011.[3]

With the success of the first systems, other sites selected the technology. There has been a sharp upswing of projects for tableware, container and flat glass as the advantages of these systems have become more widely known in the glass industry.

Catalyst Filters

Two types of filters are currently available: standard filters can remove PM or PM+SO$_2$ (and are efficient on heavy metals); and catalyst filters can destroy NO$_x$ in addition to removing the other pollutants.

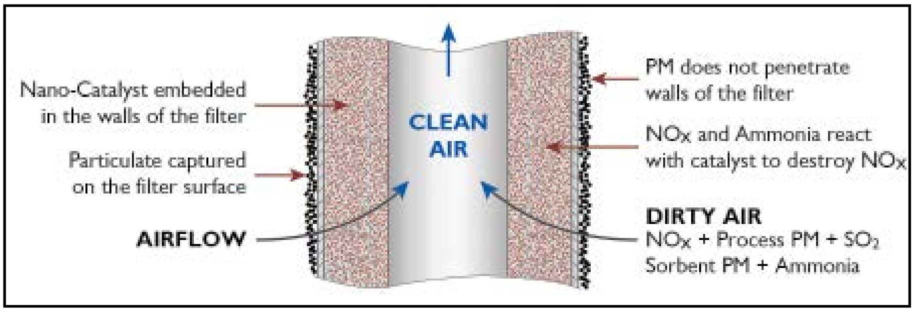


Figure 1. Nanobits of proprietary catalyst are distributed through the filter walls. With upstream ammonia injection, NO$_x$ is destroyed at the surface of the micronized catalyst.

Catalyst filters feature the same fibrous construction as the standard filters but have nano-bits of catalyst embedded throughout the filter walls. This is not a just a layer of SCR catalyst, but a distribution across the entire wall thickness that creates a very large catalytic surface area. The walls that contain the catalyst are about ¾ in. (20 mm) thick. Ammonia is injected upstream of the filters and reacts with the NO_x at the surface of the micronized catalyst to destroy the NO_x, as shown in Figure 1 (p. 23).

An analysis comparing the effectiveness of this catalyst with that of conventional catalysts was presented by Peter Schoubye and Joakim Reimer Jensen of Haldor Topsoe A/S: "The catalyst particles are micro-porous and due to their small size, they catalyze the gas phase reactions without diffusion restriction (i.e., almost 100% utilization of the catalyst's intrinsic activity), as opposed to usual pellet or monolithic catalysts. In industrial plants, the conventional catalyst types typically operate with 5-15% catalyst effectiveness in the SCR (selective catalytic reduction of NO_x by NH_3), and with even lower catalyst utilization in dioxin destruction."[4]

System Design Criteria

The filter elements have been manufactured in various lengths, but it is the latest generation of 3 m (10 ft) filters that make industrial applications practical. The filters are placed in a housing module configured identically to that of a reverse pulse-jet baghouse.

Furnace emissions enter the bottom of the housing. Process particulate and sorbent are captured on the filter surfaces, and NO_x is destroyed as the flow passes through the filters. Cleaned air passes up through the center of the filter tubes and out the space above (see Figure 2). Each housing has a footprint of 440 sq ft, roughly 10 ft wide and 44 ft long. Multiple housings are operated in parallel for correspondingly larger flow volumes (see Figure 3). A single housing accommodates approximately 150 tons per day of glass production for air-fuel furnaces and 300-400 tons per day for oxy-fuel furnaces (see Figure 4).

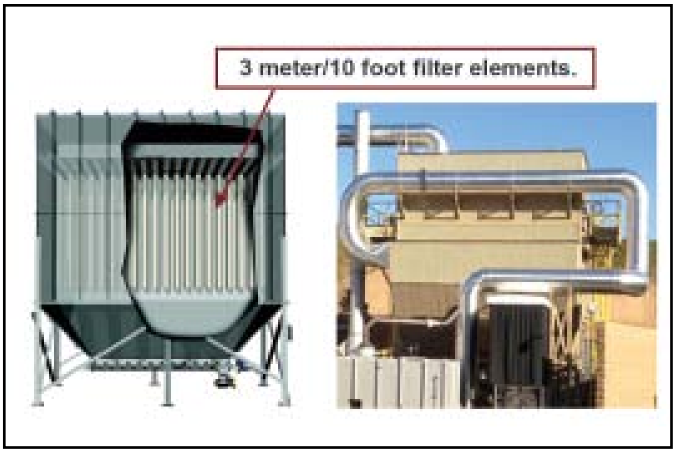


Figure 2. A single housing module containing 3-m filter elements.

Figure 3. Multiple housing modules are operated in parallel to handle large volumetric flow rates.

It is important to note that the modular design of the housing units allows filters to be configured to handle even the largest gas flow volumes. The modular nature of the system also provides redundancy, so that a single module can be taken offline while the other modules receive the flow. The system temporarily operates at a slightly higher pressure drop, which the fan design accommodates. The pollution control system does not compromise the uptime of the facility.

Pollutant Control for Glass

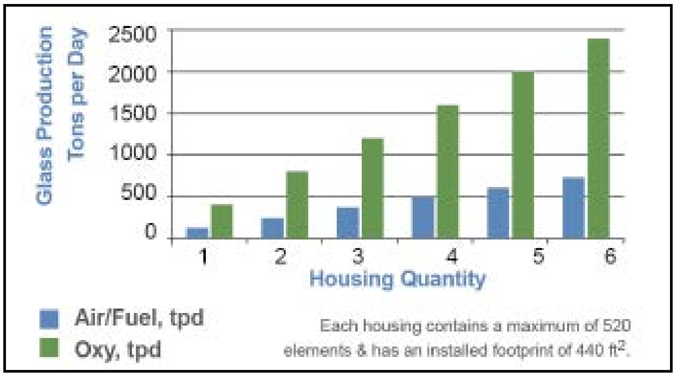
The typical level of particulate material at the outlet of the ceramic filters is less than 0.001 grains/dscf (2 mg/Nm^3) based on a spectrum of different applications. Particulate results for glass have been shown to be less that 5 mg/Nm^3.[1,3]

With the exception of mercury, heavy metals are captured at the same rates as other particulate (over 99%). There is no selective lack of capture, as is sometimes reported in other devices.

Particulate is captured on the face of the filter and does not penetrate deeply into the filter body, thus facilitating repetitive and complete cleaning. This important quality is enhanced by pretreatment with a coating powder during startup. As a result, over the life of the filter, the pressure undergoes a very gradual increase, which averages about 5 in. water gauge at startup for a typical system.

At some point, when pressure has increased several inches (generally in the 5-10 year range), companies replace the filters when it makes sense in terms of operational cost in fan power. In this respect, filter life is considered to be 5-10 years across a wide range of applications. Observations and measurements of the first ceramic filter system installation in a glass plant (which began operating nearly four years ago) lead to the expectation that this typical filter life will hold for glass emissions.

Conventional reverse pulse-jet methods are used for filter cleaning. Compressed air is pulsed down the center of the tubes to clean the accumulated PM from the outer surfaces. PM falls to the bottom of the hopper and is removed. Filters are cleaned on-line, staggered within each housing module to prevent dust re-entrainment, with no need to isolate individual modules. The required amount of com-



Each housing contains a maximum of 520 elements & has an installed footprint of 440 ft².

Figure 4. Number of filter housings required for oxy and air/fuel glass production. Flexible configurations fit into existing space restraints.

pressed air is very small; each filter is cleaned about once per day.

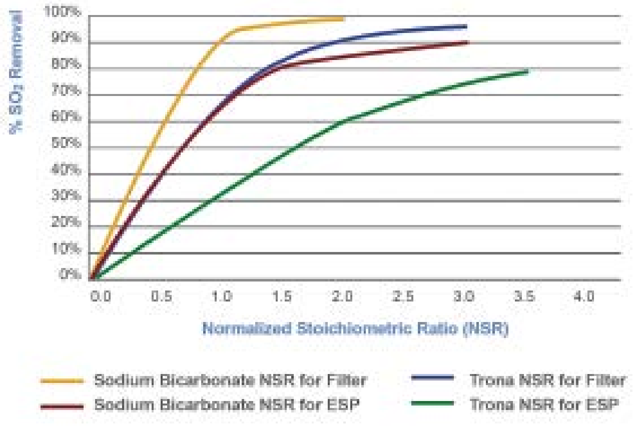
Ceramic filters, like fabric filter baghouses, can use the dry injection of calcium or sodium-based sorbents for the removal of acid gases. Lime is the typical calcium-based sorbent. Sodium bicarbonate (baking soda) and trona are typical sodium-based sorbents. Trona is the naturally occurring ore from which soda ash and sodium bicarbonate are produced. When properly milled, trona can be used as a dry sorbent with no other processing required; it is available throughout North America.

Injected in the duct, upstream of the filter modules, the additional sorbent particulate is easily captured along with its pollutant gas. The reaction occurs within the duct prior to the filter and on the cake that builds up on the filter surface. The chemical reaction of the sorbent with the acid gas creates a solid particle that is captured on the filters alongside the unreacted sorbent and process particulate.

The existence of a sorbent cake on the filters increases the exposure of the SO_2 to the sorbent and increases the removal rate. For a given removal efficiency, the filters require significantly less sorbent than ESP, which can result in a large savings in sorbent costs (see Figure 5, p. 26).

With sorbent injection, SO_2 removal is typically in the range of 90% for glass applications. Previously reported results showed 85% efficiency using lime, easily meeting the project requirement.[3] Lower requirements equate to less sorbent and cost. HCl is preferentially removed at a higher rate than SO_2.

NO_x control is being required for air-fuel furnaces. In addition to the need for high temperature, a common problem with



*Courtesy of Solvay Chemicals, Inc., supplier of sodium bicarbonate and trona for industry.

Figure 5. Filter vs. ESP sorbent usage for SO_2 removal. (Comparison of SO_2 removal efficiency achieved by filter systems and ESPs with various normalized stoichiometric ratio values of sodium bicarbonate and trona. Data courtesy of Solvay Chemicals, Inc.)

traditional SCR is that the catalyst becomes "poisoned" and ineffective, necessitating early replacement. Typical poisons are ordinary PM, metals and HCl. The catalyst embedded in the filters has a proprietary formulation with a fraction of the conversion rate of SO_2 to SO_3 of traditional SCR catalysts. This catalyst is not sensitive to SO_2 poisoning.

The catalyst is almost completely protected from particulate blinding by being inside the filter itself. Moreover, the reaction of the ammonia and NO_x at the catalyst surface, while the same as conventional SCR, benefits from more contact time because the mixture of gases does not have to diffuse in and out of the "big block" catalyst pores. Eliminating the "diffusion restriction" helps reduce the slippage of untreated gases.[3] NO_x destruction greater than 85% has been reported in the literature.[3]

Operating Temperatures

For PM control only, standard filters can operate at temperatures of 300-1650°F. For PM plus SO_2/HCl, the range is narrowed by the chemistry of the sorbents to 300-1200°F.

NO_x control imposes other constraints. One important feature of the NO_x filters is an operating range that is lower in temperature compared to conventional big-block SCR. Conventional SCR requires at least 650°F for high removal. For applications requiring NO_x removal in the presence of SO_2, the lower operating temperature is 450°F to avoid the formation of ammonium bisulfate at the catalyst; the upper operating temperature is 700°F (see Table 1).

Table 1.
Temperature ranges for the operation of low-density ceramic filters.

Filter	Pollutants Removed	Temperature Range (°F)
Standard	particulate matter	300-1650
Standard	PM + SO_2 + HCl	300-1200
Catalyst	PM + SO_2 + HCl + NO_x	450-700

Cooling the gas to the operating temperature range is required on some applications and is accomplished with dilution air or water spray quenching. Spray cooling the gas has the added advantage of reducing the actual cubic feet per minute (ACFM) and thus reduces the number of filter elements and the size and cost of the entire system. This is another benefit of the effective lower temperature range for NO_x of the catalyst filters. Certain heat recovery approaches also become more feasible.

Configuration Options

Various configurations can be used, depending on the application (see Figure 6). Filters achieve much higher particulate removal than ESP. For similar performance, total cost of ownership is competitive with ESP-based systems, but more expensive than fabric filter baghouses.

For SO_2 and HCl, the filters use the same dry sorbent injection equipment as ESPs and fabric filter baghouses. As shown in Figure 5, the consumption of sorbent is significantly lower

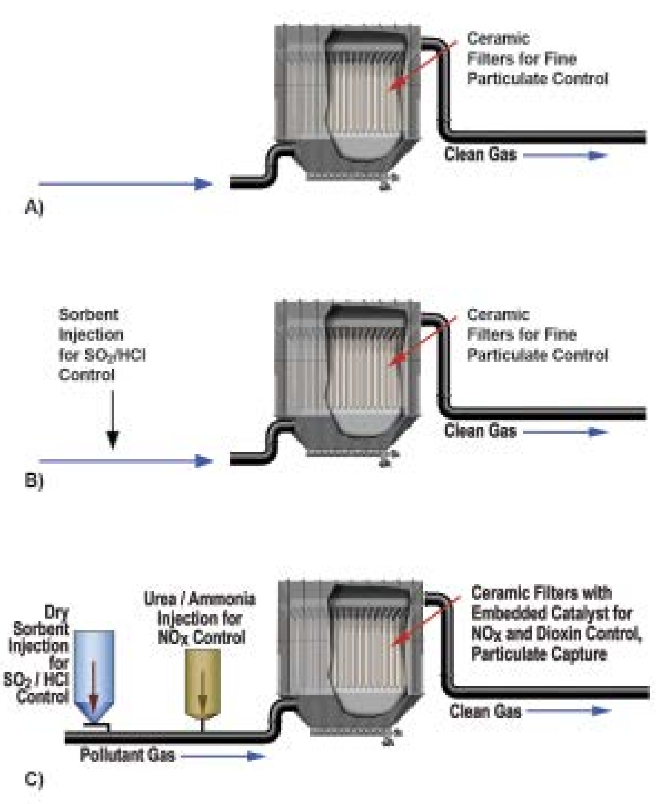


Figure 6. Various configurations can be utilized, depending on the application: A) standard filtration system for control of PM; B) standard filtration system for control of PM and SO_2; and C) catalyst-embedded filters for control of PM and SO_2, as well as HCl and NO_x.

for a given performance level for the ceramic and fabric filters compared to ESP because a sorbent layer on the filters enhances reaction contact. Sorbent costs, including storage and handling, are a major consideration in evaluating the total cost of ownership.

A catalyst-embedded filter is necessary in order to also control NO_x. This eliminates the need for a separate "big-block" conventional SCR that electrostatic precipitators require. The catalyst-embedded ceramic system can operate at lower temperatures for NO_x destruction while maintaining high removal efficiency. Ammonia slip is kept below regulatory limits. Eliminating the cost and complexity of a stand-alone SCR—including the temperature issues, pressure drop, ducting and added controls—makes the all-in-one PM + acid gases + NO_x approach very attractive.

During the last four years, the glass industry has recognized the merits of the technology and responded with rapid adoption.

Proven Solution

Standard ceramic filters have been used for PM control by the U.S. military at munitions destruction facilities in Indiana, Utah, and Oklahoma for the last 12 years, and hundreds of ceramic filter systems are operating worldwide. With the additional capability of NO_x control, the filter systems have become the technology of choice for an even wider range of applications.

During the last four years, the glass industry has recognized the merits of the technology and responded with rapid adoption. Developments in ceramic filter technology offer the glass industry a powerful, proven strategy for meeting the regulatory requirements that have resulted from an increasing federal and state focus on glass furnace emissions.

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