

POLLUTION CONTROL SOLUTIONS FOR AIR, WATER,
SOLID & HAZARDOUS WASTE



JANUARY 2012

ONE SYSTEM TO CONTROL THEM ALL



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Advanced AIR POLLUTION CONTROL in One System

Unlike other filter systems, advanced, low-density ceramic filter systems are now capable of removing particulate matter (PM), NO_x, SO₂, HCl, dioxins and mercury, all within a single system.

By KEVIN MOSS

Advanced, low-density ceramic filter systems are capable of removing particulate matter (PM), NO_x, SO₂, HCl, dioxins and mercury in a single system. Particulate matter is removed to ultralow levels (less than 2 mg per Nm³, 0.001 grains per dscf), while other pollutants can be eradicated at percentages greater than 90 percent.

Ceramic filters

Ceramic filters, often called candles because of their solid tube shape, have been used in pollution control systems for decades.

The original high-density candle filters were manufactured from refractory grains, including alumina or silicon carbide, and pressed into a basic candle shape – a tube with a closed, rounded bottom and a flange

at the top. Newer, low-density filters start as a slurry of refractory fibers and are vacuum formed. The contrast between each of these types of ceramic filter elements is shown in Table 1.

There are currently hundreds of applications of these types of filters in Europe, Japan and Australia. Each of these filters can be placed in a housing module similar to a baghouse (see Figure 1).

These lightweight ceramic filters solve many of the problems that are generally associated with “candle filters.” While effective, the latter were brittle and prone to cracking and breakage from thermal shock and vibration. As shown

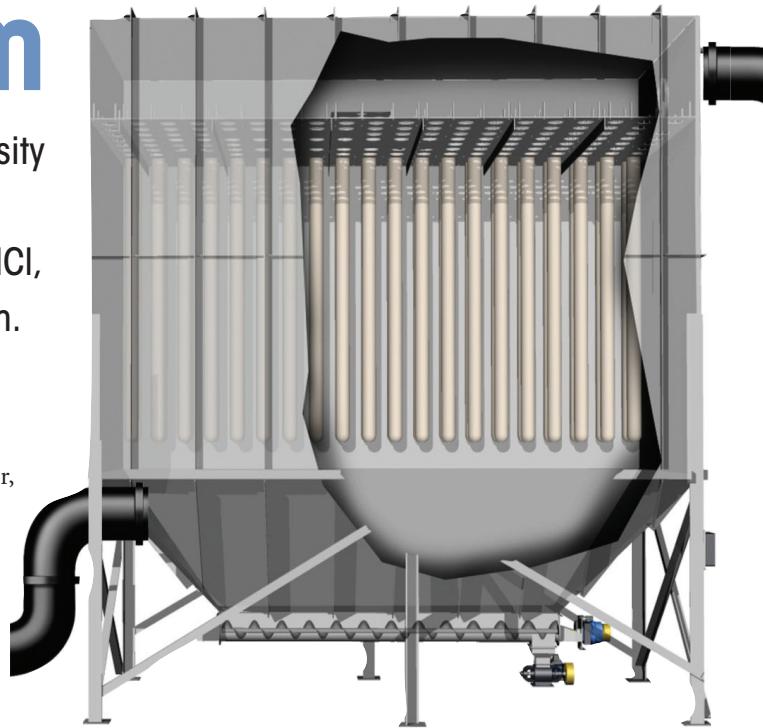


Figure 1: Many filters placed in a single module. Multiple modules are operated in parallel to handle large volumetric flow rates.

in Figure 2, the fibers maintain a very high, open area for low resistance to airflow, minimizing pressure drop and the number of elements required for a given flow rate. Due to the high, open area, elements can also be cleaned using the standard reverse pulse-jet techniques

Contrast between types of ceramic filter elements

Characteristics of high- and low-density ceramic-filter elements

	High density	Low density
Structure	Granular	Fibrous
Density	High	Low
Filter Drag	High	Low
Porosity, % (Inverse of resistance to flow)	0.3 - 0.4	0.8 - 0.9
Tensile strength	High	Low
Fracture mechanism	Brittle	Ductile
Thermal shock resistance	Low	High
Cost	High	Low

Characteristics of low-density fibrous ceramic filter elements

Form	Monolithic rigid tube
Composition	Refractory fibers plus organic and inorganic binding agents
Porosity	About 80 - 90%
Density	About 0.3 - 0.4 g/cc
Support	Self-supporting from integral flange
Geometry	Outer diameter up to 150mm (6 in.) Length up to 3m (10 ft.)

Left: Table 1, Above: Table 2

that are associated with fabric filter baghouses (see Table 2).

Operating characteristics

Ceramic filters must operate above the

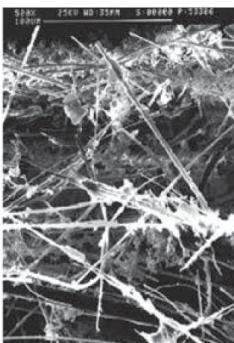


Figure 2: Micrograph of filter elements composition.

condensation temperature of the pollutants, or else the particulate will not be released from the filter surface, unless the temperature is raised and the material volatilizes, thus cleaning the filter.

Table 3 shows typical oper-

ating temperatures for the ceramic filters. The filters are chemically inert and highly corrosion resistant. Tri-Mer manufactures two varieties of filters: standard UltraTemp filters and UltraCat catalyst.

The catalyst filter is identical to the standard filter, except that it has nano-bits of selective catalytic reduction (SCR) catalyst embedded in the filter walls for NO_x removal and dioxin destruction.

Particulate control

The typical level of PM at the outlet of the ceramic filters is less than 0.001 grains per dscf. This is accurate even with heavy inlet loadings of several thousand milligrams per cubic meter. PM is captured on the face of

the filter and does not deeply penetrate into the filter body, thus allowing for repetitive and complete cleaning. The filter does not blind, and the pressure tends to drop very gradually, typically lasting five to 10 years, to the point at which filters should be changed. Pressure drop for the new clean filter is approximately six inches w.g. The pressure drop can be lowered by adding more filter elements, and capital cost can be reduced by decreasing the filter count at the expense of fan horsepower.

As a result of the filter construction, standard reverse pulse jet methods can thoroughly clean accumulated PM from the outer surface of the tube. Filters are cleaned on-line, with no need to isolate each housing module.

The filters are effective across many particle sizes, but are most often used when there is a large fraction of PM2.5 and sub-micron particulate at high temperatures (see Table 4).

SO₂ and acid gas control

Both filter systems feature an option for dry injection of calcium or sodium-based sorbents. Injected in the duct upstream of the filter modules, additional sorbent particulate is captured along with its pollutant gas. The sorbent must be milled to a small

Typical operating temperatures for the ceramic filters

Temperature range of operations

Filter name	Pollutants removed	Temperature Range
UltraTemp Standard	Particulate matter (PM)	300°F to 1650°F
UltraTemp Standard	PM + SO ₂ , HCl, or other gases	300°F to 1200°F
UltraCat Catalyst	PM + NO _x . Dioxins also destroyed	350°F to 700°F
UltraCat Catalyst	PM + NO _x (+Dioxins) + SO ₂ , HCl & other acid gases	350°F to 700°F

Table 3

particle size to maximize surface area for maximum reactivity. The reaction occurs within the duct, prior to the filter, and at the filter cake that builds up on the surface of the filters. The chemical reaction of the sorbent, along with the acid gas, creates a solid particle that captured on the filters alongside the unreacted sorbent and the process particulate.

With sorbent injection, SO₂ removal is typically 90 percent or higher, with removal efficiencies as high as 97 percent. On the other hand, HCl removal is normally 95 percent, and often as high as 99 percent. The temperature range for effective removal is 300°F to 1,200°F (See Figure 3 on next page).

Sodium bicarbonate and trona are typical sodium-based sorbents. Trona is the ore from which soda ash and sodium bicarbonate are produced. When properly milled, trona can be used as a dry sorbent, requiring no other processing, and is available throughout North America.

Ceramic filters are most effective where there is a large fraction of PM 2.5 and submicron particulate

Efficiency of fibrous ceramics filter elements in various applications

Process	Particle size $d_{50}^1, \mu\text{m}$	Inlet PM loading		Outlet PM loading		Inferred efficiency
		mg/Nm ³	gr/dscf	mg/Nm ³	gr/dscf	
Aluminum powder production	<50	550	0.24	<1	<0.0004	99.9
Nickel refining	<10	11,800	5.16	<1	<0.0004	>99.8
Smokeless fuel production	4.8	1,000	0.44	1.5	0.0007	99.9
Zirconia production	1.2	8,000	3.5	0.8	0.0003	99.85
Secondary aluminum	<1.0	870	0.38	0.5	0.0002	>99.99

¹Diameter of median size particle

Table 4

NO_x and dioxin control

For NO_x or dioxin removal, catalyst filter elements are available with nano-bits of SCR catalyst embedded in the walls. The filter walls containing the catalyst are about 3/4 inch (20 mm), as represented in Figure 4. Urea, or ammonia, is injected upstream of the filters. The embedded catalyst then

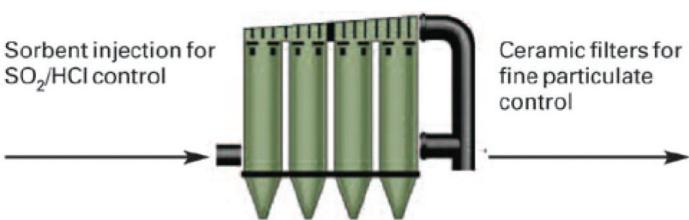


Figure 3: Standard filter system for control of particulate, SO₂, HCl, and other gases

destroys NO_x, with up to 95 percent removal efficiency.

Of note, the operating temperature required for high NO_x destruction is 350°F to 400°F, compared to 600°F to 650°F

for conventional SCR. Besides the need for high temperature, a common complication regarding traditional SCR is that the catalyst becomes poisoned and ineffective, necessitating early replacement. Typical poisons are ordinary PM, metals and HCl. The catalyst used in the filters is a proprietary formulation to improve performance.

The increased reactivity at lower temperature is partly due to their micronized form. The diffusion restriction is eliminated, and the catalyst is almost completely protected from blinding by particulate matter, since it is sheltered inside the filter itself (see Figure 5). PM removal, sorbent injection for SO₂ (and other acid gases) and catalytic reduction can be incorporated within a single system.

It is important to note that operating temperature for high NO_x removal must be kept between 350°F and 700°F to achieve NO_x removal rates up to 95 percent.

Dioxins are also broken down by the catalyst. Optimum performance for dioxins is limited to an upper temperature of 480°F. Destruction efficiency is typically 97 to 99 percent.

Multi-pollutant capability creates a powerful, all-in-one-solution that is superior, in performance and economics, to having a separate pollution control device for each pollutant. There is often insufficient temperature to operate a traditional SCR for NO_x removal. Low-temperature NO_x removal provides flexibility for industrial processes requiring control (see Figure 6).



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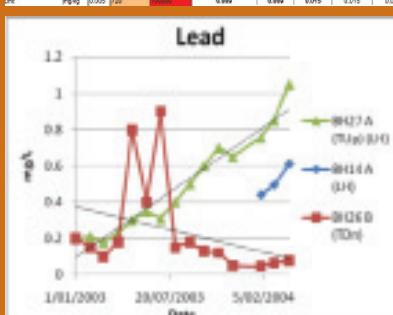
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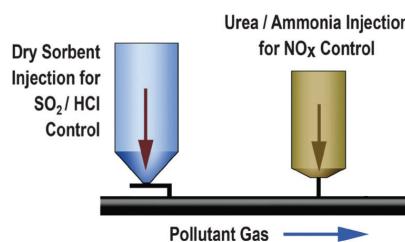
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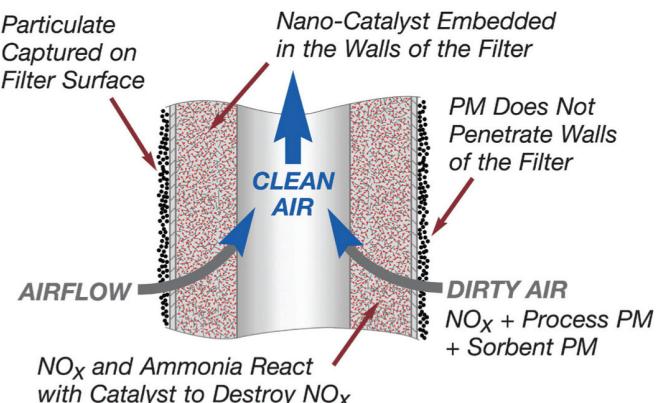


Figure 4: Ceramic fiber filter tube with embedded nano-catalysts

Mercury control

The ceramic filter systems are compatible with standard mercury removal techniques. Mercury control is notoriously difficult: each instance is individually analyzed and customized solutions are engineered. A few general observations can be made.

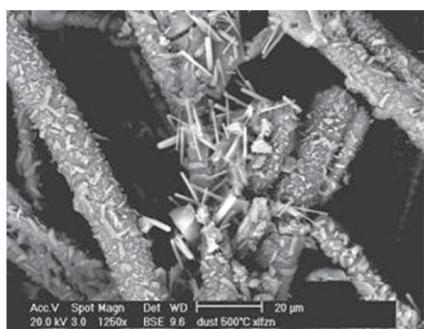


Figure 5: Micrograph of nano-catalysts embedded in ceramic-coated fibers

mercury. In general, regular PAC becomes less effective with increased temperature, topping out around 400°F. Under the right conditions, 70 to 80 percent control can be achieved. The chemical composition of the pollutant gas plays a major role. At higher temperatures, brominated PAC is required. According to the manufacturers of brominated products, temperatures of 500°F to 800°F are acceptable. Significant levels of mercury have also been captured in applications with injected powdered trona.

What conditions favor ceramic filters?

For particulate removal only, the standard ceramic filter can operate at temperatures as high as 1,650°F, exceeding the tempera-

The filters can handle high particulate loads while maintaining low outlet levels. Just as the addition of dry sorbents for the removal of acid gases is effective, so is the addition of powdered activated carbon (PAC) for adsorbing mercury. In general, regular PAC becomes less effective with increased temperature, topping out around 400°F. Under the right conditions, 70 to 80 percent control can be achieved. The chemical composition of the pollutant gas plays a major role. At higher temperatures, brominated PAC is required. According to the manufacturers of brominated products, temperatures of 500°F to 800°F are acceptable. Significant levels of mercury have also been captured in applications with injected powdered trona.

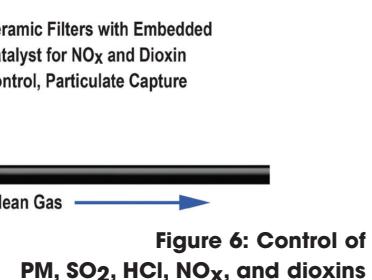


Figure 6: Control of PM, SO₂, HCl, NO_x, and dioxins

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ture range of fabric bags. If temperatures remain below 400°F and there are no special circumstances, the fabric bags are less costly than ceramic filters. In borderline cases, the ceramic filters have a much longer element life and often prove to be the most cost-effective solution.

In applications that require NO_x removal, since fabric bags and electro-

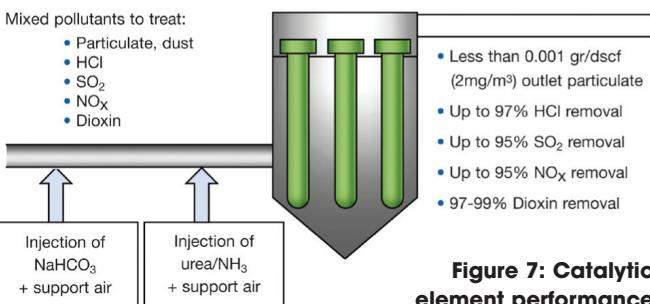


Figure 7: Catalytic element performance

static precipitators (ESPs) cannot control NO_x, catalyst filters are preferable. Ceramic filters also replace (ESPs) when there is a need for very low PM levels, especially for applications

with significant concentrations of PM2.5 and submicron particulate. The filters can handle much higher inlet loadings, are not subject to the selective removal constraints of ESPs, have lower maintenance requirements and fewer corrosion issues and are roughly equivalent (or lower) in energy usage. Because of the formation of filter cake on the filter surface, which provides more exposure to the acid gases, filter systems consume significantly less sorbent; consequently, higher removal efficiency can be achieved for acid gas removal. As stated, fabric bags and ESP do not remove NO_x or dioxins. Therefore, a second technology (perhaps with additional temperature control) would also be required. In contrast, the catalyst filter can handle all of the pollutants in a single device and at lower temperatures (see Figure 7).

The modular design of the housing units allows filters to be configured to handle large gas-flow volumes. When large flow volumes are treated, modules are placed in parallel. The systems are designed so that a single module can be taken off line if required, and the remaining two or more modules can continue to operate at a slightly higher pressure (designed into the fan) without interruption of the process itself, and with no appreciable change in emission control performance.

Lightweight ceramic filters have been used for the last 10 years by the U.S. military at munitions-destruction facilities in Indiana, Utah and Oklahoma. Hundreds of ceramic filter applications are currently located throughout the world. **PE**

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