CATALYTIC FILTERS DESTROY Air Pollutants

Figure 4: Multiple housing units operating in parallel provide redundancy and optimum uptime without compromising performance. Multi-housing system treating PM, SO_2, HCl, NO_X and metals

New catalytic filter technology provides important added flexibility in controlling PM, NO_X, SO_X and O-HAPS.

> BY TRI-MER CORP. OWOSSO, MICHIGAN

Catalyst-embedded ceramic filters offer a new technological capability of removing NO_X at lower temperatures, while simultaneously removing PM, SO_X and HCl. The technology also removes organic hazardous air pollutants (O-HAPS) THC, dioxins and mercury, all in a single compact system.

Applications for the technology include: the Cement NESHAP; Boiler MACT for coal; incinerator CISWI MACT; Hazardous Waste MACT; regulations on glass furnaces; ceramics manufacturing, including fracking proppants, kilns of all varieties; and thermal oxidizer clean up.

As regulations proliferate and become more stringent, the filters offer a powerful straightforward approach compared to a long train of stand-alone equipment. The advantages are not in performance alone, but in capital cost and operating expense.

Typically, PM is removed to ultralow levels (less than 2 mg per Nm^3, 0.001 grains per dscf), while other pollutants can be eliminated at levels greater than 90 percent.

European Successes Jump the Pond

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, dioxins and O-HAP THC became available in 2005 with the innovation of embedding filter walls with micronized catalyst.

With the success of the first systems in Europe, Japan and Australia, the United States now has regulations that require use of this advanced technology. There has been a sharp up-swing of projects as the capability of these systems has become more widely known.

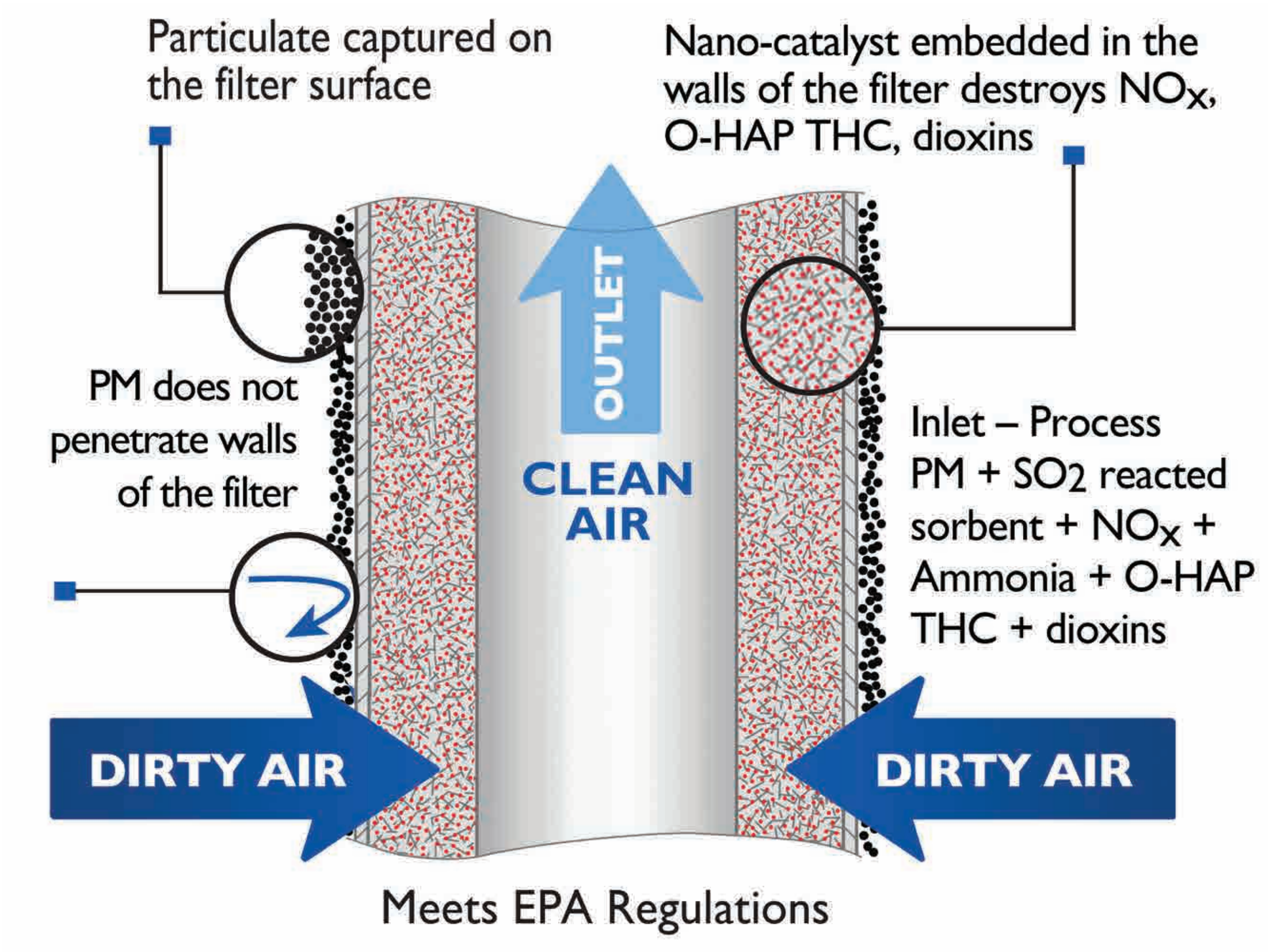

Figure 1: Nano-bits of catalyst in filter walls

Filter Types: Standard and Catalyst

Two types of filters are currently available from Tri-Mer Corporation. Standard UltraTemp filters remove PM or PM plus acid gases and metals, including mercury; UltraCat catalyst filters remove those pollutants while also destroying O-HAPS, dioxins and NO_X.

Catalyst filters feature the same fibrous construction as the standard version, but have nanobits of catalyst embedded throughout the filter walls. Distribution across the entire wall thickness, as opposed to just having a catalyst layer, creates a very large catalytic surface area accessible from all directions. The walls that contain the catalyst are about 3/4 inches thick. Ammonia is injected upstream of the filters and reacts with the NO_X at the surface of the micronized catalyst to destroy the compound. (**Figure 1**)

An analysis comparing the effectiveness of this nano-catalyst with that of conventional catalysts was summarized in a paper by Schoubye and 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 percent 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 percent catalyst effectiveness in the SCR of NO_X by NH_3 and with even lower catalyst utilization in dioxin destruction."

Another remarkable feature is low temperature activation. Substantial NO_X removal is initiated as low as 350°F, with over 90 percent removal as the temperature approaches 450°F.

System Design Criteria

Filter elements have been manufactured in numerous lengths, and the latest generation of 10-foot. filters makes even very large-scale applications practical.

Filters are placed in a housing module configured identically to a reverse pulse jet baghouse. The polluted airstream enters the bottom of the housing. Process PM and reacted acid gas sorbent PM are captured on the filter surfaces, while the NO_X and the injected aqua ammonia are transformed to harmless nitrogen gas and water vapor as the airstream passes through the filters. O-HAPS (Cement NESHAP) and dioxins (CISWI and HW MACTS) are broken down without the addition of ammonia. Cleaned air passes up through the center of the filter tubes and out of the space above. (**Figures 1, 2 and** 3) Single housings with multiple filters are manufac-

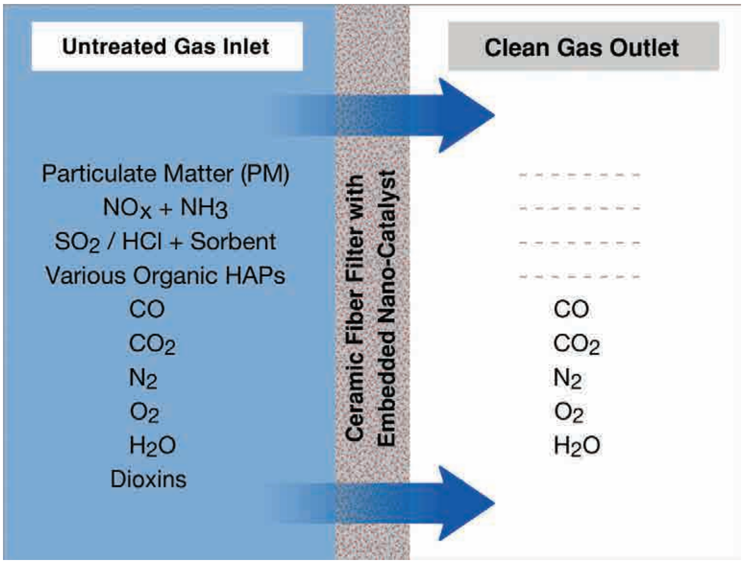

Figure 2: Catalyst filters simultaneously treat multiple pollutants

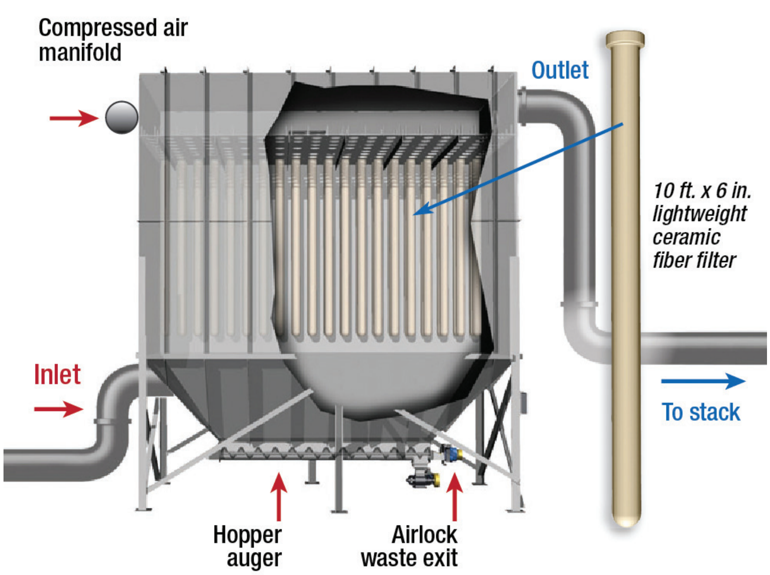

Figure 3: A single housing module containing 3-meter-long filter elements

tured in custom sizes to accommodate individual project airflows. Multiple housings are operated in parallel for correspondingly larger flow volumes.

Notably, the modular design of the housing units allows filters to be configured for 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 takes into account.

Placing multiple plenums in parallel provides built-in redundancy to maximize uptime. The system is designed so that if one plenum needs to be taken offline for service, others treat the entire flow at a temporarily higher pressure with no change in performance. Thus, the pollution control system does not compromise the uptime of the facility.

Particulate is captured on the face of the filter and does not penetrate deeply into the filter body, thus facilitating repetitive, complete cleaning. At start-up, the pressure drop is 4 or 5 inches w.g. Over the life of the filter, the pressure undergoes a very gradual increase, which averages 3 to 5 percent per year.

After many years of continuous operation, pressure drop will have increased several inches and companies will elect to replace the filters when it makes sense in terms of energy cost, rather than because of decline in performance. Even if the filters have the embedded catalyst, the need for replacement is usually due to an increase in pressure drop, rather than any significant change in catalyst effectiveness. In general, filter life is five to 10 years on a range of applications.

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, but with no need to isolate individual modules. The amount of compressed air required is minimal.

Standard Filter: Typical Pollutant Control

Particulate: 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.

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

SO_2, SO_3, HCl, other acid gases: Ceramic filters, like fabric filter baghouses, can use the dry injection of calcium or sodium-based sorbents for the removal of acid gases. Hydrated lime is the typical calcium-based sorbent. Sodium bicarbonate (baking soda) and trona are typical sodium-based sorbents.

Injected in the duct upstream of the filter modules, the additional sorbent particulate is easily captured along with its pollutant gas. 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 reaction occurs within the duct prior to the filter and on the cake that accumulates on the filter surface.

The existence of a sorbent cake on the filters increases the exposure of the SO_2 or HCl, and increases the removal rate. For a given removal efficiency, filters require significantly less sorbent than electrostatic precipitators (ESPs), which can result in a large savings in sorbent costs. This is true for calcium and sodium sorbents.

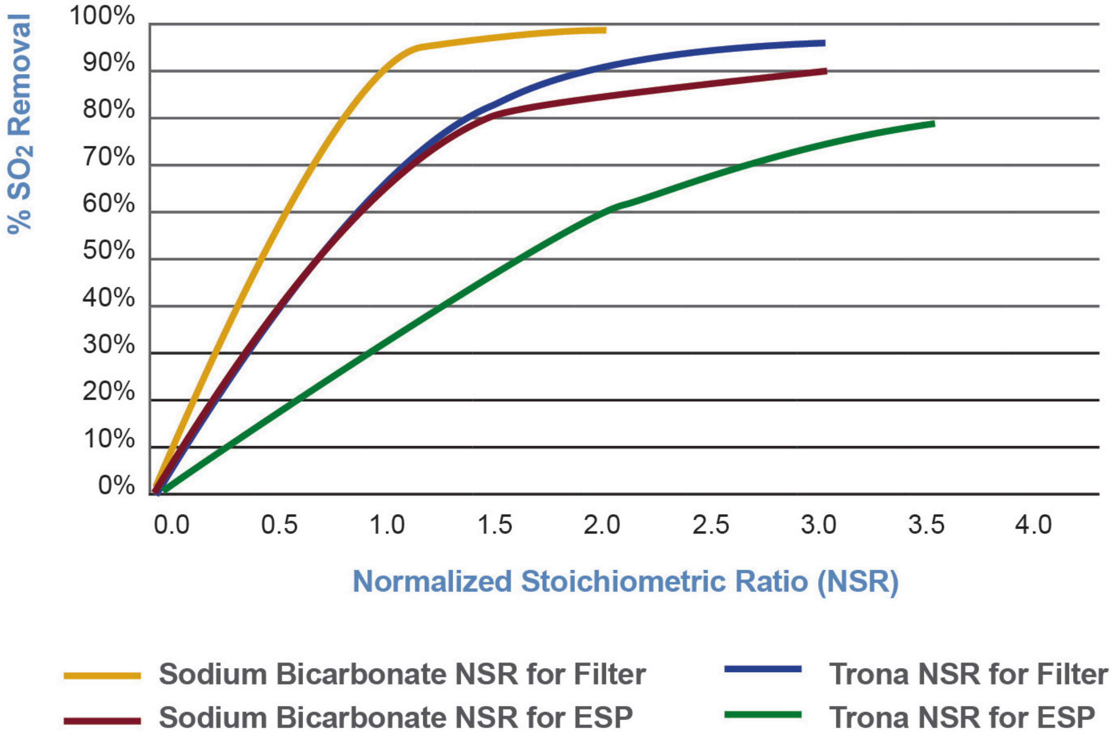

Figure 5: Filter vs. ESP sorbent usage for SO_2 removal (Data courtesy of Solvay Chemicals Inc.). Comparison of SO_2 removal effi-ciency achieved by filter systems and ESPs with various normalized stoichiometric ratio values of sodium bicarbonate and trona.

With sorbent injection, SO_2 removal is in the range of 90 percent for most applications. Lesser permit requirements equate to less sorbent consumption and associated cost. SO_3 and HCl are preferentially removed at even higher rates than SO_2. Sorbent injection of powdered activated carbon (PAC) is also an option for mercury control. The mercury chemistry and temperature of the application determine the formulation of PAC used and the resulting effective-ness. Mixtures of sorbent and PAC are commercially available. Sorbent costs, including storage and handling, are a major consideration in evaluating the total cost of owner-ship.

Catalyst Filters for NO_X, O-HAP THC, Dioxins

Catalyst filters have the same composition and capabilities as the standard filters for PM, acid gases and Hg. The difference is the addition of micronized catalyst.

NO_X: All catalysts can be severely compromised by particulate blinding of the catalyst surface, chemical interactions with particulate on the surface, and gas-phase poisons. A common problem with traditional "big block" SCR is that the catalyst becomes blinded and poisoned, drastically reducing effectiveness and necessitating early replacement. Ceramic catalyst filters address these perennial issues. Particles, including solid-phase metals, are captured on the surface of the filters.

The filter catalyst is distributed throughout the filter walls in micronized form and is almost completely protected inside the filter. This feature virtually eliminates the particulate-type interactions and extends catalyst life. Regarding gas phase, the proprietary catalyst formulation is engineered for extremely low conversion of SO_2 to SO_3 (some catalysts have over 10 times the rate) and is virtually immune to HCl.

The reaction of the ammonia and NO_X at the micronized catalyst surface is the same as conventional SCR but benefits from more contact time because the mixture of gases does not have to diffuse in and out of the big block catalyst pores, as previously mentioned by Schoubye and Jensen.

Table 1: Temperature Ranges by Pollutants Being Removed

Filter type	Pollutants	Temp Range
Standard UltraTemp	PM, SO_X, HCl, Hg	300°F – 1,600°F
Catalyst UltraCat	Above plus NO_X, O-HAPS, dioxins	350°F – 950°F

Eliminating the diffusion restriction helps reduce the slippage of untreated gases; NO_X destruction greater than 90 percent has been reported. (**Figure 6**) Ammonia slip is well under 10 ppmv.

Cement O-HAP THC: The filters are very effective in destroying formaldehyde and other targeted O-HAPS. Efficiency is dependent on temperature. (Ammonia is not needed for O-HAP destruction.) The significant reduction

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of O-HAPs results in an adjustment of total allowable THC according to the NESHAP formula. This direct approach for O-HAPS reduction is a very cost effective compared to PAC injection or thermal oxidation.

Catalyst filters virtually eliminate ammonia slip if SNCR is being used in the kiln. Excess ammonia slip, often a problem, is consumed by the filters while acting as a polishing step for NO_X removal. This is an important secondary benefit when the filter system is used to collect PM, remove HCl, and/or destroy O-HAPS. Thus the need for a fabric filter baghouse or electrostatic precipitator is eliminated while gaining an important benefit.

Dioxins: These compounds are included in regulations for incinerators and hazardous waste facilities. Dioxins are destroyed in a similar fashion by the catalyst filter. Care must be given to the operating temperature range to avoid reformation of the dioxins.

Operating Temperatures

For PM control only, standard filters can operate at temperatures of 300 to 1,650°F. For PM plus SO /HCl, the range is slightly narrowed by the chemistry of the sorbents to 300 to 1,500°F.

NO_X control imposes different temperature 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 600°F for efficient removal, while the micronized catalyst becomes effective at 350°F. (**Table 1**)

O-HAP destruction becomes effective as temperatures approach 400°F and increases rapidly with relatively small increments of added temperature.

Occasionally, gas must be heated above the natural outlet temperature to reach minimum catalyst activation levels. This is done by insulating ducts against heat loss, adjusting process temps, going upstream of economizers, and on rare occasion adding inline heaters.

The need to cool the gas is much more common. Cooling the gas to the operating temperature range is required for some applications, and is accomplished with dilution air or water spray quenching. This illustrates another benefit of the effective lower temperature range for NO_X of the catalyst filters: cooling to much lower temperatures does not affect removal efficiency. Certain heat recovery approaches also become more feasible.

Proven Solution

Ceramic filters have been used by the U.S. military at munitions destruction facilities in Indiana, Utah, and Oklahoma for 13 years, and hundreds of ceramic filter systems are operating worldwide, primarily in Europe and Japan. With the additional capability of NO_X control, ceramic filter systems have become the technology of choice for an increasingly wide range of applications.

Since 2009, diverse industries in the United States have recognized the merits of the technology and responded with rapid adoption. Single housing and multi-housing systems treat a spectrum of pollutants across many industries throughout the United States.

Developments in ceramic filter technology offer a powerful, proven strategy for meeting today's regulatory requirements, as well as those likely to be adopted in the future.

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