

IMPROVED CATALYST CAN CLEAR THE AIR

Catalyst technology can make clean coal plants look as clean as they are.

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Over the past 30 years, emissions technology has vastly improved coal-fired power plant emissions in terms of their impact on air quality. Now, it can help improve stack emission visibility as well. Although such improvements are primarily visual, their significance is immense.

Controlling sulfur trioxide (SO₃) produced and emitted from coal-fired boilers represents a growing area of interest for the North American power industry. In addition to a significant increase in the use of flue gas desulfurization (FGD) systems on coal-fired boilers, the use of eastern bituminous coal with

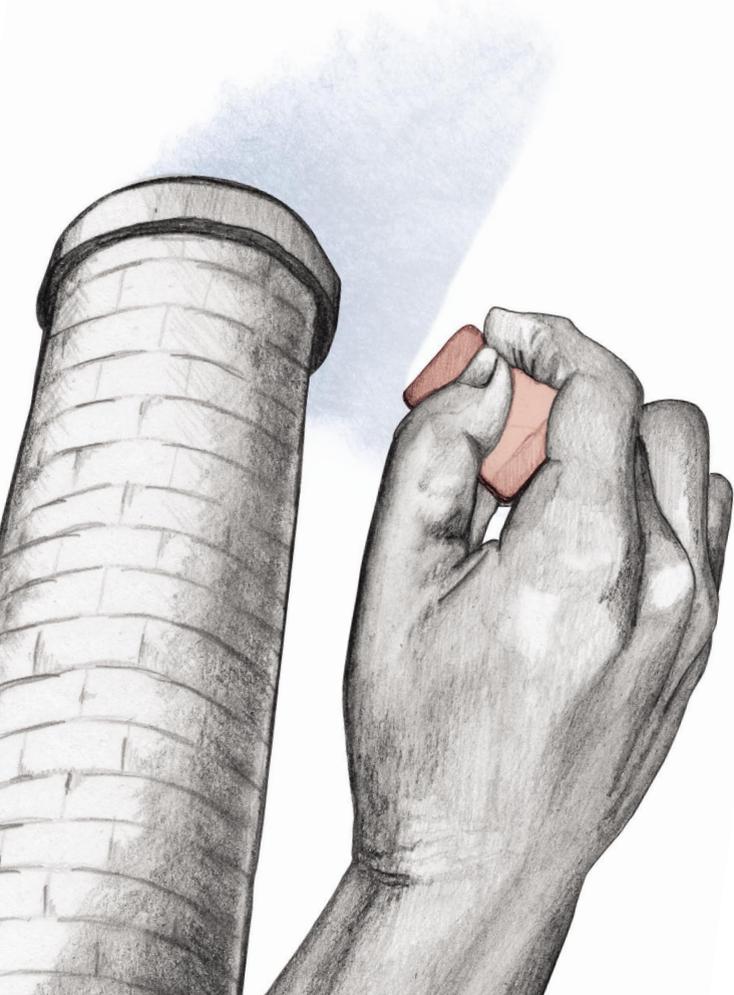
high sulfur content (three percent or greater) is also expected to increase, as will blending coal with petcoke. When SO₃ condenses to form sulfuric acid (H₂SO₄), the resulting power plant stack emissions can affect plume opacity and acid deposition. Typically, significant portions of the H₂SO₄ will be removed from the flue gas in the air pre-heater (APH), electrostatic precipitator (ESP) and FGD. However, the portion that remains in an aerosol form will not be captured, potentially creating plume opacity problems.

In addition to affecting stack plume opacity, higher levels of SO₃ in the flue gas can lead to corrosion of downstream equipment, an increase in particulate matter emissions due to the condensable component and an increased sensitivity to ammonium bisulfate formation in the APH. For all these reasons, SO₃ mitigation is a growing need among power plant owners and operators. This article examines the need and available methods for SO₃ control with a specific focus on a catalyst technology developed by Cormetech. The article also presents the results of commercial operating experience.

HIGH NO_x PERFORMANCE AND LOW SO₂ CONVERSION

Higher SO₃ emissions are typically observed at plants firing high sulfur coal or coal/petcoke blends and equipped with selective catalytic reduction (SCR) systems and wet scrubbers. Typically, a fraction of sulfur dioxide in the flue gas (around one percent) is converted to SO₃ in the furnace. With the addition of petcoke this level may increase due to the influence of vanadium. The deployment of SCR systems for NO_x emission control increases the concentration of SO₃ ahead of the APH through an undesired side reaction that oxidizes SO₂. The extent of this oxidation depends on SCR design conditions, operating parameters catalyst formulation and structure.

A major challenge facing power plant operators today is maintaining high NO_x reduction levels and low ammonia slip while yielding low conversion of SO₂ to SO₃. In the past, minimizing SO₂ conversion while maintaining high NO_x reduction levels were in conflict, and in some



IMPROVED CATALYST TECHNOLOGY

TABLE 1
CATALYST CHANNEL WALL THICKNESS

Product	Pitch	Product		Case 1		Case 2	
		Opening (mm)	GSA (m ² /m ³)	Relative Volume Required	Relative Pressure Drop	Relative Volume Required	Relative SO ₂ Oxidation Required
Conventional	7.4	6.3	445	100%	100%	100%	100%
High Performance (patent pending)	6.9	6.3	539	75%	61%	100%	25%

cases could not be achieved. Therefore, catalyst manufacturers such as Cormetech focused on developing additional catalyst product features to minimize SO₂ conversion while maintaining high catalyst activity to yield high NO_x reduction with low ammonia slip.

The product developed by Cormetech can, in some cases, achieve less than 0.1 percent SO₂ oxidation while maintaining all other key product performance and durability features. Use of the advanced SCR catalyst product may be exclusive, or combined with other SO₃ mitigation techniques including fuel switching, in-furnace mitigation with reagent, and pre/post APH mitigation with reagent.

BACKGROUND AND THEORY

Most SCR systems in the United States were designed with an SO₂ conversion rate in the range of 0.75 percent to two percent, or higher for some PRB applications. The target objective for catalyst advancements was determined based on the need for effective SO₃ mitigation (conversion rates of 0.1 - 0.5 percent) while maintaining high NO_x removal (90 percent and above) and low ammonia slip (less than two parts per million—ppm). As a result, any new catalyst design had to be optimized to reduce volume, pressure drop and SO₂ oxidation rate. Based on extensive experience and understanding of various cell structure products, reaction mechanisms, materials and extrusion techniques, Cormetech undertook a series of due-diligence and product qualification initiatives in the laboratory and the field. The goal was to extend and develop catalyst performance features that can be incorporated into new or layered addition/replacement designs. The unique capability to extrude high open area products allows Cormetech to take advantage of the inherent reaction mechanisms that achieve low SO₂

conversion and excellent NO_x activity while maintaining the hardness, mechanical strength, durability and poison resistance of a conventional catalyst.

SO₃ MITIGATION IS A GROWING NEED AMONG POWER PLANT OWNERS AND OPERATORS.

Prior to direct focus on reduced SO₂ conversion, the inherent catalyst features were conventionally applied to achieve higher catalyst activity with moderate SO₂ conversion. The SO₂ conversion process for coal application catalysts is reaction rate-limited, while the DeNO_x reaction is diffusion-limited. In other words, the DeNO_x reaction is fast and occurs mostly on the surface while the SO₂ oxidation reaction is slow and utilizes the catalyst's entire body. By understanding these reaction mechanisms, principles of catalyst deactivation, product application and manufacturing principles, the new catalyst product features increases and/or maintains the inherent DeNO_x activity while reducing SO₂ conversion by optimizing the amount of catalytic material available for both reactions. These products have been successfully applied to more than 40,000 MW of coal-fired applications and continue to be extended to achieve the lower SO₂ conversion.

PRODUCT QUALIFICATION & RESULTS

The product evaluation and qualification process for the new

product features included laboratory and field testing for:

- *Mechanical durability (that is, abrasion resistance and hardness, strength and washability).*
- *Chemical durability (that is, poison resistance and operating life).*
- *Overall performance comparison with other lower open area products.*

As with the basic principles governing the SO₂ conversion and DeNO_x activity, the principles of abrasion are also critical to understand. The abrasion phenomenon is governed by the following equation and is inversely related to material hardness:

$$\text{Abrasion} \sim \text{particulate loading} * \text{Velocity}^3 * \text{time}$$

Key to the successful development of the new product features was to assess the potential abrasion risk. Catalyst abrasion analysis validated the theory that no increased risk of abrasion existed with the low SO₂ conversion catalysts.

During normal operations observation showed that primary particle impingement occurs at the face of the catalyst, not on the catalyst walls. This is primarily because “entrance effects” cause more abrasion at the face due to flow contraction into the cells. Following the “entrance effect,” the laminar boundary layer starts to form immediately. This results in low gas velocity and particle mass flow at the cell wall. This is also demonstrated by historical experience that shows effectively no change in wall thickness within the catalyst channel from front-to-rear of the catalyst element (Figure 1).

The risk of abrasion along the catalyst wall depends on the catalyst material's hardness. The abrasion rate is inversely related to the hardness. At high velocities risk of abrasion along

the catalyst wall is less for harder products. Cormetech's low SO₂ conver-

ally, a reinforced cellular structure, material additives and leading edge

erational experience. In addition, even at units with large particle ash (LPA) plugging problems that were used to represent an accelerated abrasion test, results were equal to, or better than, low open area honeycomb products, corrugated or plate type products.

The lower SO₂ conversion achieved by the new catalyst compared with a conventional catalyst is due to greater open area, thinner wall thickness and improved composition and geometry for strength. The new design is optimized to reduce volume, pressure drop and SO₂ oxidation. Table 1 outlines some of the performance characteristics of the new product in comparison to the conventional catalyst in terms of relative catalyst volume, pressure drop and SO₂ oxidation. The two cases illustrate the alternative methods for utilizing the features of the high open area product.

Initial installations of the low SO₂ conversion catalysts at full reactors with less than 0.5 percent SO₂ conversion were designed in 2002 and installed in 2003. They continue to operate successfully. Subsequent individual layer additions of the low SO₂ conversion catalyst have been designed and installed with conversion rates of less than 0.1 percent. Table 2 compares the design considerations and performance test results for the low SO₂ conversion catalyst at two recent installations.

The need for cost effective SO₃ mitigation is clear and immediate. Advanced high performance catalysts with low SO₂ conversion and high NO_x reduction are now available. They can be used in combination with other SO₃ mitigation strategies. They can progressively achieve less than 0.1 percent conversion, are applicable to new and existing SCRs and provide advanced catalyst management solutions as layer additions and replacements. Additional beneficial features include reduced pressure loss and lower weight. Future advancements for more advanced catalyst products for further reduction of the SO₃ impact and improved NO_x reduction are in development. 

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TABLE 2
DESIGN CONSIDERATIONS AND PERFORMANCE TEST RESULTS
FOR THE LOW SO₂ CONVERSION CATALYST

Plant	A	A	B	B
Description	Initial Charge	Addition (planned)	Initial Charge	Addition
<i>(in storage)</i>				
Size (MW)	560	560	1080	1080
Reactors	2	2	2	2
Number of layers	2	1	2	1
Product Pitch, mm ⁽¹⁾	7.1	6.9	7.1	8.2
Opening, mm	6.4	6.3	6.4	7.6
<i>Flue gas temperature</i>				
at SCR (°F)	623	623	670	670
Inlet NO _x ppm	283	283	418	418
SO ₂ , ppm	2100	2100	1600	1600
SO ₃ , ppm	21	21	16	16
NO _x Reduction, %	90	90	90	90
NH ₃ Slip, ppm	2	2	2	2
SO ₂ to SO ₃ conversion ⁽²⁾	0.5	<<0.1	1	≤0.1

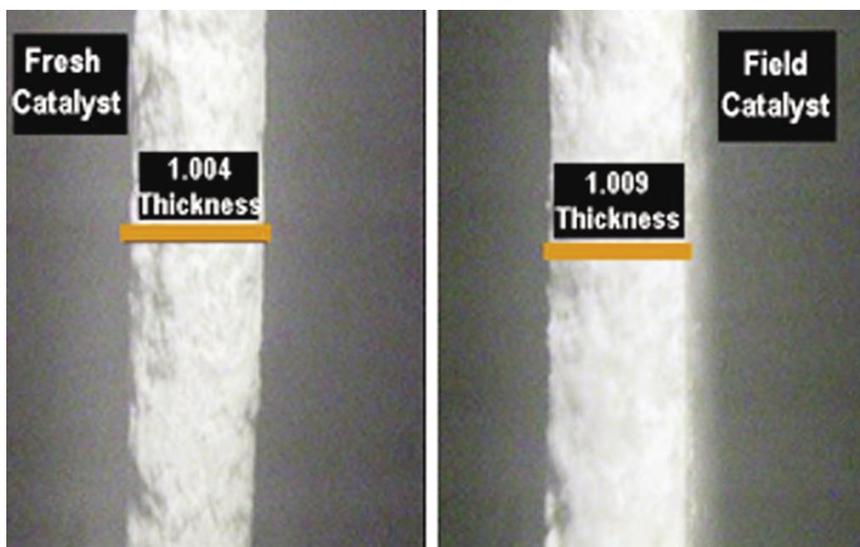
(1) All products are high open area products. Further reduction can be achieved with next generation products described in table 1.

(2) Design levels shown without ammonia injection. Field measurements showed lower values for installed volume.

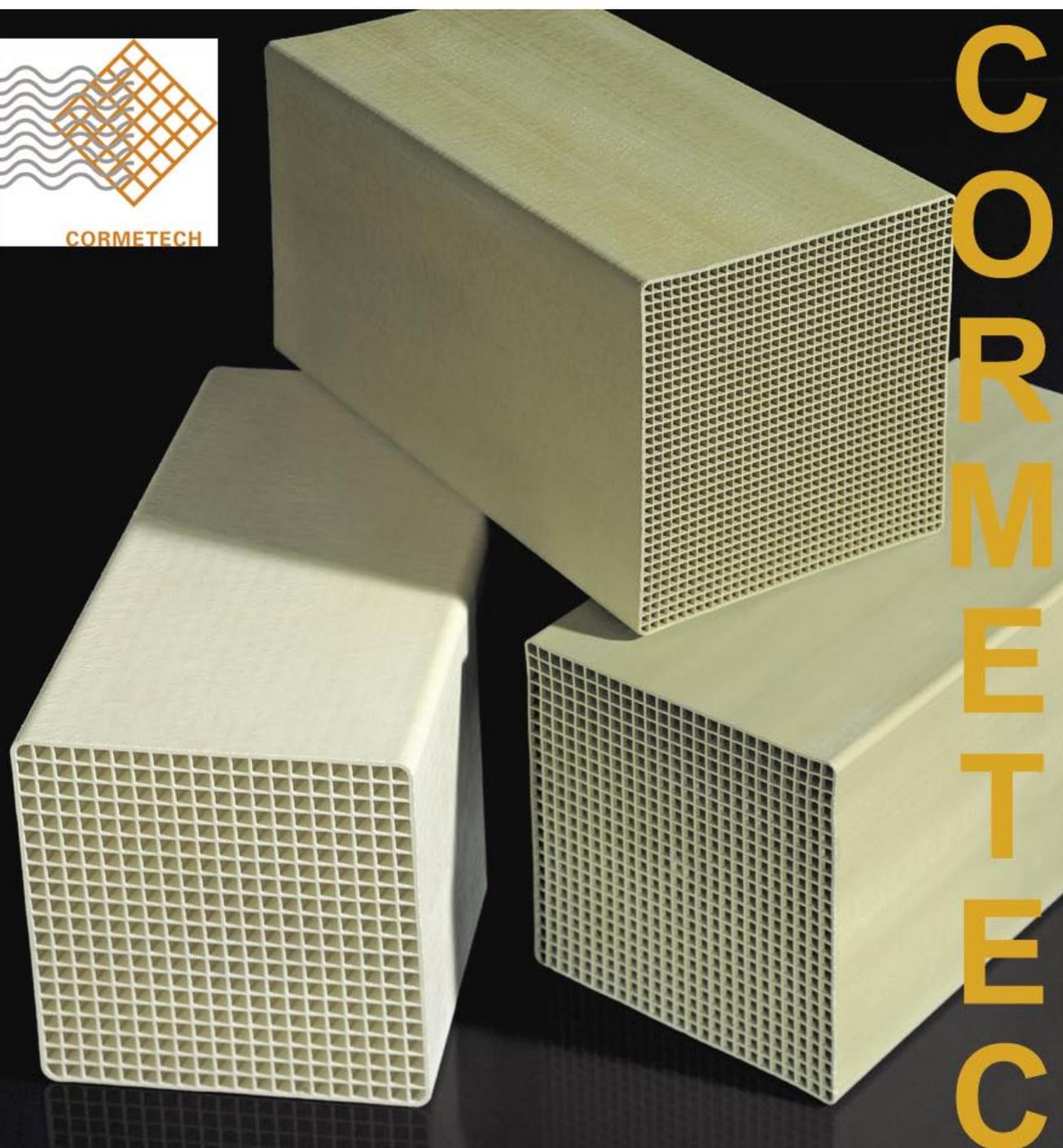
sion catalyst products have incorporated materials technology to ensure abrasion resistance and washability without sacrificing poison resistance and represent one of the most durable products in the industry. Addition-

hardening are all used to achieve required strength and abrasion resistance properties.

The assessment that the new catalyst shows no abrasion issues has been confirmed over more than five years of op-



The catalyst sample comparison here shows no change in wall thickness after 50,000 hours of operation in a high dust coal application using technology detailed in this article. Shown is an older-generation, low-open-area product, which inherently has a greater chance for wall erosion due to the higher channel velocity caused by its low open area. Particle impingement is actually reduced for the high open area product due to the reduced frontal area blockage. Photos courtesy of Cormetech.



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Cormetech High Performance Catalyst

- > Higher Surface Area per Unit Volume at Same SO₂ Oxidation rate and volume
- > Improved geometry for Strength
- > Harder Material to Ensure Erosion Resistance & Washability
- > Included Additives for Strength

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