TECHNICAL PUBLICATION

Advanced Erosion Protection Technology Provides Sustained Low NO_x Burner Performance

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Presented at:

Electric Power, March 30-April 1, 2004

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ABSTRACT

Electric power generators are experiencing the most complex confluence of market pressures in the history of the industry. Environmental regulations are stricter than ever, forcing producers to make substantial capital investments in emissions conformance, while the pressures of deregulation are making available maintenance dollars ever more scarce. The threat of non-conformance penalties weighs heavily against the pressures of Wall Street, and the decisions between capital expenditures, potential fines, and everyday equipment maintenance becomes a precarious balancing act.

The current high-cost of LNG combined with transmission bottlenecks places low NO_x coal-fired megawatts at a premium, particularly in those regions where generating capacity closely matches demand. This increased value of low NO_x megawatts puts further pressure on personnel to maintain peak performance of their NO_x management systems.

After an electric power generator invests in NO_x reduction technologies to achieve conformance, it is faced with maintaining the equipment to ensure that NO_x rates remain within specified tolerance. Pulverized coal traveling at high velocities through coal burners and burner tips typically produces significant component erosion, causing owners to repeatedly replace parts and even entire burner assemblies. During the period between repairs, changes in burner geometry caused by excessive erosion can impact combustion characteristics, resulting in upward trending NO_x emissions.

The most advanced Low NO_x burner technologies utilize a unique tungsten carbide cladding applied through an infiltration brazing process to protect components against erosion wear, substantially increasing burner life while maintaining combustion characteristics for sustained low NO_x performance. This paper will discuss the exhaustive laboratory analyses used to find the best wear solution for this extreme application, how it is applied, and the performance results of these burners in actual operation after more than two years of service.

CONFLUENCE OF MARKET PRESSURES IN POWER GENERATION

Power production facilities are under ever-increasing pressure to reduce production costs to compete in a market environment that is more complex today than it's ever been in the past. Failure to effectively reduce production and maintenance costs to a competitive level means reduced profits for each MW-hr sold, and may result in reduced dispatch load—a double jeopardy in a market plagued by over capacity.

The situation is exacerbated by the need for production facilities to balance costs against compliance with a growing number of stringent air quality restrictions for NO_x, SO_x, particulates, and now mercury. These challenges often manifest themselves in a conflicting effort to reduce day-to-day operating costs while optimizing the return on capital investments.

POWER GENERATION AS A BUSINESS

Deregulation and the 1990 Clean Air Act Amendments have often created significant constraints to the operation and maintenance of generation facilities. Before The Clean Air Act Amendments, power producers were relatively unconstrained in the fuels, technologies, and production strategies they employed to meet the market demand. Their primary objective was to provide a reliable source of quality power. Whatever equipment was in place per original design could be used without a great deal of concern for the quality or type of fuel being burned. Original equipment design took into account the planned fuel formulation, and auxiliary equipment was selected primarily based upon these original specifications. Equipment deterioration was accepted as a normal cost of operation, and was dealt with through frequent and relatively long maintenance outages.

Today's competitive market conditions, combined with strict emissions standards, have created entirely new challenges that generate potential conflicts between fuel formulations, equipment configurations, and maintenance programs. Capital expenditures for new advanced Low NO_x burning systems, while designed to support environmental compliance, can lead to unexpected system maintenance challenges, such as rapid component wear. The time deviation between major plant outages for maintenance has increased from one (1) year to as much as four (4) years.

Asset managers are now faced with ever-rising capital investment costs combined with the often-unexpected increase in maintenance costs required to ensure unit availability and acceptable performance. The competitive power generation environment and Wall Street pressures to increase short-term profits further complicate these demands. The combination of these pressures, relatively new to the industry, often drives the use of short-term solution approaches in order to minimize the initial cost of implementation. These factors, all too often, mean that maintenance teams end up chasing ongoing performance and reliability problems with an ever-decreasing staff. While initial capital investment may have been reduced, the ongoing cost of maintaining availability and performance can create a drag on cash flow and reduce the overall return on investment.

RETHINKING INVESTMENTS IN COMPLIANCE

Selection, installation, and implementation of emissions reduction systems frequently involve a large contingent, including plant personnel, corporate engineers and asset teams, numerous contractors and subcontractors, and even subs to the subcontractors. Throughout this complex web of influences, each party has a vested interest in showing the greatest return for the lowest cost. Only a few suppliers, those who have confidence in the value of their innovative and value-added technologies, will be willing to risk losing a project, which might be perceived to be an initially more costly installation. Because of the complexity of the evaluation process, only the savviest of asset owners are able to effectively cut through the smoke and mirrors of promises to recognize the longer term return possible through more advanced, albeit more costly, technologies.

Large power generating assets certainly cost a great deal of money to operate; but they cost even more when, due to degradation of performance and reduced reliability, they are forced into a premature maintenance outage or have to operate at sub-par performance. Higher costs are driven by the incremental replacement power costs. Oftentimes, the payoff for installing lower-cost components is an increased risk of downtime and frequency of maintenance. By thinking about the importance of long-term performance, savvy asset owners are able to parlay smart investments into quantifiable returns. Therefore, it is important to plan capital projects so as to reduce the need for periodic and unnecessary maintenance. The selection of "Best Available Control Technology" will, in many cases, increase initial installation costs only nominally. Savvy asset owners will seek out and explicitly specify such technologies, thus protecting their overall investment against the ill-advised cost-cutting measures employed by many contractors and their subcontractors.

BALANCING ENVIRONMENTAL STEWARDSHIP AGAINST WALL STREET EXPECTATIONS

The war against pollution is mounting, with an ever-increasing list of forbidden effluent constituents, including particulates, SO_2, NO_x, and mercury. NO_x, one of the industry's oldest and most familiar foes, has been challenging boiler designers for the greater part of three decades. Advanced design burner configurations have become one of the industry standard approaches to NO_x abatement, and burner designers are continually developing new ways to achieve and maintain lower levels of NO_x output.

Burner designers are faced with several challenges in the war against NO_x:

- Designing within the parameters of the existing system not originally sized or configured for Low NO_x operation
- Varying coal specifications from the customer which cover wider and wider ranges of fuel properties
- Mill system performance and limitations
- The high heat release rates of some wall-fired cell configurations
- Retrofitting of cell configurations for NO_x reduction without required spacing modifications and pressure part reconfiguration
- Non-homogenous coal flow typically resulting in sub-optimal burner performance
- Coal flow imbalances between pipes requiring additional flexibility of the burner design to compensate for adjusting the airflow to be consistent with coal flow imbalances
- The requirement for burner parts to last up to four (4) years between major outages
- The continuing struggle between decreasing NO_x emissions and maintaining some reasonable level of UBC in the flyash
- The often employed "solution" of highly turbulent mixing resulting in hotter initial burn temperatures and harder to control NO_x

Current state-of-the-industry wall-fired Low NO_x burner designs combine sophisticated mixing and stabilization designs with Best Available Control Technology in wear protection.

Riley Power Inc's (RPI) CCV® burner technology employs a venturi coal nozzle to provide more controllable fuel mixture combined with a low swirl coal spreader to provide good mixing without excessive turbulence. Integral air diverters and stabilizer rings improve flame attachment and reduce NO_x emissions. This combination of sophisticated design component geometries, utilizing an infiltration brazed tungsten carbide protective cladding, ensures that homogenous non-turbulent coal mixing and controlled burn rate is maintained over extended periods of operation. With Best Available Burner Technology, NO_x levels will not only test low at initial startup, but can be expected to remain low throughout the majority of burner life between major outages. This extended performance is achieved by significant reduction in erosion-driven changes in component geometry. The net result is more prolonged compliance with NO_x emissions with reduced risk of both planned and unplanned downtime and an increase in overall unit productivity and reliability.

PERFORMANCE AND LONGEVITY CONSIDERATIONS

The advanced CCV® burner technology has evolved significantly since its initial inception in the early 1980s. Using increasing computing power over the years to perform complex computational fluid dynamic (CFD) analyses and full-scale test facilities, the burner has reached its current advanced state of performance. On a unit firing bituminous fuel with burners only and no overfire air, the NO_x level obtained is 0.36 lb/MMBTU. This can be achieved with a simple "plug-in" retrofit requiring no pressure part replacement, over fired air (OFA), or burner respacing. Burner turndown ratio of 2.5:1 is still maintained. Similar retrofits on units burning sub-bituminous coal achieve NO_x emissions as low as 0.15 lb/MMBTU or less.

In order to protect components against erosion degradation and maintain long-term performance, burner designers performed comprehensive laboratory evaluation of multiple wear protection materials, many of which were industry-accepted, to identify and specify the Best Available Control Technology for the application.

Burner designers tested the following erosion protective materials:

- STOODY 101HC
- SA1750 CR
- Conforma Clad WC219
- Stellite 31
- A560 Grade 50Cr-50Ni
- A532-82 Type II Class C
- A532-82 Type I Class A
- Silicon Carbide
- Stellite 6

Figure 1 - Test Fixture with Sample

Testing utilized an ASTM standard G73 method utilizing Black Beauty Coal Slag as the erodent material (See Figure 1). As a result of this testing, burner designers selected Conforma Clad infiltration brazed WC219 tungsten carbide cladding as the Best Available Control Technology for protecting burner components against erosion deterioration to ensure long-term performance (See Figure 2). Conforma Clad's proprietary cloth application technique makes it highly unique in that it can be easily applied to very complex geometry components, forms a true metallurgical bond with the base component, has an extremely uniform thickness and density, and is not subject to spalling, with the ability to withstand continuous operation at temperatures in excess of 1900 º F. The method of application produces an impervious cladding layer with no interconnected porosity or check cracking, and carbon dilution at the bond line is virtually zero. This, combined with its non-magnetic characteristic, allows for precision in situ measurement of remaining thickness and life-extrapolation in support of predictive maintenance programs.

Erosion Test Results- "Black Beauty" Coal Slag Fine Grit
90 Degree Impringement Angle
240 ft/second - 30 minute test

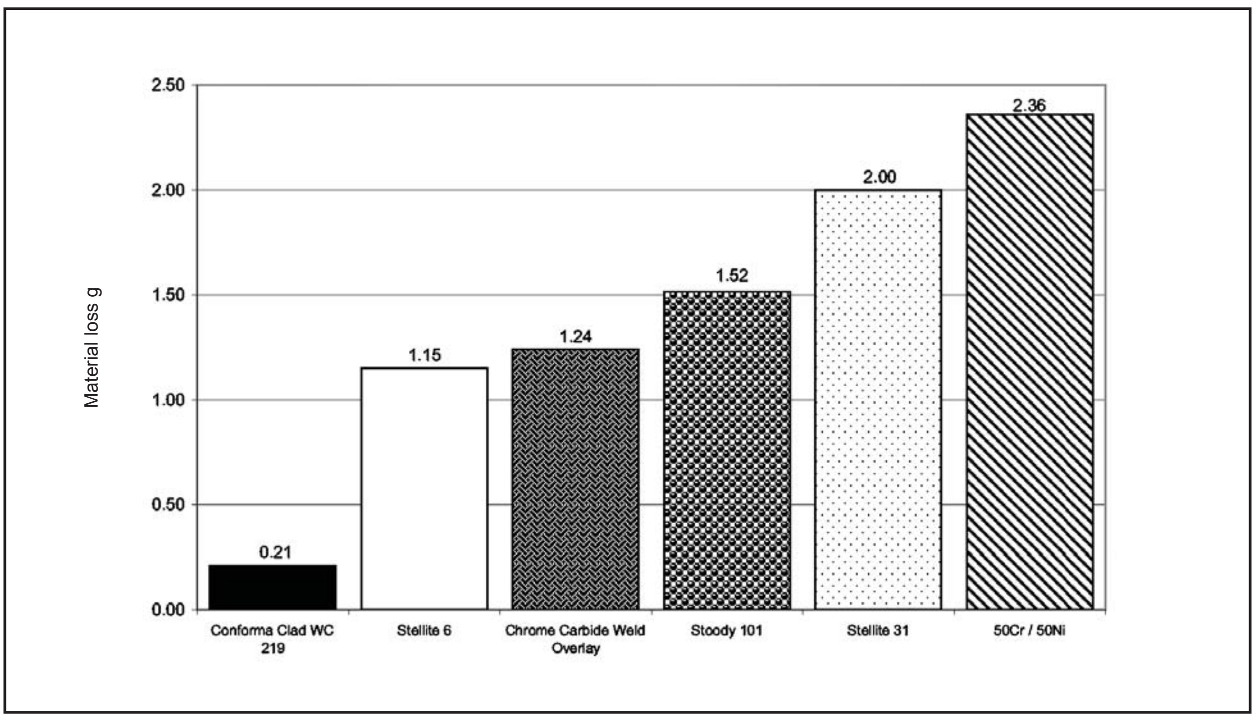

Figure 2 - Erosion Comparison Results

CASE STUDY I

In 1994 RPI retrofitted all four boilers at We Energies, Valley Power Plant, with *first* generation low NO_x burners. The pre-retrofit NO_x levels were 1.02 lb/MMBTU. After the installation of the burners, NO_x levels were reduced to 0.41 lb/MMBTU. An integral component of the RPI design is the low swirl coal spreaders found in the coal nozzle of the burner. The spreader is designed to enhance the combustion by controlling the flame length and minimizing both NO_x and Unburned Carbon (UBC).

New low swirl coal spreaders were installed into the existing CCV® low NO_x burners at We Energies Valley Station, Unit 2, Boiler 3 in February of 2003 as part of the normal maintenance schedule. Several of the materials tested in the laboratory were supplied for a direct comparison. They were installed in burners fed by the same mill. Three (3) low swirl coal spreaders were supplied for installation; one of Riloy 74 clad with Conforma Clad infiltration brazed tungsten carbide, and two of cast silicon carbide.

RPI, working in partnership with We Energies, chose Valley Power Plant as a test site due to the burner velocities and fuel properties, which contribute to high erosion rates. Typical coal/primary airflow velocity through burners at full load is approximately 87 ft/sec. The pulverized coal fired at this station is blended with approximately 9% petroleum coke and the ultimate analysis is shown below:

Carbon:	61.29 - 69.31 %	Sulfur:	0.74 - 0.98 %
Hydrogen:	4.18 - 4.82 %	Ash:	4.19 - 15.37 %
Nitrogen:	1.36 - 1.51 %	Moisture	8.14 - 10.51%
Oxygen:	8.92 - 9.31 %	Hard Grove	46 HGI

Valley Station stopped receiving pet coke April 2003

Due to relatively high nozzle velocity, combined with the high silica and alumina content in the coal, this burner application is considered to be a moderately high erosive environment. This is evident from the wear that can be seen on the burner components that were not protected with tungsten carbide cladding (See Figures 3 and 4).

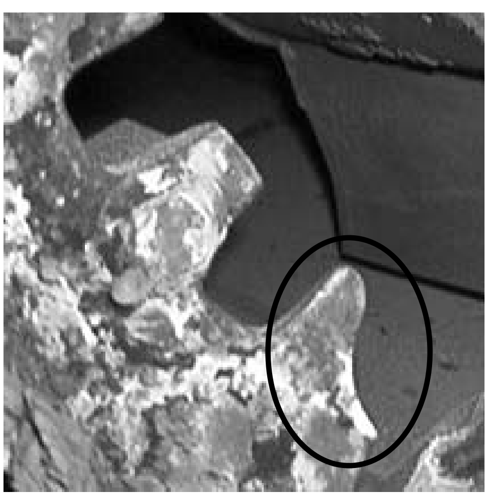

Figure 3 - Unit # 2, Boiler # 3 unprotected burner component showing typical wear after 22 months of service

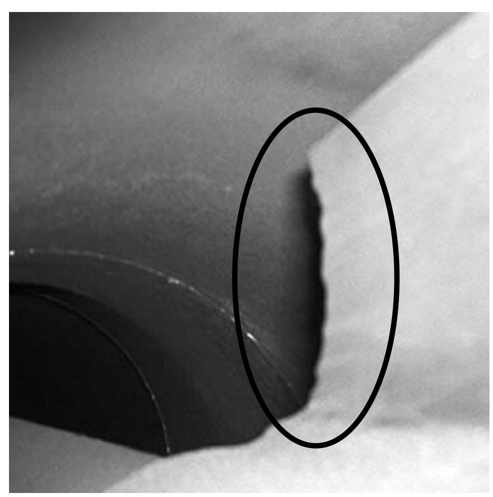

Figure 4 - Stellite Weld Overlay on the leading edge shows approximately 1 1/2" off vane leading edge after nine months of service

As part of development and evaluation of the selected tungsten carbide erosion protection, burner designers chose to install a single component (coal spreader, See Figure 5) protected with the chosen material as a test to confirm performance in operation. This prototype burner test piece was protected with 0.040" thickness of Conforma Clad WC219 applied directly to the leading edge of the spreader base material using a proprietary infiltration brazing process. The prototype coal spreader was installed in Unit 2, Boiler 3, D1 burner location on February of 2003 along with the balance of coal spreaders being supplied with stellite weld overlay on the leading edges. After approximately 9 months of continuous service, the prototype test piece was inspected on October 20, 2003.

Figure 5 - Conforma Clad infiltration brazed tungsten carbide spreader shows no visable wear

Prior to the installation of the test spreader and new coal spreaders in the remaining burners, recorded NO_x emissions from the CEMS for the third quarter of 2002 show a sustained NO_x performance of 0.423 lb/MMBTU at full load. The NO_x emissions recorded from the CEMS for fourth quarter of 2002 after the equipment component changes showed an average of 0.413 lb/MMBTU at full load.

Results for Case Study I

The stellite protected coal spreader shown in Figure 4 has approximately 1-1/2" of the coal spreader vane missing. The prototype test piece, protected with tungsten carbide cladding was visually inspected and showed no visible signs of erosion (See Figure 5). Due to the non-magnetic nature of the cladding protection, it was possible to measure actual remaining cladding thickness using an Elcometer eddy current thickness gauge. Measurements showed that the maximum extent of erosion was 0.007", or less than 20% of the total protective layer thickness (See Table 1). From these results the predicted life of the coal spreader protected by the tungsten carbide coating is estimated at approximately 5 years.

Table 1

Cladding Thickness Measurements

	BASE	MIDDLE	TIP	
LEADING EDGE				
VANE 1	.042"	.036"	.039"	
VANE 2	.040"	.033"	.043"	
VANE 3	.038"	.036"	.039"	
VANE 4	.039"	.037"	.040"	
BODY	1	2	3	4
LOCATION	.038"	.039"	.037"	.036"

CASE STUDY II

A second installation of Conforma Clad was applied to the new coal flow distributor elements installed at We Energies, Presque Isle Power Plant. In 2001 PIPP installed RPI's low NO_x CCV® second generation Dual Air Zone Burners. In conjunction with this installation, modifications were made to the coal mill system to improve the coal pipe-to-pipe balance to improve the overall unit performance. The coal flow distributor installed by RPI was designed for installation in the coal stream exiting the mill. This location has the potential to experience severe erosion due to sliding and impact abrasion.

Conforma Clad Inc. agreed to test their tungsten carbide material on this application due to the unique location of the device and the wear characteristics of the fuel.

Fuel Composition:		Ash Composition:	
Carbon:	73.8 - 74.2 %	Silicon Dioxide:	56%
Hydrogen:	5.0 - 5.1 %	Aluminum Oxide:	25%
Nitrogen:	1.6 %	Iron Oxide:	5%
Oxygen:	8.8 - 9.1 %	Sulfur Trioxide:	2%
Sulfur:	0.82 - 0.85 %	Calcium Oxide:	4%
Ash:	9.1 - 9.9 %	Other:	8%

Results for Case Study II

The coal flow distributors were installed in Unit #6 pulverizers in December of 2002. The coal flow distributors for Unit #5 were installed in February of 2003. Although the two units have slightly different operating times, a good comparison can be made between the unprotected flow elements in Unit #6, which were inspected in September of 2003, and the Unit #5 elements which were inspected in October of 2003.

Figure 6 - No protective cladding on the flow element

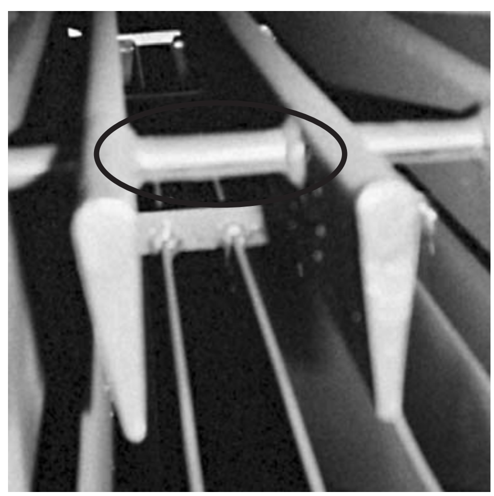

Figure 7 - Leading edge protected with Conforma Clad infiltration brazed tungsten carbide

Figure 6 shows the unprotected element installed in the Unit #6 D pulverizer. These elements are made from a heat-treated alloy with a hardness of 300+ Brinell. Figure 7 shows the same element design clad with tungsten carbide supplied by Conforma Clad.

Initial base cladding thickness was 0.040". With braze scale (Un-melted Chrome), the resulting total cladding thickness was approximately 0.045 - 0.050". From the thickness measurements shown in Table 2, it can be seen that the braze layer, which has a hardness of approximately 57Rc and is relatively erosion resistant, had not yet been penetrated.

Table 2

Cladding Thickness Measurements

	Inboard						Outboard
Location on Vane	1	2	3	4	5	6	7
Left	0.047	0.048	0.049	0.048	0.050	0.048	0.050
Left Center	0.048	0.048	0.047	0.046	0.046	0.046	0.048
Right Center	0.046	0.047	0.046	0.046	0.046	0.047	0.048
Right	0.049	0.051	0.047	0.051	0.049	0.049	0.049

CONCLUSION

Plant maintenance teams are experiencing ever-increasing pressures to reduce the cost of maintaining critical low NO_x burner equipment, and are expected to use innovative methods to maintain emissions compliance while extending the operating period between unit shutdowns. Technologies are available that have proven their ability, in both the laboratory and in the field, to provide substantial protection against some of the most common causes of aggressive equipment wear present in coal-fired power plants, including those present in Low NO_x burner systems.

Innovative burner designers can take advantage of sophisticated protection technologies to extend run time between repairs and component replacement to ensure that their systems provide peak performance not only at startup, but for several years thereafter. Asset managers can realize greater returns on their capital investments with only a nominal increase in initial installation cost through their awareness of proven Best Available Control Technologies.