

Executive Summary

[SCR Performance Enhancement for NOx Emission Reductions – SO₃ Removal is an Important Aspect of a Successful Emission Reduction Strategy](#)

By Sterling Gray and Jim Jarvis, AECOM Process Technologies

Two strategies that can cut NOx emissions in response to tightening regulations are boosting the percentage NOx reduction efficiency during periods of higher-load operation and developing the ability to keep SCR systems in service during reduced-load operation. SO₃ mitigation with SBS, implemented upstream of the air heater or upstream of the SCR system, addresses both strategies while offering the opportunity for increased SCR operating flexibility and reduced operating costs.

Full Story....

[Jim Bridger's Control Overhaul](#)

By Zac Phelps, PacifiCorp and Rob Sosinski, Redkob Industries

Utility testimonial on the four year implementation of a turnkey, flexible, low-cost solution for upgrading failing precipitator controls using SMPS technology without taking the units off line.

Full Story....

[Environmental Compliance in a Connected World](#)

By Volker Schmid, CleanAir Engineering, Inc.

Discussion of EPA's Next Generation Compliance Initiative started in 2013 due to the continued emphasize by the prior administration on the concept of Environmental Justice. This initiative has resulted in the development and promotion of low-cost sensors. A particular concern is the generation of large amounts of untested data with often questionable quality. This can lead to data misinterpretation with potentially damaging consequences to the reputation of otherwise law abiding companies.

Full Story....

[20 Economical Ways to Improve the Performance of a Baghouse Dust Collector](#)

By Mike Allen, CLARCOR Industrial Air

The proper maintenance and upkeep of baghouse dust collection equipment is really fairly inexpensive and easy to implement with the correct plan of attack. Most of the 20 hints given are inexpensive and will definitely help with the proper operation of the equipment.

Full Story....

[Reducing the Cost of Operating DSI Systems Using Sorb-Tec™ Lance-less Injection Technology](#)

By Nick Evans, Nol-Tec Systems; Mitch Lund, Nol-Tec Systems; Haley Turner, LG&E/KU; Ross Meinhart, Dynegy

Presentation of three full-scale case studies of the Sorb-Tec proprietary lance-less sorbent injection technology on power generation units. Sorb-Tec uses boosted high velocity air to create additional particle momentum for optimized penetration and dispersion without requiring any lance to protrude into the duct and with no changes required to the existing DSI setup.

Full Story....

SCR Performance Enhancement for NO_x Emission Reductions SO₃ Removal is an Important Aspect of a Successful Emission Reduction Strategy

Written by Sterling Gray and Jim Jarvis, AECOM Process Technologies

BACKGROUND

As a result of the Cross-State Air Pollution Rule (CSAPR) and the Ozone National Ambient Air Quality Standards (NAAQS), utilities are faced with the need to achieve further reductions in annual and ozone-season NO_x emissions. Consequently, utilities must develop ways to maximize the value and performance of their SCR system equipment. Two strategies that can cut emissions include boosting the percentage NO_x reduction efficiency during periods of higher-load operation and developing the ability to keep their SCR systems in service during reduced-load operation.

Implementation of these strategies is hampered by the presence of SO₃ in the flue gas. During higher-load operation, SO₃ produced in the boiler and by the SCR catalyst itself forces operation with low ammonia slip levels (typically less than 2 ppm) to avoid air heater fouling from ammonium bisulfate (ABS) deposition. Although many variables are involved, the ammonia slip constraint effectively caps the NO_x reduction efficiency for a given SCR system configuration. Similarly, ABS deposition within the catalyst due to “capillary condensation” dictates the minimum operating temperature (MOT) for the SCR system and, therefore, the minimum reduced-load operating condition where ammonia can be injected. The ability to keep the SCR system in service across the load range affects operating costs (due to costs associated with unit start-ups and shutdowns), and affects unit dispatch.

SO₃ removal upstream of the air heater, and ideally upstream of the SCR reactor itself, is becoming an increasingly important part of both the higher- and reduced-load strategies for reducing NO_x emissions. For higher-load operation, the concept is to reduce SO₃ to very low levels at the air heater inlet. This relieves the constraint on

ammonia slip because there is not enough SO₃ available to form appreciable amounts of ABS in the air heater. With the ammonia slip constraint removed, modest increases in ammonia slip are possible, which allows the NO_x reduction efficiency to be increased.

Reducing SO₃ to very low levels also helps minimize ABS condensation within the SCR catalyst when operating at reduced-load (low temperature) conditions. With less SO₃ present, the MOT decreases, which allows the SCR system to stay in operation at conditions where ammonia injection would not otherwise be possible.

Duke Energy employs both dry and wet sorbent injection technologies for SO₃ control. At the Gibson station, Duke has used the SBS Injection™ technology for SO₃ control on all five units since 2005. In the period between 2009 through 2014, Duke relocated the sorbent injection equipment from downstream of the air heater to upstream of the SCR reactors. As the equipment on each unit was relocated, Duke used this “pre-SCR” SO₃ mitigation capability to expand the operating range of their SCR systems and keep the reactors in operation at lower loads. Duke has recently performed testing to further leverage this capability to allow even lower-load operation. Although reduced-load operation was the focus of the testing, Duke also has an interest in operating at higher percentage NO_x reduction efficiencies (via elevated ammonia slip) and in operating at lower air heater outlet temperatures to boost plant efficiency. The goal is to use their SO₃ mitigation system investments to meet ever-changing emission control and economic challenges.

ENHANCED NO_x REDUCTION EFFICIENCY

Ammonia slip from SCR systems on higher-sulfur boiler

ers must generally be limited to less than 2 ppm. At this level, ABS accumulation can be managed by soot blowing and through the scouring of the air heater surfaces by fly ash. If SO_3 mitigation is performed upstream of the air heater, and if the SO_3 concentration can be reduced to a few ppm or so at the air heater inlet, then ABS accumulation will remain low even if the ammonia slip concentration rises above 2 ppm. Even modest increases in ammonia slip can permit a significant decrease in the outlet NO_x emissions.

If a reduction in NO_x emissions is not needed, then an alternative approach is to instead operate the SCR reactor at a lower average reactor potential. This might be accomplished, for example, by operating with two catalyst layers instead of three, or alternatively, through less frequent catalyst replacement. Over time, these approaches result in a lower catalyst consumption rate and a reduction in life-cycle catalyst costs. Potential savings could exceed \$500,000 annually for a 500 MW unit.

One Midwestern utility recently performed testing to explore the relationship between NO_x removal and ammonia slip at outlet NO_x concentrations well below their normal operating condition. The results of the testing were somewhat surprising, and showed that the NO_x reduction efficiency could be increased if there was a need to do so, without much increase in ammonia slip. Since the reactor appeared to have excess catalytic potential, the utility elected to forego a scheduled catalyst replacement, and the ability to operate with increased slip if that occurred was a factor in their decision. The utility is currently evaluating options and associated costs for alternative catalyst replacement strategies, including a reduction in the layers of catalyst.

The elevated ammonia slip operating strategy is only practical if the air heater indeed does not become fouled with ABS and if the excess ammonia in the flue gas does not cause problems downstream of the SCR. The ability to operate with elevated ammonia slip and without air heater fouling has been demonstrated at plants using the SBS Injection process during both short-term testing and longer-term operation at slip lev-

els well above 2 ppm. Indeed, the ability to adopt an elevated ammonia slip strategy may more often be constrained by the presence of higher ammonia levels in the water and scrubber solids streams, rather than air heater fouling.

In summary, data collected at multiple installations demonstrates that operation at slightly elevated ammonia slip levels is feasible when implemented in conjunction with SO_3 mitigation upstream of the air heater. However, very low SO_3 levels (less than a few ppm) are necessary to avoid air heater fouling. While the application of this operating strategy may be site specific, the potential benefits include decreased NO_x emissions and a reduction in catalyst consumption and replacement costs.

REDUCTION OF THE MINIMUM OPERATING TEMPERATURE

The presence of SO_3 in the flue gas often dictates the minimum operating temperature (MOT) of the SCR system during reduced-load operation. When SO_3 is present, the reactor temperature must be maintained above the minimum operating temperature when ammonia is being injected to avoid ABS condensation within the catalyst pores. In practice, the reactor can be operated below the MOT for short periods of time if these periods are followed by operation at higher reactor temperatures. Nonetheless, operation below the MOT has the potential for both short-term and long-term impacts to catalyst performance.

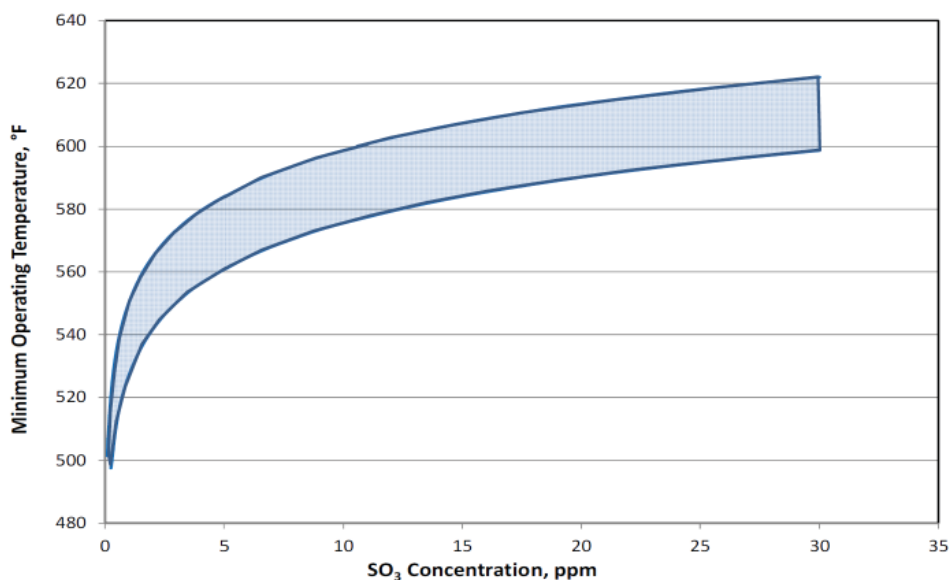


FIGURE 1: Minimum SCR operating temperature versus flue gas SO_3 concentration

The consequences of an MOT limitation can be significant. If the minimum load with the SCR system in service is higher than the minimum load for the boiler, then power producers may be forced to operate at higher than desired loads during periods of low or negative power pricing, just to keep the SCR systems in service. In some cases, operating costs may increase due to unit shut down and startup costs, or the unit may even be idled. With the trend towards reduced capacity factors for many coal-fired boilers, the ability to keep the SCR system in service at the lowest-possible load conditions is a significant economic benefit.

The minimum operating temperature for SCR catalyst is a function of the concentrations of both ammonia and SO_3 , and the tendency for ABS formation within the catalyst is the greatest near the inlet of the SCR where the ammonia concentration is the highest. Figure 1 depicts the relationship between the minimum operating temperature and the concentration of SO_3 in the flue gas. The relationship is a function of many variables, including the SCR inlet NO_x concentration, the desired percentage NO_x removal, the type of catalyst, and other variables; thus, the minimum operating temperature is shown as a range in Figure 1. However, the figure illustrates a key point - the minimum operating temperature can be significantly reduced if the SO_3 can be reduced to very low levels. Thus, SO_3 mitigation upstream of the SCR reactor allows full or at least partial NO_x reduction at significantly lower boiler loads relative to what would be possible without SO_3 mitigation.

The SBS SO_3 mitigation technology has been installed at locations along the flue gas path from the economizer outlet to scrubber inlet. Many recent installations, however, have been installed upstream of the SCR, and at the present time, the process has been applied at the pre-SCR location on 14 units. In many of those applications, minimum operating temperature was a factor in selecting the injection location.

In the pre-SCR configuration, the reagent injected upstream of the SCR is intended to control the boiler SO_3 , as well as the SO_3 produced by the SCR catalyst. At the inlet to the SCR, however, only the boiler SO_3 is present. Consequently, the concentration of the reagent is very high relative to the concentration of the SO_3 , and the SO_3 concentration at this critical location can be reduced to very low levels. As shown in Figure 1, this is exactly what is needed to achieve significant reductions in MOT.

SCR PERFORMANCE ENHANCEMENT AT GIBSON
The Gibson station initially installed the SBS SO_3 mitigation

technology downstream of the air heaters on all five units. In the period from 2006 to 2008, work sponsored by a consortium of utilities demonstrated the feasibility of injecting sodium-based reagents upstream of the SCR. Based on the favorable results from this testing, the Gibson station elected to move the reagent injection location upstream of the SCR reactors on Unit 5. Similar conversions were implemented on the remaining units, and the final conversion was completed in 2014. All five units are now operated in the pre-SCR configuration with soda ash reagent injection upstream of the SCR reactors.

Once the conversions were completed, the Gibson station used the pre-SCR capability to operate the SCR's with ammonia in service at lower loads and temperatures than were permitted prior to the conversions. For example, prior to the relocation on Unit 1, the SCR system was operated at the design minimum operating temperature was 622°F. After relocating the SBS system to the pre-SCR location, a phased injection approach was implemented:

- ✦ 85% NO_x reduction at temperatures down to 580°F
- ✦ 50% NO_x reduction at temperatures down to 570°F
- ✦ 25% NO_x reduction at temperatures down to 550°F (about 250 MW).

This strategy was based on the premise that the SO_3 concentration at the SCR inlet was nominally 5 ppm (even though test data showed the actual concentration was be much lower). Over time, this operating strategy has resulted in significantly lower NO_x emissions for this unit than would have been possible before the pre-SCR SBS conversion.

Duke has conducted testing at several stations to demonstrate the capability to keep the SCR's in service at even lower load conditions. At Gibson, one objective of the testing was to demonstrate full NO_x reduction at a minimum boiler load of 200 MW, where the minimum flue gas temperature entering the SCR reactor approaches 500°F. Figure 2 (see page 4) illustrates the current SCR operating goal relative to the actual current operation and the operation prior to pre-SCR SBS.

The program being conducted by Duke included SCR pilot testing, which was conducted by Cormetech, along with full-scale testing at several plants. The Cormetech testing has confirmed that it is possible to operate an SCR reactor at temperatures as low as 500°F if the SO_3 concentration at the SCR inlet can be reduced to very low levels (~1ppm)

Data from testing on Unit 1 at Gibson is shown in Figure 3. For operation at full load, the SO₃ concentrations of no more than a few ppm would be necessary to permit operation at elevated ammonia slip levels. The results show that the SO₃ concentration was reduced from about 47 ppm (without SO₃ mitigation) to an average of 2.4 ppm (with SO₃ mitigation in service). For low-load operation, the SCR inlet SO₃ concentration is also important (for the purpose of reducing the MOT). On Unit 1 at Gibson, the SO₃ concentration is higher during low-load operation than at full load, probably as a result of higher excess oxygen concentrations in the flue gas. Nonetheless, the average SO₃ concentration was reduced to about 0.5 ppm at the SCR inlet location with SO₃ mitigation in service. This is an SO₃ concentration

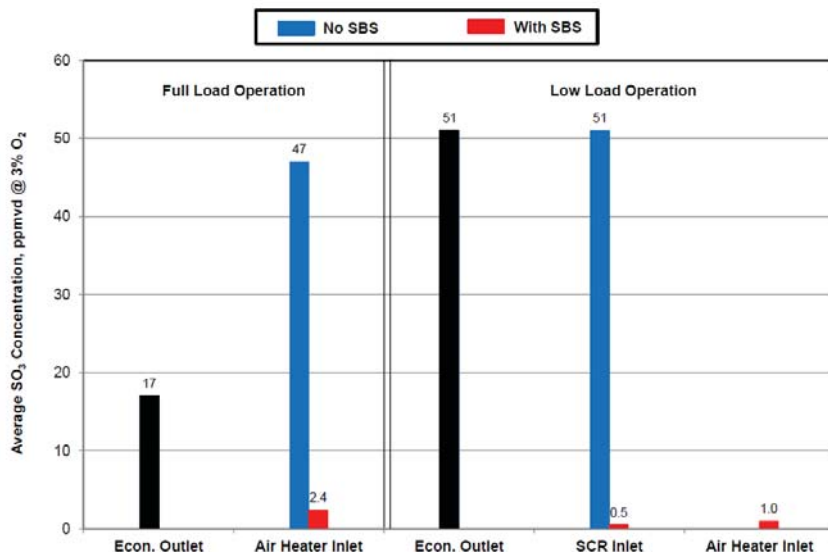


FIGURE 3: Full-Scale test results from Unit 1 at Gibson

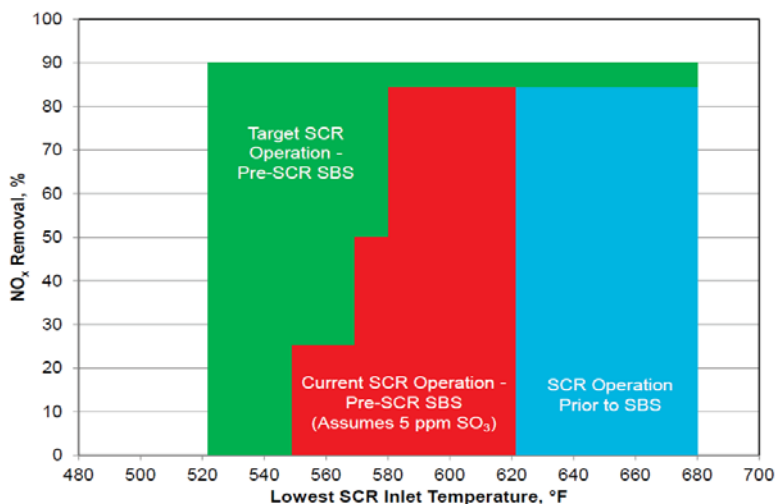


FIGURE 2: Evolution of SCR operation and NO_x reduction goals for Gibson Unit 1

that is even lower than what was used in the Cormetech pilot testing.

Based on the test results, the plant modified the SCR operating guidelines in late 2016 to be consistent with the goals depicted in Figure 2. Initial operating experience on Unit 3 included considerable low-load operation at loads as low as 236 MW. The NO_x removal efficiency was maintained at 85 percent with no indication of problems associated with the new SCR operating guidelines. Based on this success, and as part of a fleet-wide CSAPR compliance strategy, the plant increased SCR NO_x removal levels to 90% to minimize emissions during the 2017 summer ozone season.

SUMMARY

As a result of regulatory and economic conditions, utilities are looking for new strategies to improve the performance of their SCR systems. SO₃ mitigation, implemented upstream of the air heater or upstream of the SCR system, offers the opportunity for increased SCR operating flexibility and reduced operating costs. Consequently, utilities are continuing to evaluate alternative operating strategies to maximize the value of their existing emission control systems.

For further information, contact Sterling Gray at sterling.gray@aecom.com

BIOGRAPHY



Sterling Gray has been with AECOM for over 30 years. He is currently a Business Development Manager for AECOM's Process Technologies Group in Austin Texas, and manages marketing and business development activities for several air pollution control technologies including the SBS

Injection™ technology for SO₃ mitigation. He holds a Bachelor of Science degree in chemical engineering from Michigan State University.



Jim Bridger's Control Overhaul

Written by Zac Phelps, PacifiCorp and Rob Sosinski, Redkoh Industries

ABSTRACT

On a rather balmy mid-February day in Rock Springs, WY, Senior Engineer Zac Phelps overlooks 120 brand new Transformer Rectifier controls with a sense of pride and relief.

Over the past four years the Jim Bridger Power Plant has undergone a TR and control overhaul. Four identical electrostatic precipitators, 6 gas paths with each being 5 fields deep. Redkoh Industries sat down with Zac to talk about the process, the trials and tribulations, and the successes.

RS: "What were the main factors in deciding to upgrade your control system?"

ZP: "Reliability was the biggest factor, parts were failing and becoming obsolete. We were no longer getting the support we required and repairs just took too long."

RS: "When going over the options for new controls what were must haves?"

ZP: "I was very lucky in that the plant let me take the reins on this project, so I was able get exactly what I wanted. The most important thing for me was to have

a system that was completely turn-key. The control manufacturer that was awarded the job needed to design, supply and install the controls. I wasn't going to compare a bid unless it included the install.

Completely new cabinets were discussed but, I felt that a retrofit was the best option for our facility. There were other things I wanted as well, having a keypad and display at every cabinet was a must have, our old system had 1 keypad and display per gas path, and we would run into a lot of communication problems. It was also very important for us to be able to tie all the TR information into our DCS."

RS: "How did the idea of Switch Mode Power Supplies get introduced?"

ZP: "I would say around 2006/2007 through word of mouth we started to hear more about switch mode power supplies.

We were fortunate enough to get a SMPS Demonstration in by Redkoh. They installed the demo cart on an inlet field. The power levels went up and the power levels in the field behind it went up. It was a good test

FIGURE 4: From start to finish, Redkoh's Switch Mode Power Supply Upgrade



Before



During



After

because not only did Redkoh prove their product but, it proved that the Switch Mode Power Supply technology worked.”

RS: “Explain how the bid process went for this project.”

ZP: “Material costs between all the companies was comparable but, installation cost was where the big difference was. The other big difference in cost was that some companies were going to struggle with temperature issues in the penthouse, that meant extra money allocated to cooling and exhaust systems.

When I ultimately decided to go with Redkoh it was because they offered a completely turn key project, no extra cooling systems needed to be put in place, and being able to use our standard TR, that we never had any issues with, at elevated frequencies was perhaps the biggest factor.”

RS: “What was the process like once the job was awarded?”

ZP: “As expected we had a few bumps in the road in the very beginning, but once the installation crew got more comfortable with what they were doing the process really started to fly by.

We were able to install all the 60 Hz control panels while the plant was online, prior to the scheduled outage. The crew would isolate one cabinet per day, completely gut the existing components, install and wire a brand new control panel that was pre-assembled. Because of the pre-outage work the project was always on schedule and it would change the way we would complete the next 3 units.”

RS: “How so?”

ZP: “Well, the fact that we could do the upgrade online wasn’t a thought at first, but like I said after the first unit it completely changed the way I wanted to approach the remaining units.

For the following 3 units, the upgrade was done completely while the plant was online. Because the Redkoh control was able to operate at variable frequencies, we were able to run at 100 Hz with our existing TR. Once the outage did finally come around, we went in

and changed all the TR’s on the SMPS fields to a 400 Hz TR. Really the biggest benefit was when it came time for commissioning. We were able sort out any problems that we had one at a time and not all at once when the timing was critical. The crew was able to get approximately 1 control upgraded per day, sometimes more. We were able to do a full upgrade without losing any working time at all. It took a lot of stress off of everyone, and was something that operations especially seemed to like.”

RS: “You hired a General Contractor & Consulting Service, Bilcatco Construction LLC, to help with the upgrade process. What were the reasons and benefits behind that? How valuable of a tool was it for you?”

ZP: “I’ve known Bill of Bilcatco for sometime, he’s always been involved with the plant. I had many projects going on throughout the upgrade and Bill was someone that I could trust in my absence. It took a lot of stress and pressure off of the installation crew as well because Bill served as a liaison between the team and the plant.”

RS: “Now that the project is over, what issues have you experienced up to this point?”

ZP: “Most, if not all issues have been plant related issues like broken wires or full hoppers. If there even was a suspected problem the Redkoh guys were always available. Just having the availability of them by simply sending a text message or by calling and getting to speak to the president or vice president of the company made me feel good about the decision that I made to go with them.”

RS: “Closing Comments?”

ZP: “We are just very pleased with our controls and the way the overall system runs. I think we all learned a lot from this process and it took all the parties involved to make this happen as smoothly as it did.”

*For further information contact
Rob Sosinski at rob.sosinski@redkoh.com*

BIOGRAPHY

Rob Sosinski is the Lead Product Technologist at Redkoh Industries where he specializes in the development and promotion of new technology. He graduated from Kutztown University in Pennsylvania with a bachelor's degree in Liberal Arts and Sciences in 2010. After graduating, he worked as a game day operations director for Madison Square Garden in New York City, New York. As a native New Jersey, he moved back to New Jersey and has been with Redkoh since 2011.



Zac Phelps is the Emissions Control Engineer at PacifiCorp's Jim Bridger power plant where he is responsible for maintenance and operation activities for the four Electrostatic Precipitators and four FGD Scrubbers. He graduated from Utah State University with a Bachelor's degree in Mechanical Engineering in 2009. After graduating, he worked at PacifiCorp's Hunter power plant in Utah for approximately 2 years where he was involved with projects in the boiler, precipitator, bag houses, and FGD scrubbers.



He moved to Wyoming in September 2012 to begin his current job at the Jim Bridger power plant.



A Bi-Annual Newsletter Sponsored by the WPCA

Is a bi-annual technical journal sponsored by and for the
Worldwide Pollution Control
Association
www.wpca.info

Purpose

To foster new ideas and greater awareness concerning pollution control in the energy industry

Publisher

Reinhold Environmental Ltd.

Comments & Other

Inquiries to:

Reinhold Environmental
3850 Bordeaux Drive
Northbrook, IL 60062 USA
1.847.291.7396
sreinhold@reinholdenvironmental.com
©2017 WPCA

*For more information on the WPCA
Please visit our website at
www.wpca.info*

ENVIRONMENTAL COMPLIANCE IN A CONNECTED WORLD

Written by Volker Schmid, CleanAir Engineering, Inc.

INTRODUCTION

Over the past years, the U.S. Environmental Protection Agency (EPA) has been increasingly asked to do more with less. In the same time, there has been an incredible leap in sensor and information technology. Terms such as Optical Gas Imaging, Optical Remote Sensing, Low-Cost Sensors and Cloud-Based Remote Monitoring have become buzz phrases that are frequently encountered in regulatory initiatives or industry-related news. As early as 2013, the EPA recognized the inherent benefits of these emerging technologies and monitoring approaches, especially the prospect of enabling and promoting public participation in the compliance process.

Conversely, the EPA also realized the many pitfalls in such a participatory compliance assurance approach, especially when it comes to the accuracy, analysis and interpretation of data collected by a new class of participants, the Citizen Scientists. Thus, the agency formulated an integrated compliance strategy that aimed to take advantage of the new technology and approaches, but also to establish a framework for its uniform use. This compliance strategy is commonly referred to as EPA's Next Generation Compliance initiative, or Next Gen in short. This paper will introduce the principles of Next Gen and discuss some of the challenges of participatory compliance assurance monitoring.

WHAT IS NEXT GENERATION COMPLIANCE?

Next Gen consists of the five core principles shown in Figure 5. These principles are interconnected and start with the requirement to consider modern monitoring and information technologies in new regulations, permit designs and enforcement actions.¹ In many cases this includes the verification of compliance with settlement provisions by third-party contractors. By doing so, the agency hopes to achieve a more comprehensive compliance assurance coverage while reducing its involvement in the monitoring process.

One major aspect of this approach has been the drive towards increased transparency with the public. The agency

attempts to achieve this by making all data collected in existing compliance programs available possibly in real- or near real-time. This focus on transparency is driven in large part by EPA's continued emphasis on environmental justice, a longstanding concept involving communities that are thought to be disproportionately impacted by industrial emissions. The agency's Environmental Justice 2020 Action Agenda promotes the empowering of these communities to get actively involved in the compliance assurance process.²

An essential requirement for such an empowerment is unrestricted access to information, which the agency provides through its Central Data Exchange (CDX). Data retrieval from the CDX is facilitated via a variety of online tools such as the air quality system (AQS) for ambient air quality data. Other information portals publish environmental enforcement and compliance and enforcement history online (echo.epa.gov). Others allow the mapping of environmental and health-related data in conjunction with demographic and environmental justice indicators, such as level of income, education, age, distance to industrial facilities, among others (Environmental Justice Screening and Mapping Tool at www.epa.gov/ejscreen).

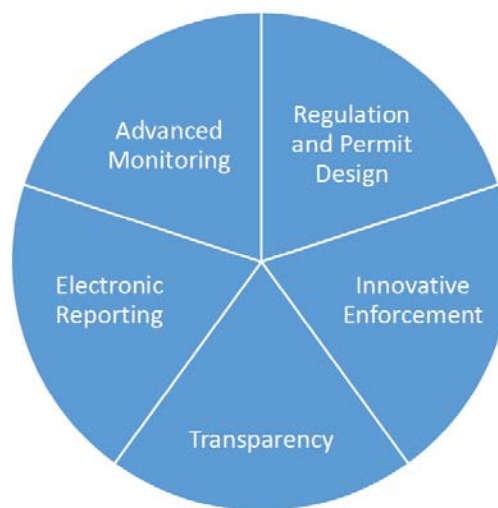


FIGURE 5: U.S. EPA's next generation compliance principles

The prerequisite for this increased transparency is the electronic reporting of all compliance and related data to the EPA. This has become an agency-wide policy for all new regulations since 2013. Familiar examples of tools facilitating electronic data reporting to the CDX are the Compliance and Emissions Data Reporting Interface (CEDRI) used to submit compliance and emissions reports for 40 CFR Part 60 and 63 affected sources, or the Greenhouse Gas Reporting Tool (GGRT), to name two. It is thought that electronic reporting does present the agency with the opportunity to preserve resources. At the least, it provides for more consistent data, as electronic submission generally involves data quality and consistency checks.

ROLE OF LOW-COST AIR POLLUTION SENSORS

Arguably, the most lively discussed aspect of Next Gen compliance has been the drive by the EPA to develop and use low-cost sensors as an alternative approach to measuring pollutants with official monitoring stations. Originally driven by media attention and the increasing public availability of data covering all aspects of daily life, small start-up companies saw an opportunity to satisfy the growing public demand for monitoring personal exposure to critical air pollutants. This led to a large variety of simple devices based on off-the-shelf components that readily transmit data into the cloud for exposure mapping and other analysis. In many cases, the cost for these sensor packages is below \$500.

Besides a response to ever-increasing budget pressures, the EPA quickly recognized the upside of deploying low-cost sensors. For example, these sensors provide a larger temporal and geographic data coverage than traditional air quality monitoring stations at a fraction of the cost. In turn, live personal environmental exposure data would allow for more in-depth health research and give the agency the opportunity to assess the impact of environmental policies, as well as to screen for compliance on a much more comprehensive level. One area of consideration of such an approach has been fence line monitoring at perimeters of facilities adjacent to environmental justice communities. This gives the public immediate access to real-time information about changes in ambient air quality that may impact them.

Consequently, over the past years EPA has spent significant efforts in supporting the development of low-cost sensor networks through grants and in-house research to both supplement ambient air monitoring stations and provide source compliance information. These Next Generation Air Monitoring Efforts focused on the following three goals,

which were formulated in 2013.³

1. Promote development of affordable, near source, fence line monitoring technologies and sensor network-based leak detection systems for selected hazardous air pollutants to support new regulatory strategies and enforcement.
2. Supplement air quality monitoring networks through development of low cost, reliable air quality monitoring technology measuring criteria air pollutants.
3. Support environmental justice communities and citizen science efforts to measure air pollution in local areas.

CHALLENGES

Despite the development and testing efforts over the past years, significant challenges remain, some related to deficiencies in sensor hardware, others related to the way the data generated is used in decision-making processes.

Data Quality

The implication of using low-cost sensors in any decision-making process are far reaching. For one, such a use assumes that these sensors are fit for that purpose. Typically, monitoring for compliance assurance and decision-making is done with instrumentation that has well-characterized and understood accuracies and interferences, and have been extensively tested over a wide range of operating conditions. Such pollutant-specific instrumentation is then designated the status of a Federal Reference Method (FRM) or Federal Equivalent Method (FEM) and included as such in the respective Code of Federal Regulations (CFR).

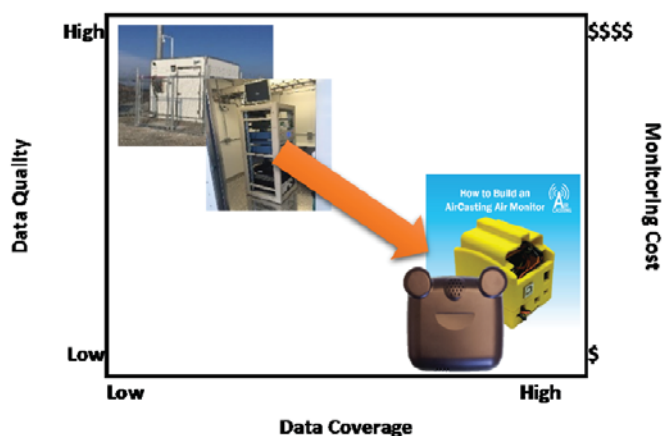


FIGURE 6: Data quality, cost and coverage relationship. The displayed low-cost sensor is the AirBeam, an AirCasting particulate monitor. AirCasting is an open-source solution for collecting, displaying, and sharing health and environmental data using a smartphone (www.aircasting.org).⁴

Furthermore, all aspects of the use and operation of that instrumentation in a monitoring station are governed by uniform standards, including the monitoring site selection, sampling system design, frequency and criteria for calibration and quality control checks and quality assurance audits, preventive maintenance procedures, etc. The goal is to generate high quality, accurate and representative data that can be compared to the results obtained by other stations. Of course, such level of effort comes with an associated cost, which makes the deployment of a large quantity of these stations cost-prohibitive. This relationship is shown in Figure 6. (see page 9)

By contrast, low-cost sensors are rarely tested rigorously, nor frequently calibrated. In addition, it is questionable whether the way the data is collected provides for sufficient representativeness for the data to be used in any compliance-related decision process. The EPA recognizes that large volumes of untested data generated under questionable circumstances should only be used with caution. However, Citizen Scientists may not make such a distinction. In fact, such data could be used to make personal decisions, such as personal health or hazard alert decisions, with potential dramatic consequences.^{5,6} In another scenario, using low-quality sensor data in compliance assessments could damage the reputation of companies that otherwise fully abide by limits established by law.

To mitigate the risk posed by poor data quality, the EPA has set out to establish a technical framework for testing low-cost sensors in public use. Much of that information is published in the Air Sensor Toolbox for Citizen Scientists (www.epa.gov/air-sensor-toolbox). The idea is to create an independent third-party program to evaluate the performance of new sensors and provide a certification process that assures that the sensors are marketed consistently with their capabilities and come with some definition of measurement uncertainty.

In addition, the EPA is evaluating a procedure to benchmark low-cost sensors on a regular basis against established FRMs or FEMs. However, it is questionable whether the public will get engaged in such an approach for a sensor that costs less than \$500, or whether the manufacturers will adopt it unless legally required. Even if less accurate data became certified, once it becomes publicly available there is concern that it will become indistinguishable from high-quality data.

Data Use and Interpretation

Most of the low-cost sensors in public use produce real-time data in increments as short as one minute, sometimes every

second. Interpreting such short-term data without any corresponding health studies can lead to misunderstanding and misinterpretation of the implication of that data. In other words, how does the low-cost sensor reading correlate to bad air quality or danger to health when there are no health-based standards available at that time scale?

Current primary National Ambient Air Quality Standards (NAAQS) are developed through rigorous risk assessment and are set at levels that aim to protect public health, including the health of at-risk populations. These standards are typically derived from longer term exposure data. For instance, the NAAQS for ozone is based on an averaging period of eight hours. Specifically, the ozone NAAQS is defined as the annual fourth-highest daily maximum 8-hour concentration, averaged over three years. Consequently, in absence of short-term health studies, citizen scientists could draw unsupported conclusions when trying to link short-term sensor data to air quality and related health outcomes.⁷

Data Privacy

Low-cost sensors are increasingly used as mobile sensors to monitor personal exposure during daily activities. Daily data logs are then subsequently uploaded into the cloud. In many cases, data can be shared with other participants and displayed in crowd maps, as metadata such as location and time is collected alongside air quality data. The possibility that this data can be publicly connected with the individual collecting the data constitutes a privacy concern.

EFFECTS OF CHANGE IN ADMINISTRATION

The Next Gen initiative was started under a different administration from today and in a different regulatory climate. The previous administration directed significant funding into the development, testing and use of low-cost sensors for a variety of reasons. Since then, EPA's funding priorities have changed and the effects of this change on the Next Gen initiative are still unclear. The initiative could be starved through targeted budget cuts. Alternatively, the potential loss of EPA funding in general could, in fact, spur further development of low-cost alternative solutions.

This particular aspect of Next Gen was originally driven by a changing public awareness of air quality and changes in lifestyle, which created a demand for these devices and services. The demand has not lessened and will continue to drive further sensor development and usage. This is evidenced by the number of venture-capital fueled small start-up companies servicing this market. In addition, academia has started to embrace low-cost sensors as a way

to leverage the technology to collect more personalized air quality data at a much-increased data density in an effort to support a large variety of study objectives.

The prospect of collecting large amounts of personalized data and the chance to influence consumer behavior has also brought about the interest of “Big Data” companies such as Google. This has caused further development and use of low-cost sensing technology and information services. In fact, recently Google Earth Outreach has partnered with Aclima, a provider of mobile sensing platforms, to equip Google Street View as a first step towards generating an outdoor air quality map to the public much like Google’s Traffic Map. The result of this partnership can be seen in Figure 7 and is just one example of Big Data’s increased involvement in the proliferation of low-cost sensing technology.

CONCLUSION

Next Gen has been a major EPA focus since 2013, especially due to the continued emphasize on the concept of Environmental Justice. One of the aspects of that initiative has been the development and promotion of use of low-cost

sensors, which has brought about a new participant in the air pollution compliance process, the Citizen Scientist. This push towards a participatory compliance process coupled with the availability of low-cost sensing and information technology has effectively led to the democratization of air quality. As a result, large amounts of untested and at times questionable environmental data are becoming readily available to the public. The EPA has tried to take advantage and steer participatory compliance, but also address some of the shortcomings of this approach, namely data quality, use, interpretation and privacy.

Undoubtedly, upcoming changes in EPA funding will have an effect on the Next Generation Compliance Initiative. Regardless, there is an increasing public environmental awareness and resulting demand for personal air quality monitoring, which is evidenced by the existence of several startup companies servicing the market with low-cost sensing products accompanied by cloud-based social media solutions. Many of these products are available as mobile sensors that provide truly personal exposure monitoring.

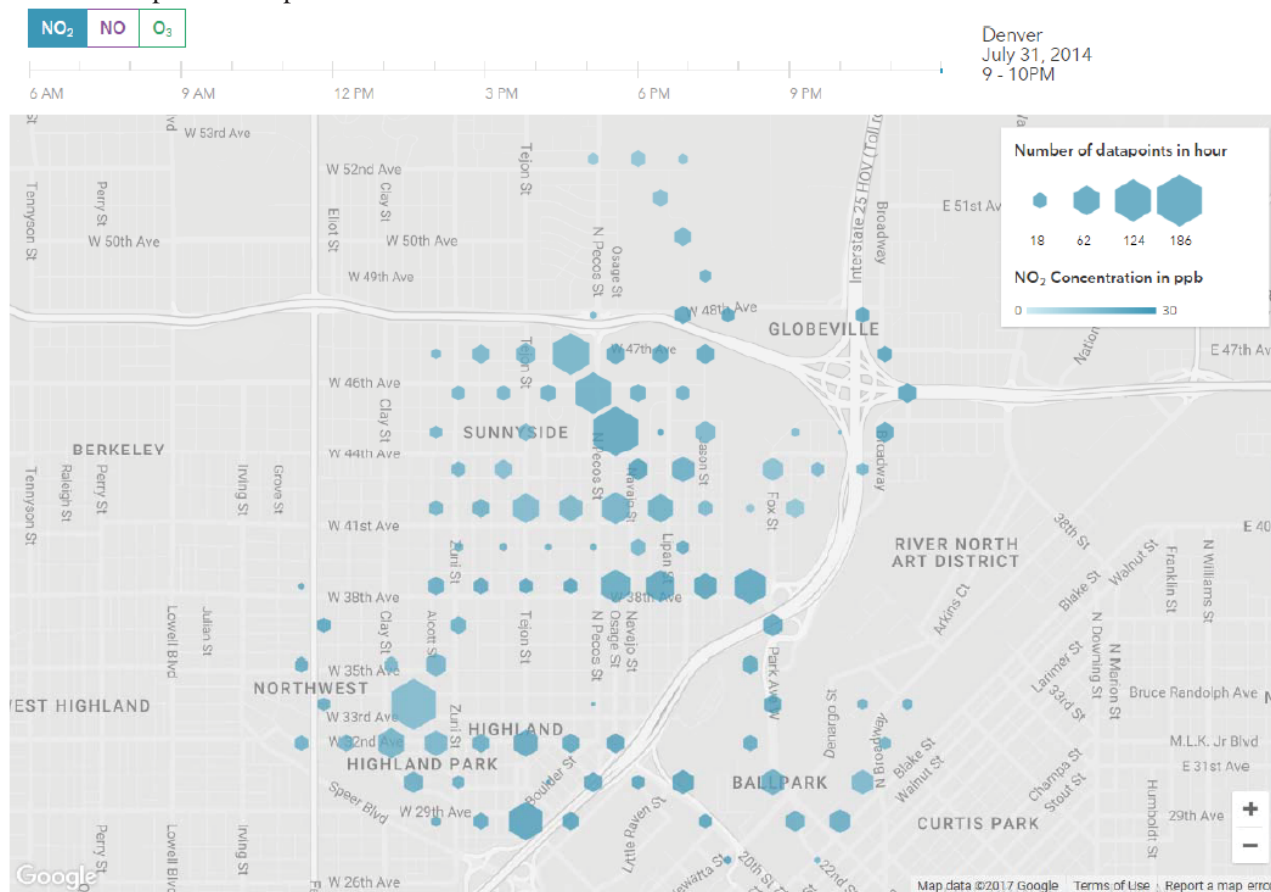


FIGURE 7: Street-Level Air Quality Map (insights.aclima.io).
Hexagon size = number of data points collected in the area during the hour.

The resulting large amounts of personal data combined with the potential for using such data to influence customer decisions have generated considerable interest by Big Data. Private partnerships are forming, spurring further sensor and service development. Consequently, even if the regulatory impetus for Next Generation Compliance changes, the public interest and involvement in the form of Citizen Scientists will not. In fact, participatory compliance will most likely increase.

From an industry perspective, there are several challenges with such an approach. A particular concern is the generation of large amounts of untested data with often questionable quality. This can lead to data misinterpretation with potentially damaging consequences to the reputation of otherwise law-abiding companies. Unlike the low-cost sensing approach, protecting image and reputation will require considerable effort by the industry in generating high-quality, defensible data. In turn, such data can be used to supplement industrial compliance data requirements for a more comprehensive defensible compliance approach.

REFERENCES

1. U.S. Environmental Protection Agency, Next Generation Compliance. Available at www.epa.gov/compliance/next-generation-compliance, Accessed April 2017.
2. U.S. Environmental Protection Agency. EJ 2020 Action Agenda - The U.S. EPA's Environmental Justice Strategic Plan for 2016-2010. EPA-300-B-1-6004, October 2016.
3. U.S. Environmental Protection Agency. DRAFT Roadmap for Next Generation Air Monitoring. March 2013, Available at www.epa.gov/sites/production/files/2014-09/documents/roadmap-20130308.pdf, Accessed April 2017.
4. Snyder, E.G., Watkins, T.H., Solomon, P.A., Thoma, E.D., Williams, R.W., Hagler, G.S.W., Shelow, D., Hindin, D.A., Kilaru, V.J., Preuss, P.W. The Changing Paradigm of Air Pollution Monitoring. *Environ. Sci. Technol.*, 47, 11369-11377 (2013)
5. Lewis, A., Edwards, P. Validate Personal Air Pollution Sensors. *Nature*, 35, 29-31 (2016).
6. Hindin, D., Grumbles, B., Wyeth, G., Benedict, K., Watkins, T., Aburn Jr., G., Ulrich, M., Lang, S., Poole, K., Dapolito, D. Advanced Monitoring Technology: Opportunities and Challenges. *EM*, November 2016.
7. Keating, M., Benedict, K., Evans, R., Jenkins, S., Mannshardt, E., Lyon Stone, S. Interpreting and Communicating Short-Term Air Sensor Data. *EM*, November 2016.

*For further information
contact Volker Schmid at vschmid@cleanair.com*

BIOGRAPHY

Dr. Volker Schmid joined CleanAir Engineering (CleanAir) in 2002 and since has been responsible for the identification of innovative measurement technologies and their incorporation into services or products offered by CleanAir. He has been the driving force in the development of CleanAir's mercury emissions monitoring and ambient air monitoring programs, and is currently the leader of CleanAir's Advanced Monitoring Group. Besides his responsibilities with the Advanced Monitoring Group, Dr. Schmid has provided technical input on a variety of regulatory matters including fugitive emissions from the coke and steel producing industries. In addition, he has contributed to several guidance documents addressing measurement of emissions from carbon capture processes, as well as accurate carbon dioxide and flow measurements in industrial flue gases. He can be reached for questions or comments via email (vschmid@cleanair.com) or phone at 724-227-0148.



20 Economical Ways to Improve the Performance of a Baghouse Dust Collector

Written by Mike Allen, CLARCOR Industrial Air

INTRODUCTION

The baghouse dust collector is an integral component to many industrial processes. However, many baghouses in operation do not offer adequate technology to accommodate today's aggressive production demands. Thus, plant operators and owners are faced with one of three possible decisions concerning their inefficient baghouse:

1. Allow the baghouse to continue operating without modifications;
2. Buy a new baghouse or upgrade the baghouse to a new to a more efficient design, such as a pulse-jet, that can take advantage of high efficiency pleated filter elements instead of filter bags and cages; or
3. Make minor modifications and/or employ modestly-priced devices and tools to improve the operation of the existing baghouse.

This paper will focus on #3 and outline many cost effective ways that can have an immediate impact on overall performance, without the need for a full rebuild of the baghouse.

Some of these solutions revolve around the mechanical parts of the baghouse, suggesting ways to improve performance of the existing design, or upgrading to newer technology. Topics for discussion will include ductwork configuration, rotary valve operation, and particulate buildup in hoppers. Each of these areas can inhibit overall dust collection effectiveness and must be addressed so that other modifications to the baghouse will have maximum benefit.

The paper will also discuss upgrading to higher performance accessory items such as pleated filter elements, fabric finishes, and door seals. These inexpensive devices are offered in many styles to fit a variety of OEM designs and are engineered to overcome original design flaws that lead to short bag life, improper filtering/cleaning, and emissions. Included in these suggestions are tips for correct filter bag installation in various styles of baghouses.

These and other ideas are presented to provide a baghouse

owner a full range of options in which to enhance dust collection performance. Understanding these options, along with the benefits each offers in terms of time savings, reduced energy consumption, and filtration enhancement, can enable a decision maker to discover solutions that provide maximum impact at minimal cost.

DISCUSSION

• Proper design of new equipment

Many baghouses in operation today were improperly designed from their inception, which may cause problems during the entire life of the baghouse. Some of these units were not engineered properly, or were sized too small to save money in a budget decision. One of the most important aspects in design that is sometimes overlooked is a proper air-to-cloth ratio. This ratio is an expression which shows how much air volume is being handled versus how much cloth area is available in the baghouse.

Pulse-jet baghouses that utilize felted material and clean while online can operate at higher air-to-cloth ratios. Shaker and reverse air units that use woven material and clean offline require more filter area. The air-to-cloth ratio is a very important factor to consider in the design and operation of a baghouse. Improper ratios can contribute to inefficient operation of the baghouse. Operating at an air-to-cloth ratio that is too high may lead to a number of problems including high pressure drops, insufficient cleaning, and inadequate ventilation at the pickup point.

Shaker and reverse air systems should not be sized to operate above a 2.5:1 air-to-cloth ratio. Most pulse-jet systems should be sized at no more than a 6:1 air-to-cloth ratio (and much lower on units that utilize fiberglass filter media). The correct design from the initial installation will definitely save money over the life of the unit.

• Optimize differential pressure

Proper operation of a baghouse dust collector requires the use of differential pressure gauges on the entire collector. Magnehelic® gauges measure differential pressure by installing

one port to the clean side and one port to the dirty side of the baghouse or plenum. By indicating a sudden decrease in pressure, a system leak can be detected. A sudden rise in pressure denotes the filter bags are becoming “blinded” or caked with particulate. Magnehelic gauges are available for point-of-use or remote installation. U-tube manometers can also be used for the same purpose as Magnehelic gauges, but they are less technically advanced. These can also help identify problems with dampers and bags by indicating the difference in pressure across the baghouse.

• **Utilize Clean-On-Demand Systems**

Differential pressure gauges should also be used in conjunction with gauges that can set the cleaning system to “clean-on-demand.” Photohelic® gauges use pressure sensors to monitor coordinates to determine cleaning cycles. The gauge is manually set to operate between a high and low pressure point. When baghouse differential pressure changes to reach the high pressure point, the cleaning cycle is automatically activated. When the low pressure point is reached, the cleaning is discontinued. The ideal spacing between the high and low set points should be no more than 1” with the ideal setting of 1/2” between the two points. These settings help to control the system by not cleaning too much material off of the filter bags, which can cause a slug of material to exit the system.

Sequential controllers enhance the prevention of over and undercleaning of the filter bags which causes a decrease in airflow, production levels, and filter bag life. The Photohelic® Gauge Sequential Controller is used to automatically

or manually activate, as well as discontinue, the baghouse cleaning using preset high and low pressure points. The system automatically adjusts the cleaning cycle to match the baghouse load to prevent overcleaning of the filter bags. An LED Sequential Controller operates in the same manner as the Photohelic unit, but provides a 4-20mA signal. This signal enables an external monitor or recording device to be used for remote monitoring or connection to a PLC controller.

The Reverse Air/Shaker Sequential Controller automatically sequences through a Close Damper-Reverse Air (or Shake)-Settle Time-Open Damper cycle. The cycle will repeat for all compartments and return to the first compartment. The active cleaning cycle is indicated on the timer panel. Cleaning can be scheduled on either a continuous or on-demand cycle.

All of these gauges will help improve control of the system. They are all fairly easy to install and inexpensive in comparison to the benefits received. They also help in record keeping to pinpoint problem areas and how to correct them.

• **Proper inlet design**

The importance of proper inlet design is extremely significant as it relates to the operation of a baghouse dust collector. Many baghouses are of a standard design and use “off the shelf” products. These products are delivered to the end user with the inlet already installed in the hopper. Some of these designs incorporate a baffle over the inlet duct opening that directs incoming air downward into the hopper area.

This airflow into the bottom of the hopper area can cause particulate in the hopper to swirl upward and to be re-entrained into the filter media. When combined with the incoming material, the material re-entrained from the hopper produces a higher grain loading on the filter bags. If the incoming material is directed straight across a narrow hopper, excessive wear from abrasion is likely to occur on the sidewall opposite the inlet.

Enlargement of the inlet duct prior to the hopper can reduce the inlet velocities on entry. Inside the hopper, the installation of “ladder vane” baffling creates a more uniform velocity profile in the hopper. The ladder vane baffles are installed to evenly distribute the inlet plenum gas stream, reducing turbulence and uneven grain loading. Better distribution of inlet air minimizes the re-

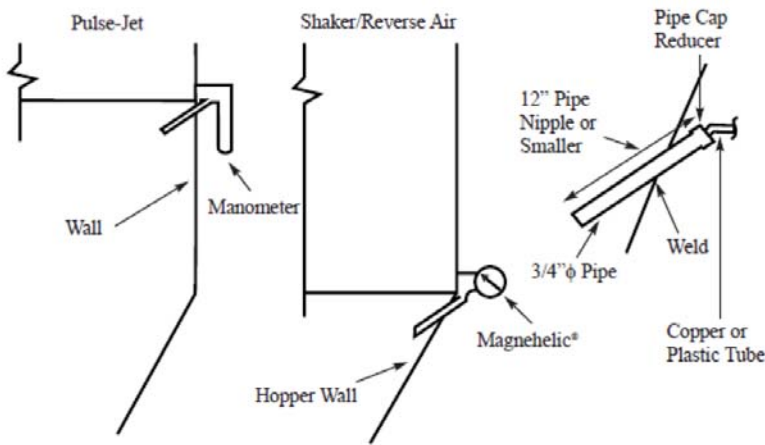


FIGURE 8: This illustration shows the correct installation for the gauges. A 2 1/2” pipe cap reducer attached to a 1/4” hose helps to reduce the potential of pluggage.

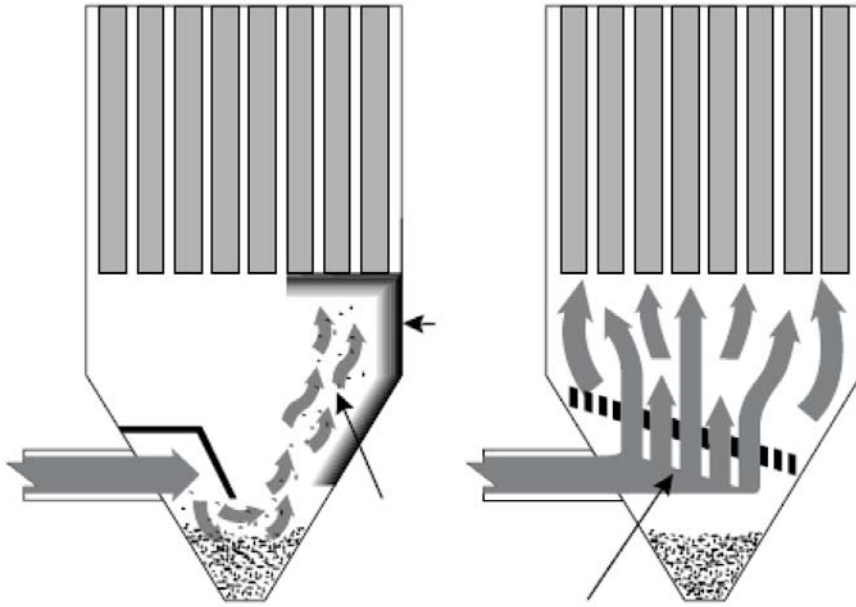


FIGURE 9: Ladder Vane Baffles more evenly distribute airflow

entrainment potential and reduces the amount of material carried to the filter bag surface. These baffles are inexpensive and easy to install for most baghouse designs.

- **Don't use the hopper for material storage**

Many problems can occur when the hopper in a baghouse dust collector is used for storage of material. The primary purpose of a hopper is to be used as an inlet into the baghouse, and for facilitating the removal of material into a bin or screw conveyor for further transportation. When material is stored in the hopper and not removed, it can cause severe problems by allowing the re-entrainment of material into the filter bags. This re-entrainment may shorten filter bag life, caused by abrasion on the lower portion of the filter bags. Material that is cleaned off of the bags should be removed from the hopper as soon as possible to prevent this re-entrainment problem. The material can be removed continuously by the use of an airlock or dump valve that removes the material into the collection system.

Even if the hopper is not used for storage, there can still be problems with material building up on the side-walls or bridging over the outlet of the hopper. These situations can cause the same problems as listed previously when the dust re-entrains onto the filter bags, or causes slugs of material to be emptied all at once instead of a steady, even flow.

Acoustic horns have shown to be an inexpensive way to prevent bridging and build-up by helping to fluidize the material with the use of sound waves that do not let the material

adhere to each other. These acoustic devices can be installed easily with a throat or a flange mounting system that causes minimal damage to the hopper and will not cause the hopper walls to warp or crack at the seams.

- **Utilize pleated filter elements to improve the operation of pulse-jet units**

Pleated filter elements provide a simple retrofit for upgrading existing dust collection systems and improving problem systems. A pleated filter element is a one-piece pleated product of spun bonded polyester media and is a direct replacement for traditional filter bags and cages. This media resists surface penetration of particulate, dramatically increasing efficiencies while operating at significantly lower differential pressures than felted or woven materials.

The media is pleated and molded into a filter element, increasing filtration surface area over bags by 100-200+%, depending on existing bag sizes. The unique spun bonded media used in the manufacture of Pleated filter elements is unlike traditional felt fabric. It has a tight pore structure and rigid physical properties that allow it to hold a pleat without the need for supporting backing material. Because of this, as much as three times more filtration area can be installed in the same tubesheet hole to replace a conventional bag and cage.

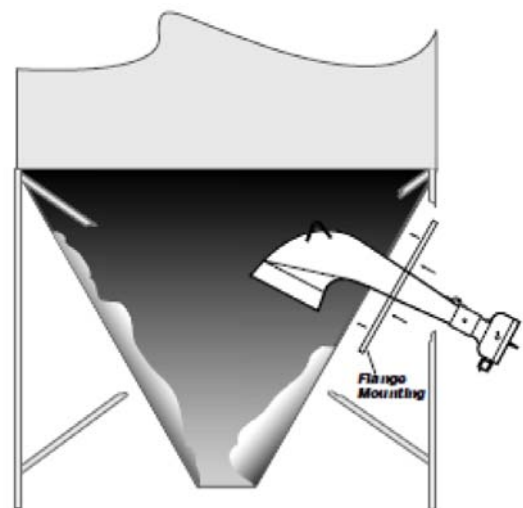


FIGURE 10: Acoustic Horn Throat Flange mounted in hopper

Because of the ability to increase filtration area so dramatically within the existing dust collection equipment, pleated filter elements provide a very economical alternative to having to purchase new equipment or spend significant capital funds. They also provide other substantial side benefits, which make this a very cost effective way to improve the performance of existing equipment without the need for major changes.

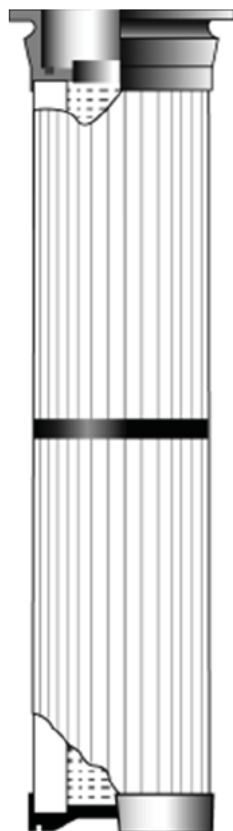


FIGURE 11: Top Loaded Pleated Filter Element

moved away from the gas entrance and eliminates the recirculation of collected materials. By not re-entraining material, greater gas flow and extended bag life is achieved. Screw conveyor wear is also reduced resulting in less maintenance needed on the equipment.

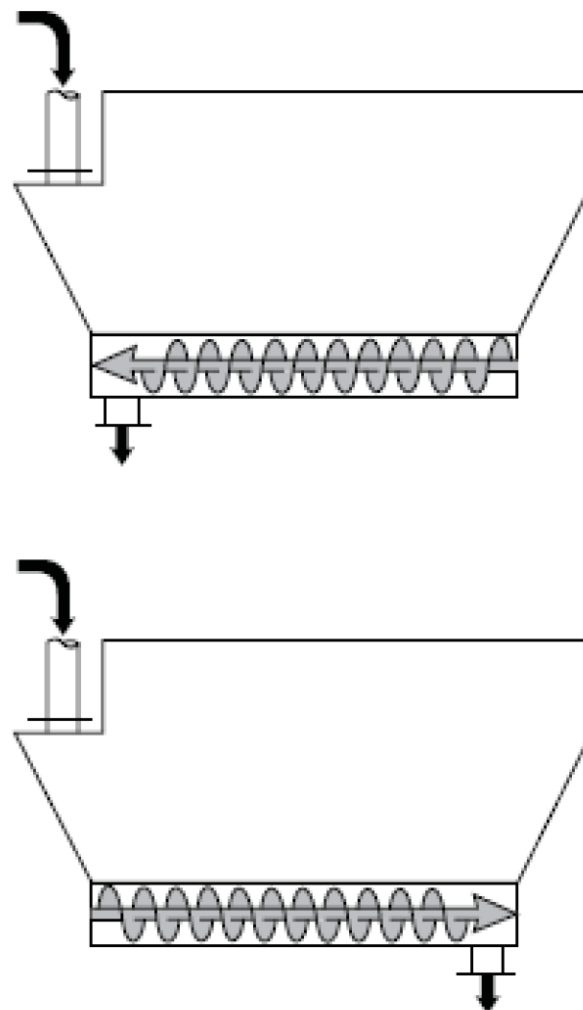


FIGURE 12: Trough Hopper Screw Conveyor

• Correct trough hopper screw conveyor direction

On collectors with a trough-type hopper and hopper inlet, dust can be re-entrained by high inlet gas velocity. On these units where the screw conveyors move the material towards the gas inlet of the hopper, there is a greater potential for dust re-entrainment. By design, material collected in the screw conveyor must be moved to a single discharge point and as the collector loads the screw conveyor, the material depth in the screw conveyor increases. When this mass of material is moved toward the dirty inlet (the point of highest velocity in the hopper) it often becomes airborne and is carried back to the filter bags. This increases the recirculating load in the collector and creates artificially high pressure drops.

An easy recommendation to this problem is to reverse the screw conveyor and move the discharge point to the opposite end of the collector. The mass of material collected is now

• Screw conveyor leakage & discharge

Airlocks on hoppers and screw conveyors are a necessary evil. Airlocks can be double dump valve design, rotary airlock feeders, or other style systems. The 8", 9", 10", or 12" diameter rotary airlock should not run faster than 20 RPM. It is possible for the pockets of the rotary airlock to move too fast for material to fall out and be removed from the collection area. In this case, the rotary airlock can act more like a fan than a true airlock.

The relationship of revolutions to capacity is linear for a rotary airlock up to about 10 RPM. At 10 RPM this relationship is at 93% efficiency to about the 20 RPM level. Above 20

RPM, this relationship will drop to 65% efficiency. In order to obtain the required 20 RPM, a double reduction drive, either in a drive unit or through sprockets must be used.

The screw conveyor feeding the rotary valve can also create problems. Dust trapped in the hopper has the potential of being re-entrained and conveyed back to the bag. Any screw designed for a dust collector should be sized as a feeder. The screw should be sized at 100% full. Most problems occur when the screw is sized at 30% to 60% loading. Due to slugs or surges of material being removed from the compartments through cleaning, the screw can very easily run 100% full, complicating the dust removal system and overloading the airlock or rotary valve.

Conveyor screw flighting should be cut back to where there is no flighting over the airlock because it will drive the material directly through the gasketing and seal. The flighting should be cut back and then the material should not pack and build-up.

- **Proper sealing of access doors**

Access doors allow for maintenance personnel to enter the baghouse equipment for leak detection, filter bag changes, and proper identification of operational problems. These doors need to create a positive seal to reduce baghouse air leakage and heat loss on all negative systems. They also need to seal properly to reduce condensation that can cause bag failure and severe corrosion.

Care needs to be taken to ensure a positive contact between the door seal and the door pan to prevent air infiltration. Door seal material is used to help prevent the problems of metal corrosion and filter bag damage caused by leakage of ambient air into the baghouse. There are various designs to meet all specific needs of many doors and applications based on gas chemistry, temperature, and door configuration.

The proper use of door seal is a very inexpensive and easily installed fix that can prevent many problems from occurring. All doors should be inspected and analyzed to evaluate what materials are needed to properly seal the doors. This evaluation should be done on a periodic basis and whenever the baghouse equipment is down for repairs or changeouts.

- **Modulating damper installation**

The dustcake that is collected on the filter bags presents a variable static resistance to the ventilation system. As dust builds on the bags, the resistance to flow increases. After the filter bags clean, the resistance is lower. In many applica-

tions, the fan operates against high resistance and produces lower volume as grain loading rapidly builds the dustcake on the bags. When the load is completed and the grain loading is reduced, the fan suddenly runs against lowered resistance and the air volume increases. The resulting high velocity can cause small particulate to penetrate the fabric, leading to blinding and bleedthrough emissions. The cycle would then repeat as the next cycle begins.

A good recommendation is to install a modulating damper on the fan that adjusts to the pressure changes. The damper maintains a more regulated volume to the baghouse, which protects the fabric from impingement. A control based on static pressure measured at the inlet of the baghouse will cause the damper to restrict airflow to compensate for the reduced resistance of clean bags. This will open wider to allow more volume as the static resistance builds.

The use of a modulating damper will help the operator of the equipment to have a better handle on the process. This control should lead to much better bag filter bag life because of the constant state of the airflow and dustcake on the bags. There are different styles of these modulating dampers that are available and should be evaluated based on the particular aspects of the process.

- **Correct filter bag installation**

Correct filter bag installation is important to maximize the life of the fabric. The recommended procedure for installing bags in pulse-jet collectors is to position all bag seams facing the same direction. This can provide a reference point that helps to identify problems that result from inlet abrasion. This can be a very useful troubleshooting technique that provides a history on bag failures.

Bags with flanges or cuffs that fold over the tops of their support cages should be checked for smoothness around the edge to prevent leakage and bag abrasion. Seam placement on bottom load bags should be 180 degrees from the split or gap in the cage collar. The clamp on these bags should be installed 90 degrees in relation to the seam on the bag and positioned on the groove in the cage. Snapband bags for top access pulse-jet units should be installed with the seams all facing the same direction. This allows for identification of areas where problems are occurring and improved troubleshooting of the unit.

Filter bags installed in reverse air collectors should have the seams positioned at a 45 degree angle to the walkway and

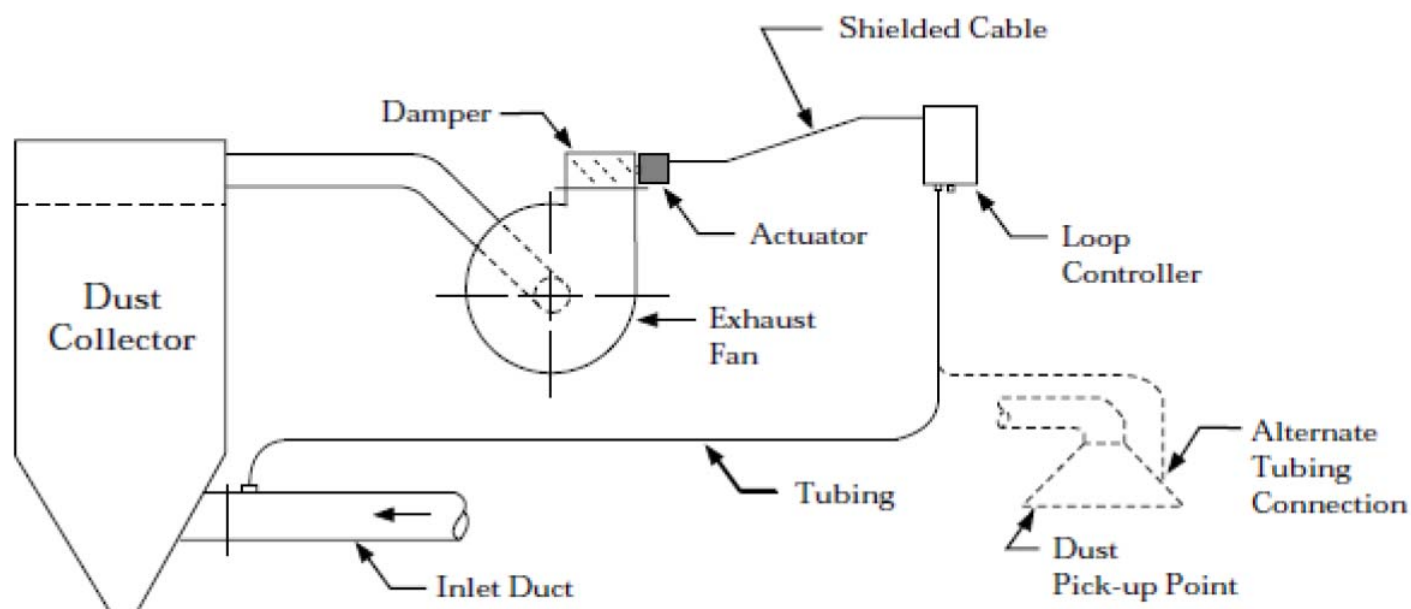


FIGURE 13: Modulating Damper Installation Schematic

access door, which allows for easy verification that seams are installed straight and plumb. This also ensures the bags are the maximum distance apart, reducing the potential for bag-to-bag abrasion.

Proper tensioning is also a critical element in bag performance. Loose unsupported bags do not provide for proper collection, and the resulting bag-to-bag abrasion can cause premature failure. Overtensioned bags will lead to stress on the filter bag and reduced bag life. The use of proper tensioning tools ensures equal and adequate tension to all bags, eliminating guesswork that can cause damage during bag-house operation.

On shaker collectors it is recommended that the shaker log be rocked to one side allowing all bags in that row to be installed taut. Once that row is installed, the shaker should be rocked in the opposite position and the other row of bags installed in a similar manner. Utilizing this method will not put any additional strain on the shaker bearing, bushing, or other parts and will not leave the bag too loose to cause bottom bag abrasion or the possibility of the bag pancaking shut.

- **Clean air in compressed air lines**

The problem of moisture, oil, and dirt in compressed air lines can affect the cleaning ability of pulse-jet style dust collectors. When compressed air that cleans the filter bags is contaminated, it can cause many problems. Premature wear on pneumatic components can result because these compo-

nents were manufactured to be used most effectively with clean compressed air. The pressure drop across the system can also rise because dirty air does not clean the filter bags properly. The contaminants are pulsed down into the filter bag which can cause reverse blinding of the bags and a possible increase in material build-up on the bags due to moisture.

The problems of dirty compressed air can be cured fairly inexpensively with the use of filtering systems installed directly on the compressed air lines. Some of these systems can eliminate oil and water in the airstream with an efficiency of 99.97% of particles above 0.7 micron. With this type of production you can drastically improve the operation of your equipment with a small investment.

- **Utilizing 1-1/2" Pulse Valves**

In pulse-jet style systems, a pulse action for cleaning the filter bag is a function of shock to the filter bags, not a function of air volume. The "shock wave" developed in the bag by the instantaneous release of pulse air must be strong enough to travel the full length of the bag in order to clean down completely.

A 1-1/2" double diaphragm pulse valve is significantly more effective at accomplishing this cleaning than a single diaphragm valve or any smaller size valve. The first reason for this is that a single diaphragm valve must release all of the air that is holding the diaphragm closed. This occurs by

the air traveling the length of the pilot tubing and escaping through a small vent port in the pilot solenoid valve, which slows the release of the pulse air into the blowpipe. A double diaphragm valve must only release a comparatively small volume of air that is holding the small diaphragm closed through the vent port in the pilot solenoid valve. At the same time, the air pressure holding the main diaphragm closed is released through a large vent port in the pulse valve, which allows an immediate release of the pulse air into the blowpipe.

The second reason for superiority is that a 1- 1/2” pulse valve and blowpipe contain a 1.76 square inch cross-sectional area. A 1” pulse valve and blowpipe contain a .88” square inch cross-sectional area. In comparison, fifteen 3/8” diameter blowpipe orifices contain a combined cross-sectional area of 1.65 square inches. This shows that the 1-1/2” pulse valve will provide sufficient area for the pulse air to flow unimpeded to all blowpipe orifices. In contrast, a 1” pulse valve, or smaller, imposes a restricted area which impedes the flow of air to the blowpipe orifices.

A double diaphragm valve produces a crisp, instantaneous pulse and results in a stronger shock wave being developed in the filter bag. This, in turn, provides much more effective cleaning. This change to a 1-1/2” pulse valve is fairly easy to accomplish and should save a significant amount of money in regards to bag changeouts and possible loss of production due to insufficient cleaning of the filter bags.

• **Pulse-Jet Cleaning Set-Up**

In pulse-jet collectors, the cleaning function not only removes the collected dust, but it rearranges the remaining dustcake structure on the bag, resulting in a change in differential pressure. In a unit with high upward gas

velocities, mechanical separation of the fine submicron dust can occur, creating a dustcake structure that is very dense. A dense dustcake creates a resistance to airflow and higher differential pressures.

The cleaning sequence can play an important part in lessening the re-entrainment of material. Pulsing one row right next to another row (sequential order) can cause the fine, sub-micron material to migrate to the cleaned row. Staggering the order or rows to be pulsed can improve the dustcake for optimum filtration. An example would be to pulse rows 1 then 4,7,10,13,16,2,5 8,11,14 and so on until the entire system has been cleaned.

The cleaning cycle for pulse-jet collectors should be designed so the pulse duration produces a short, crisp pulse in order to create an effective shock wave in the bag. This duration is generally set to fire for 0.10 second. The frequency of pulse-jet cleaning is also vital to proper dustcake retention. This frequency can vary from 3 to 30 seconds or more and is adjusted by means of a potentiometer on the timer panel. The frequency should be adjusted so that the differential pressure across the collector ranges from 3” to 6” w.c. (75-150 mm).

On pulse-jet collectors, the pulse frequency can be increased, but the next pulse should not be programmed to fire until the compressed air pressure in the header is regained. This allows the same force of pulse for each row cleaned. The regain of air pressure is dependent on the capability of the compressed air system tied to the baghouse and the size of the compressed air piping to the header tank.

• **Bag-to-Cage Fit**

A major cause of failures in pulse-jet systems is improper fit of the filters to the support cage. For proper performance the

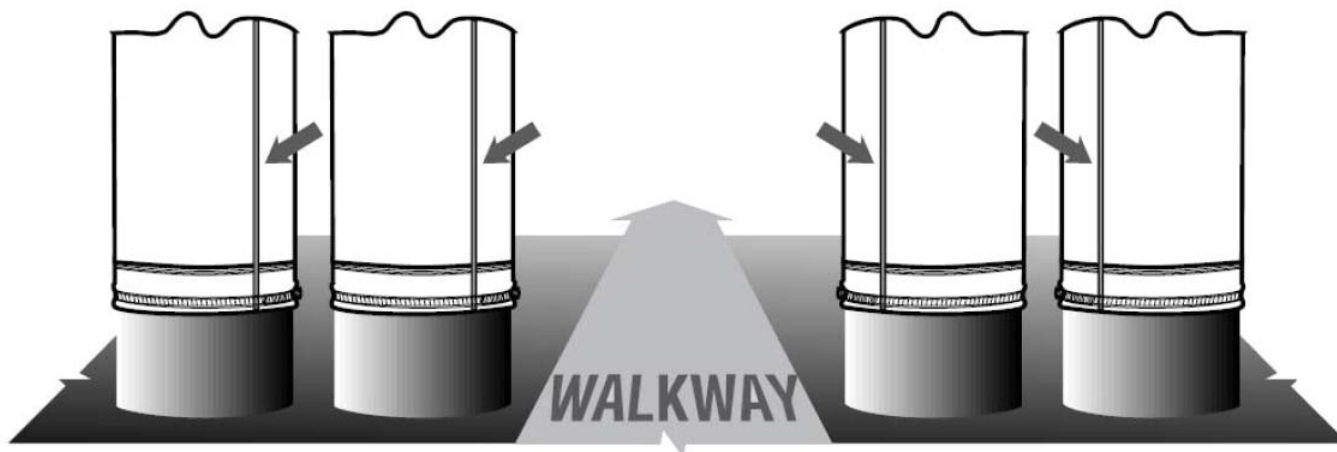


FIGURE 14: Installing Filter Bags Correctly Helps in Troubleshooting Equipment

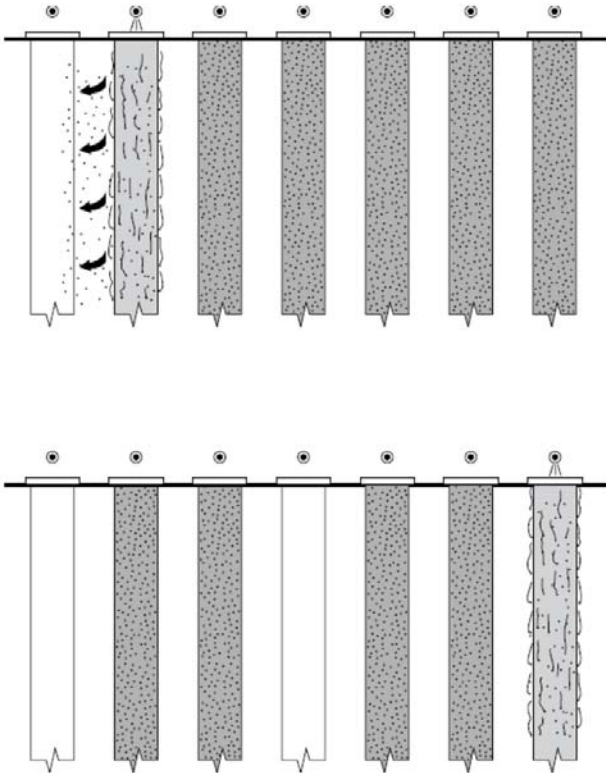


FIGURE 14: Incorrect & correct sequencing in Pulse-Jet Systems

pulse-jet filters, the fit relationship between the bag and cage is critical. Filters that are too loose or too tight will severely limit collection efficiency and lead to premature failure.

A related area is the importance of the proper support cage to support the filter bag. There are many types of cages in the marketplace but proper care must be taken to ensure that the cage construction will properly support the filter bag as well as optimize cleaning and efficiencies. The variables that are important for review include the number of vertical wires used and what type of ring spacing should be employed to operate properly in the dust collection equipment.

• **Blowpipe alignment**

One major cause of filter bag failure in pulse-jet style cleaning dust collection units is the improper alignment of the blowpipes in the cleaning system. The blowpipes serve to provide the compressed air cleaning which sends the air into the top of the filter bag and cage assemblies. If the blowpipe holes are not aligned properly over the filter bags, then the proper cleaning of the filters will not occur.

If the blowpipe holes are not properly centered, holes may develop in the top portion of the filter bags due to the excessive force that is seen by the fabric. These holes will eventu-

Fabric	“Pinch”	Rec. Cage/Ring Spacing
Felted Materials	0.25-0.75 inches (6.4-19 mm)	Any/Any
PTFE Membrane on Felted Materials	0.25-0.5 inches (6.4-12.7 mm)	20-wire/6 inches (15.24 cm)
Fiberglass	0.125-0.375 inches (3.2-9.5 mm)	20-wire/6 inches (15.24 cm)
PTFE Membrane on Fiberglass	0.0625-0.25 inches (1.6-6.4 mm)	20-wire/6 inches (15.24 cm)
Ryton®/Procon®	0.25-0.5 inches (6.4-12.7 mm)	10-wire/Any
P84	0.125-0.375 inches (3.2-9.5 mm)	20-wire/6 inches (15.24 cm)
Teflon®	0.375-0.625 inches (9.5-15.9 mm)	Any/Any

FIGURE 15: Nominal recommended “Pinch”

ally cause the bags to fail and have to be replaced. Another potential problem is that the pulse-jet cleaning energy is reduced and the filter bags may not be cleaned properly due to the lack of cleaning seen by the bottom portion of the filter bags. If the holes are not aligned through the center of the filters, then not as much extra cleaning air is added to be able to create the proper shock wave in the filters.

A thorough review of the blowpipe installation and how they are aligned in respect to the filters should be undertaken and changes made to ensure the proper operation of the equipment. This is a very quick fix that is easy to change which can also produce significant improvements in the system.

• **Conditioning of new bags**

Conditioning agents are injected into a baghouse to establish a porous control layer on the filter bag surface. This protects the bags from particulate bleedthrough, blinding, and problems caused by hydrocarbons and moisture carryover. Conditioning agents should be utilized to pre-coat all filter bags after an entire changeout and can even be used on an ongoing basis to improve the operation of a baghouse.

The best available agents consist of multi-shaped particles which are used to develop an initial control layer on the filter bag. The varying particle sizes allow air passages to remain open, keeping pressure drop minimized and airflow maximized. Proper agents can also improve dustcake release by

allowing the dustcake to break away from the bag during the cleaning cycle rather than compacting into a permanent mass. The results will be prolonged bag life, higher airflows, and decreased emissions and pressure drops.

There are also conditioning agents available that are specifically designed for applications where spark carryover can lead to baghouse fires. These agents are of similar composition to the standard agents, but with the addition of spark retarding chemicals. As a spark comes into contact with the agent, a chemical reaction occurs which extinguishes the spark. Injection procedures should be available for all agents and should be followed exactly to ensure proper installation. This simple process will improve efficiencies and prolong filter bag life once in service.

- Using leak detection powder

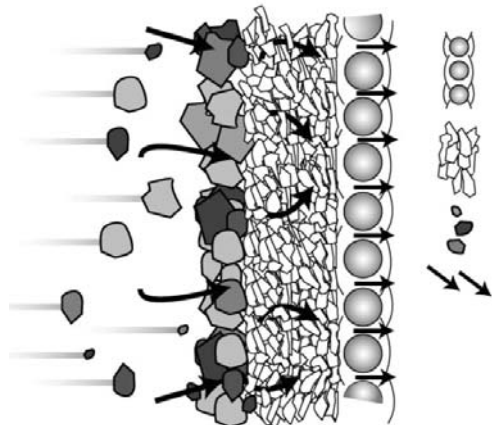


FIGURE 16: Pre-coating agents establish a proper dustcake for filtration

Many plants in the past as well as today, spent time inspecting each filter bag manually for tears, holes, and leaking seams which took many hours and was often inaccurate. In addition, structural air leaks in the system such as weld cracks and mis-fitting metal enclosure covers could not be detected unless they were clearly visible.

A better way to test for all of these possible leaks is by the use of a leak detection powder. Leak detection powders are inexpensive, lightweight fluorescent powders that are injected into a baghouse. Because the powder takes the path of least resistance, the tracer will accumulate around the source of leakage to pinpoint the location of the leak and its severity. A monochromatic light is then used to locate the areas of

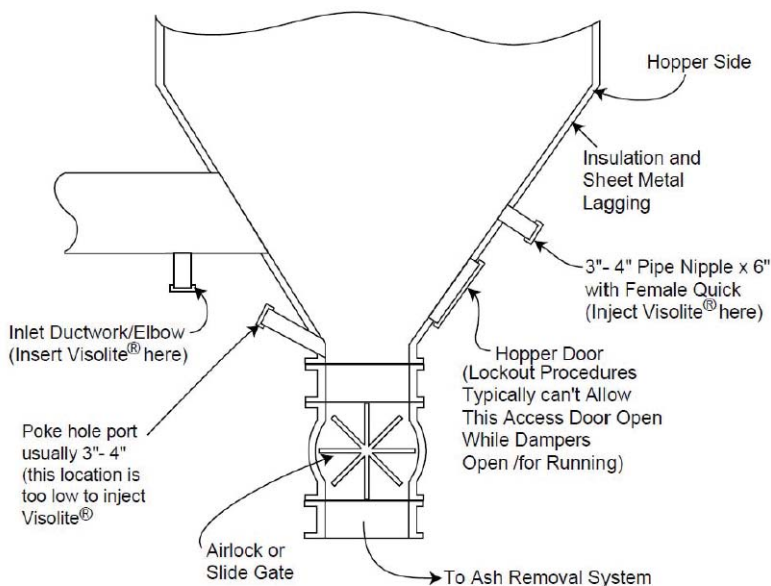


FIGURE 17: Recommended injection points for leak detection powder

accumulated powder. When a leak has been spotted, the fluorescent powder glows brightly under the light. Once leaks are found and repaired, a second test should be run with a different color to determine if all leaks have been eliminated.

It is important to note that a leak detection powder should be used that incorporates varying particle sizes to minimize fabric bleedthrough. This makes sure that all leaks will be found regardless of their size for proper leak identification. There are usually four colors that are available that work better in varying degrees depending on the application and dust being collected. It is very important to choose the appropriate color for your specific application.

- Maintenance & recordkeeping

Proper maintenance and recordkeeping play a vital role in the operation of a baghouse. The information gathered can assist in implementing an effective preventive maintenance program. The documentation of inspections, observations, and maintenance will help determine the baghouse operating efficiency and help prevent a plant from reaching non-compliance status.

Areas that require monitoring and careful documentation include changes in baghouse operation, production processes, grain loading, or fuels. All of these variables can have a substantial impact on baghouse performance. Pressure drop fluctuation, cleaning cycle adjustments, and emission levels should be monitored and recorded as well.

Recordkeeping consists of information that is recorded regularly and information that is recorded on specific events. Records that should be kept regularly include chart recordings which track baghouse pressure drop and inlet temperature. System chart recordings should be maintained to be used in comparison to current baghouse data. System Operation Reports may be maintained on an hourly basis during original system startup to establish initial operating criteria. After the system has been operating for some time and there is greater familiarity in its operation, these reports can be reduced to once or twice per shift. Event records are kept at specific times, such as startup, shutdown, bag inspection, and during periods of malfunction.

All of this information is very easily obtained and very inexpensive to maintain at the plant. Some specific documents that are useful include baghouse fact sheets, failed bag charts, baghouse maintenance reports, and emergency worksheets.

- **Filter bag testing and analysis**

The only way to really analyze how a filter bag has performed while in operation is to conduct filter bag analysis done by a reputable testing organization. Bags removed from the collector must be kept in their actual removal state so that accurate test results can be completed. The used filter bag should then be sealed completely in a proper container and sent to the testing laboratory.

Properly equipped laboratories will provide troubleshooting for fabric filters by doing complete lab testing on weight, breaking strength, permeability, mullen burst, flex cycles, and chemical analysis of the fabric and dust. Test reports should also be written in clear and concise language, complete with well-organized conclusions and recommendations. This information will then need to be evaluated against the current operating parameters of the equipment to make proper adjustments.

Some labs also offer testing procedures which help to select the proper filter media for a baghouse. A sample of dust particulate from the baghouse can be fully evaluated for micron distribution with mass volume, population counts, and surface area dust expanding both submicron and micron sizes. Testing chambers can then be used to generate exact inlet concentrations and various fabrics are operated under the systems designed air-to-cloth-ratio. The collection efficiency and operating differential pressure performances are continuously monitored throughout the test. This evaluation, along with a chemical analysis, allows for proper filter media selection and eliminates the need for extensive trials.

DISCUSSION

When optimizing a baghouse there are a large number of variables that needs to be considered. Each baghouse is unique based on its application, temperature, dust loading, micron distribution, chemistry, air to cloth ratio, can velocities and the list goes on. When sizing or evaluating a system it is important that all the parameters are considered. Gathering data and documenting that data over a period of time can be valuable in troubleshooting the system when a problem does arrive.

CONCLUSIONS

This paper shows that the proper maintenance and upkeep of baghouse dust collection equipment is really fairly inexpensive and easy to implement with the correct plan of attack. Most of the hints given are inexpensive and will definitely help with the proper operation of the equipment.

*For further information
contact Mike Allen at mike.allen@clarcor.com*

BIOGRAPHY



Mike Allen graduated from Missouri Southern State College with a BS Marketing & Management. He started his career with BHA in 1985 and worked in a number of sales and management role over his years. Mike has published a number of articles in the environmental space and has worked with all industries across North America. Currently,

he leads a team that is focused in bringing solutions to the Utility and Metal Industry.



Reducing the cost of operating DSI systems using Sorb-Tec™ Lance-Less Injection Technology

Written by Nick Evans, Nol-Tec Systems, MN; Mitch Lund, Nol-Tec Systems, MN; Haley Turner, LG&E & KU, Trimble County Generating Station, KY; Ross Meinhart, Dynegy, Newton Station, IL

SUMMARY

Dry Sorbent Injection (DSI) systems have been widely applied to meet environmental legislation for SO₂, SO₃, HCl and Hg pollutants by injecting a variety of dry sorbents into the post-combustion flue gas duct.

It is common for most DSI systems to use injection lances, which insert into the flue gas duct at varying lengths to assist with sorbent dispersion. Such injection lances often turn out to be maintenance-intensive due to sorbent buildup within the sorbent convey lines and lance plugging. Additionally, injection lances are known to be an inefficient technology, promoting poor mixing and dispersion of the sorbent in the flue gas, leading to high sorbent usage for the targeted reduction goal.

This paper will present both the basis of Sorb-Tec™ - a proprietary lance-less sorbent injection technology, and recent field results demonstrating a range of benefits including sorbent reduction up to 85% compared to lance-based injection. By replacing lances on a like-for-like basis with Sorb-Tec, enhanced mixing and dispersion of the sorbent ensues within the duct, allowing for a significant reduction in sorbent consumption to meet emission targets.

Unlike conventional injection lances, Sorb-Tec is mounted flush to the duct wall, using high velocity/low pressure ambient air to deliver maximum sorbent mixing and dispersion. Sorb-Tec is proven to provide up to 85% reduction in sorbent usage, providing significant reduction in sorbent costs for the client. Additionally, each Sorb-Tec injector negates almost all lance-based build-up and plugging, allowing the DSI system that can provide increased system availability, reduced maintenance and is more cost effective.

The paper evidences the performance achieved on three recent projects at coal-fired utility plants across the United States.

BACKGROUND

Sorb-Tec is a proprietary injection technology that has been developed to mitigate the range of issues associated with

lance-based injection, replacing these lances on a like-for-like basis for both DSI and ACI systems (Figure 18). Rather than using a lance or similar to penetrate the duct, Sorb-Tec uses high velocity boosted ambient air to allow the sorbent to better penetrate the duct, promoting enhanced mixing and dispersion. Each injector has its own variable frequency drive (VFD) to provide per-injector tunability for adjustment of penetration depth (and air flow) to be added to the duct (Figure 19). This tunability not only allows the optimum mixing to occur, but allows greater flexibility to optimize and control the performance that can be achieved at any load range.

Sorb-Tec is installed to the existing flange/port and sorbent lines, ensuring Sorb-Tec can be retrofitted to any DSI or ACI system, with no modifications to the existing system. Sorb-Tec not only reduces the volume of sorbent required through better sorbent mixing and dispersion, but also provides increased operational flexibility through load ranges and minimizing routine maintenance caused by lance-based designs

Sorb-Tec requires minimal modifications to the existing dry sorbent injection system, taking the sorbent from the existing convey line with no changes to existing conveying



Figure 18: Image of Sorb-Tec Lanceless Injection Technology installed on a major utility-scale coal-fired power plant.



Fig 19: Image of Variable Frequency Drives (VFD) installed on a major utility-scale coal-fired power plant



Fig 20: Image taken by an in-duct camera demonstrating the effect of Sorb-Tec on a major utility-scale coal-fired power plant.

parameters like pressure and CFM. The existing convey line is attached to the Sorb-Tec injector (tailored to meet the existing dimensions, which typically are between 1½” to 3” diameter). The sorbent continues to flow through the injector via a T-bend and continues through the convey line pipe to the duct wall (Figure 21). A fan is located within each injector, providing boosted ambient air to flow down through the injector at high velocity. The boosted air and sorbent do not meet until the duct wall, ensuring maximum chemical reaction occurring within the flue gas stream. The boosted air acts as an envelope to the sorbent, allowing the sorbent to penetrate into the duct at the optimum depth (Figure 22).

Figure 23 and 24 show the plan view and side view of the CFD predicted sorbent particle trajectory between standard injection lances and Sorb-Tec injectors. While Figure 23 and 24 demonstrate an injection grid where both lances and Sorb-Tec inject from both sides of the duct, this is not essential to the performance of the Sorb-Tec technology. Both standard lances and Sorb-Tec injectors utilize the convey line air flow, however the momentum from the convey line

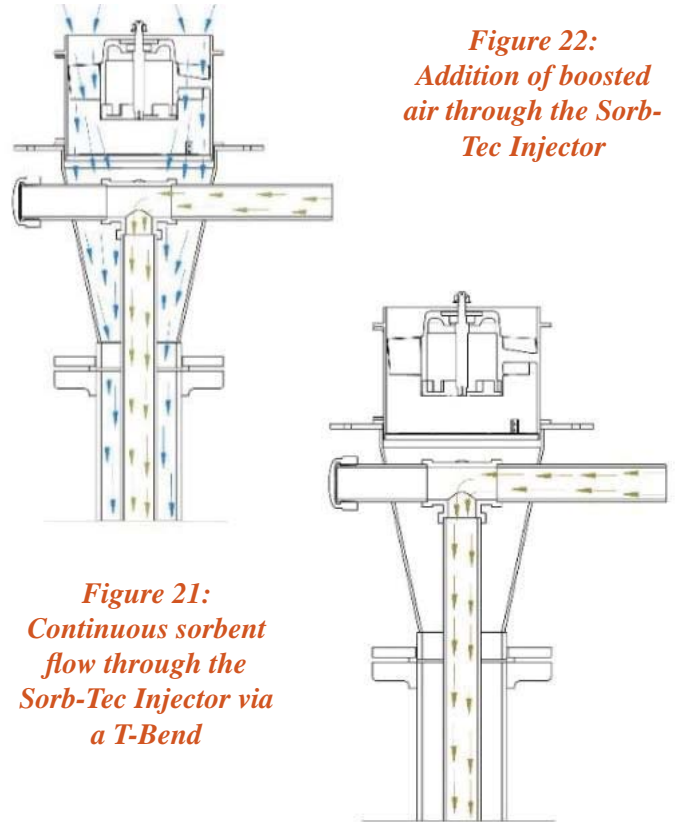


Figure 22: Addition of boosted air through the Sorb-Tec Injector

Figure 21: Continuous sorbent flow through the Sorb-Tec Injector via a T-Bend

air flow alone is too low to create significant sorbent penetration into the flue gas. In addition to the air flow from convey line, Sorb-Tec uses boosted high velocity air to create additional particle momentum for optimized penetration and dispersion without requiring any lance to protrude into the duct.

Sorb-Tec is also proven to provide additional savings and benefits including but not limited to:

- Reduction in any lance-related pluggage and/or build-up, reducing maintenance costs
- Reduced sorbent in ash will help to enhance ash sales or reduce landfill costs
- Enhanced per injector tunability through VFD drives, allowing optimal performance at all load ranges
- Ability to further reduce pollutant, enabling flexibility for both future regulations and fuel changes
- Minimal disruption to existing set-up with no changes required to the DSI setup e.g. blower speed, convey line pressure, etc)

The combination of these benefits has demonstrated payback between ½ to 2 years in most projects.

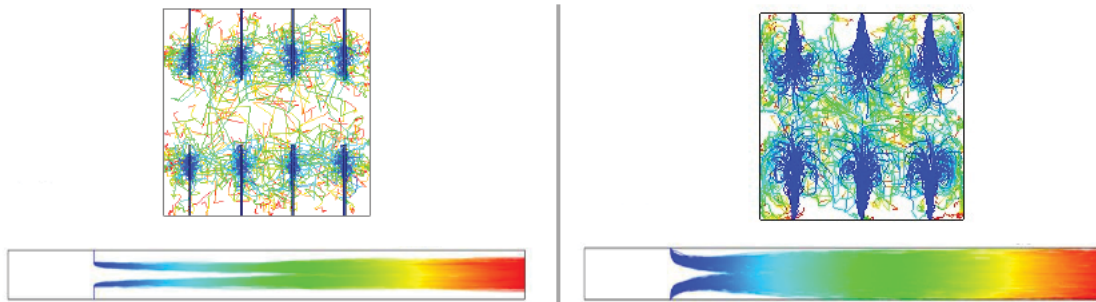


Figure 23: Dispersion Modeling based on traditional lance injection
Figure 24: Dispersion Modeling based on Sorb-Tec injection

1. Improve ABS formation temperature reduction performance of existing lance based injection system. Formation temperature (FmT) is a metric measured by a Breen AbSensor© AbS/SO₃ probe and directly correlates with sulfur condensable dew point temperature. The lower the FmT, the lower the condensable is in the APH and hence, the better the APH sootblower can clean the condensable. The better the distribution of hydrated lime, the better the effect on reducing FmT.
2. Reduce associated lance maintenance by observing injector reliability and hydrated lime build-up on the inside of the injector with continuous run time

RESULTS & DISCUSSION

SUMMARY

This paper provides discusses the set-up and performance achieved at three example utility-scale coal-fired power plants in 2016. A summary of the plant and original set-up is detailed below:

PROJECT 1 – TRIMBLE COUNTY GENERATING STATION

Objectives

A full-scale Sorb-Tec trial was conducted at Unit 1 of LG&E & KU’s Trimble County Generating Station in Kentucky. The trial was conducted on the basis of two primary objectives:

	Project 1	Project 2	Project 3
Client Name	LG&E & KU	Confidential	Dynergy
Plant Name	Trimble County Station	Confidential	Newton Station
Unit Size	514 net MW	600 net MW	600 net MW
Primary Fuel	High Sulfur Bituminous coal	Kentucky Bituminous coal	Powder River Basin (PRB) coal
Sorbent Type	Hydrated Lime	Hydrated Lime	Sodium Bicarbonate
Pollutant Targeted	SO ₃ / Blue Plume / ABS	SO ₃	SO ₂
DSI Location	Post SCR; Pre APH	Post SCR; Pre APH	Pre APH
Original Set-Up per unit	Total Lances 20 - 2 x Ducts per unit - 5 x Ports per duct - 2 x Lances per port	Total Lances 8 - 2 x Ducts per unit - Duct A: 6 Lances - Duct B: 2 Lances	Total Lances 16 - 2 x Ducts per unit - 8 x Ports per duct - 1 x Lance per port

Set-Up

For the trial, ten (10) conventional lances were maintained in A Duct, while the ten (10) lances originally in B Duct were replaced by five (5) Sorb-Tec Injectors (50% reduction in lances). The trial reliability test and performance data was recorded between April 8, 2016 and April 19, 2016 (11 days / 261 hours), with Breen AbSensor© AbS/SO₃ probes used to ascertain performance located downstream of both the A and B injection locations. Performance testing was performed by feeding identical sorbent injection rates to each duct and measuring the ABS formation temperature differences in real-time.

Results

In order to ascertain a baseline position, separate temperature readings were taken on both A & B duct. While both are almost identical ducts and are fed by the same dry sorbent injection feed system, a temperature delta of 7°F was recorded (A Duct (10 lances) recorded 263°F; B Duct (5



Fig 25: Sorb-Tec Injectors on B Duct prior to installation (sound enclosures shown).



Fig 24: Each port had two lances, a short (~6 ft.) and long (~13 ft) lance

Sorb-Tec Injectors) recorded 270°F. Performance data was then recorded between April 8, 2016 and April 19, 2016 (11 days / 261 hours) at different injection rates to provide a simultaneous curve between the two ducts.

Summary

Based on the stated initial objectives, Sorb-Tec Technology achieved significant reduction in both sorbent consumption and maintenance against when compared against lance-based injection, with the primary findings:

1. Sorb-Tec Injectors were analyzed over a period of

over 11 days to ascertain consistency in performance data

2. Sorbent consumption was reduced up to 40% (from 2,000lb/hr to 1,400lb/hr) when data was compared at the same temperature (237oF)
3. ABS Formation Temperature was reduced by 30% when data was compared using a feed rate of 2,000lb/hr (1,000lb/hr per duct). Note that formation temperature was the target of the trial in order to minimize ABS formation.
4. No plugging or build-up was observed in any of the Sorb-Tec Injectors (see Figure 28 on next page) therefore significantly reducing maintenance costs

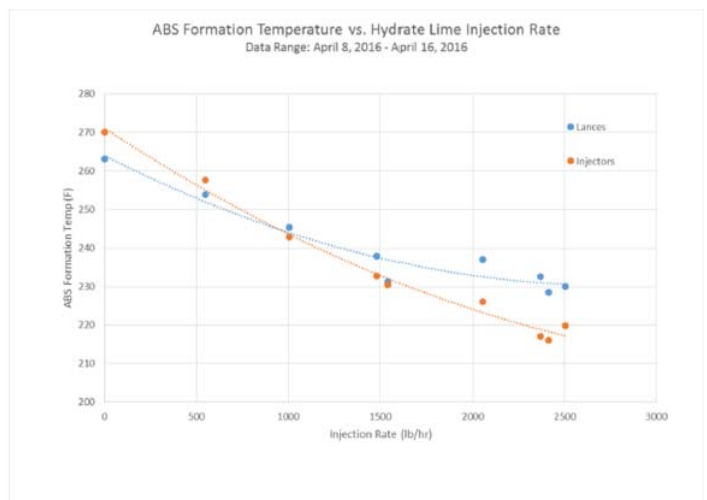


Fig 26: Actual readings on A & B Duct between April 8, 2016 and April 19, 2016 at different injection rates

Key: Lances = A Duct, Injectors = B Duct

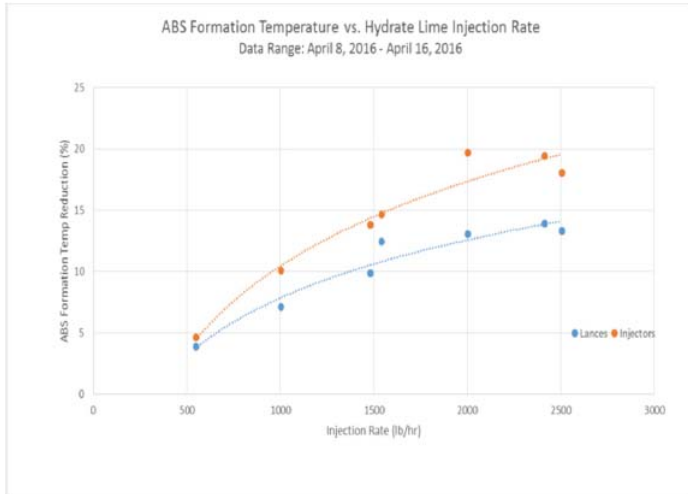


Fig 27: Exponential curve to demonstrate like for like comparison when both A & B duct are re-set.
Key: Lances = A Duct, Injectors = B

Figure 28:
Inside of Sorb-Tec
after 300+ hours of
operation.



PROJECT 2 – CONFIDENTIAL Objectives

A full-scale Sorb-Tec trial was conducted on a 600MW coal-fired unit in South-Eastern USA. The trial was conducted on the basis of two primary objectives:

1. Improve ABS formation temperature reduction performance of existing lance based injection system. Limiting formation of this substance reduces wear and tear on the air pre-heater.
2. Evaluate Nol-Tec’s lance-less injection performance vs. other technology alternatives (standard injection lances and advanced, baffled lances).

Set-Up

The trial was set-up to compare three separate technologies for injecting hydrated lime, namely

- a) standard lances,
- b) advanced, baffled lances, and
- c) Sorb-Tec Technology.

Each technology was tested for at least 2 days. In each test, six (6) lances/injectors were installed on the A duct while two (2) were installed in the B duct. The same port locations were used for each technology. Breen AbSensor© Abs/SO₃

probes were used to ascertain performance located downstream of both the A and B injection locations, while EPA method A testing was performed on the A duct only. Performance testing was performed by feeding identical sorbent injection rates to each duct and measuring the ABS formation temperature in real-time while Method 8A samples were taken simultaneously.

Results

The performance results below are from the A side only due to the multiple testing methods performed on that side (Breen probe AbSensor measurements and EPA Method 8A). Baseline measurements were repeatedly taken throughout testing to establish accurate performance improvements. Both methods show that Sorb-Tec outperformed both technologies, while the results between the lance technologies conflicted with each other (Advanced, baffled lances outperformed standard lances in Method 8A results but vice versa with Breen probe measurements).



FIGURE 29:
One (1) Sorb-Tec injector installed on the A side of the duct.

Summary

Based on the stated initial objectives, Sorb-Tec Technology was able to achieve significant sorbent savings over both of the alternative technologies available on the market (standard and advanced, baffled lances):

1. All three technologies, namely standard lances, advanced baffled lances and Sorb-Tec were evaluated over a 2 week period in September 2016
2. In order to validate the results, multiple test methods were used on the A duct to evaluate performance

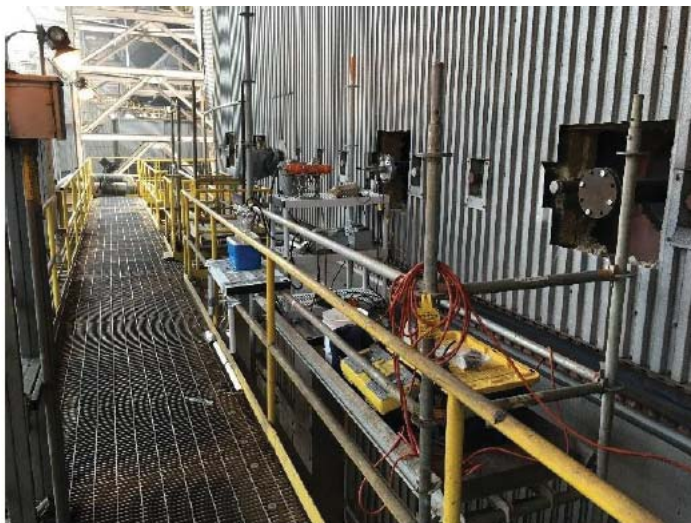


FIGURE 30:
*Method 8A and Breen probe set up on A side
air heater inlet location.*

3. Method 8A and Breen probe measurements had conflicting results in terms of which lance produced better results, but both methods agreed Sorb-Tec offered superior performance over both lance technologies; this evidence suggests lance technologies produce more localized results than Sorb-Tec.
4. Both test methods showed Sorb-Tec offered significant sorbent savings over other market alternatives
 - When compared to standard lances, EPA Method 8A tests resulted in Sorb-Tec matching existing system performance utilizing 85% less sorbent (2000 lbs/hr compared to 300 lbs/hr).
 - When compared to advanced, baffled lances, EPA Method 8A tests resulted in Sorb-Tec matching existing system performance utilizing 63% less sorbent (2000 lbs/hr compared to 750 lbs/hr).
5. No plugging or build-up was observed in any of the Sorb-Tec Injectors therefore significantly reducing maintenance costs

PROJECT 3 – NEWTON STATION

Objectives

A full-scale Sorb-Tec trial was conducted at Unit 1 of Dynegy's Newton Power Station in Illinois. The trial was conducted with two primary goals in mind:

1. Reduce the amount of sodium bicarbonate required to achieve stack SO₂ compliance (client was Targeting ~60% SO₂ removal needed) compared to standard lances

2. Evidence low maintenance benefits of Sorb-Tec against standard lances

Set-Up

Sorb-Tec and standard lances were installed for a period of 14 weeks for comparison purposes, with a formal performance test for each technology performed on the same day. Eight (8) injectors were installed on the A duct while eight (8) lances were installed in the B duct. The same injection grid was installed on each duct. An SO₂ CEMS was used to measure SO₂ at the stack. Pitot tube measurements were used to verify equal airflows on each duct while FTIR's were installed at the inlet injection locations to observe SO₂ inlet measurements. Performance testing was performed by first feeding sorbent injection rates to the A duct (Sorb-Tec) then switching to the B duct (lances) and replicating the same injection rates.

Results

The results from the one day formal performance test are summarized in Figure 33. Please note that removal results are reported in relation to a stack baseline SO₂ value with no sorbent injection occurring.

Summary

Sorb-Tec evidenced a significant improvement in performance against standard lances, with notable performance including:



Figure 31: *Sorb-Tec installed on the A side of
the duct*



Figure 32: Lances installed on the B side duct

1. Sorb-Tec offered 16% sodium bicarbonate savings over lance based technology at a targeted 70% SO₂ removal.
2. Based on the data collected (both during the 1 day performance test and subsequent operation of the technology at Newton Station), greater savings are achieved at higher percent removal requirements.
3. Sorb-Tec evidenced minimal maintenance requirements over standard lances over a 2 month extended period, with Sorb-Tec units recording <10% of the recorded maintenance incidents compared to lances.
4. Sorb-Tec has since been installed on both ducts on Unit 1.

Summary

Sorb-Tec is a proven and cost-effective retrofit solution to both significantly minimize operating costs, but importantly provide improved flexibility for existing dry sorbent injection systems. As Sorb-Tec is both vendor, system and sorbent neutral, Sorb-Tec can be applied to any dry sorbent system injecting limebased, sodium-based and carbon-based sorbents.

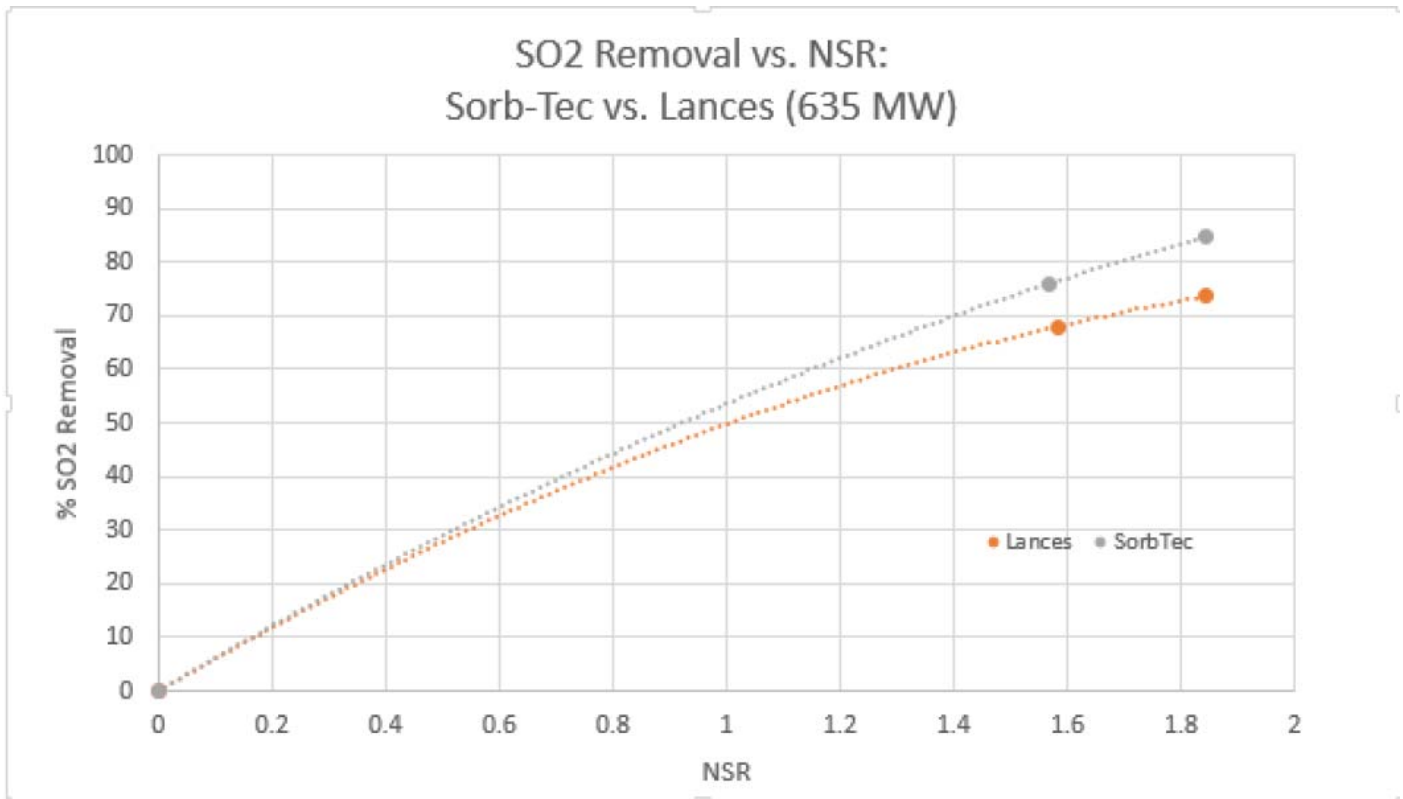


Figure 33: Summary of the performance test on Unit 1 at Newton Power Station. Approximately 16% reduction in sodium bicarbonate was demonstrated against standard lances (at 70% removal) which equated to a 1 year payback.

These three example projects evidence the immediate and significant benefits Sorb-Tec Lance-Less Injection Technology can provide to DSI systems. In addition to reducing sorbent consumption by up to 85%, Sorb-Tec evidenced significant reduction in maintenance when compared to alternative technologies.

Nol-Tec has completed, and continues to conduct a large number of projects across a large number of DSI and ACI systems injecting a wide range of dry sorbents including Hydrated Lime, Sodium Bicarbonate, Trona and Activated Carbon. In each case, Sorb-Tec evidences a wide range of notable improvements to both standard and advanced baffled lances.

ABBREVIATIONS

ABS	Ammonium Bisulphate
ACI	Activated Carbon Injection
APH	Air Pre-Heater
CEM	Continuous Emissions Monitors
CFD	Computerized Fluid Dynamic Modeling
CFM	Cubic Feet per Minute
DSI	Dry Sorbent Injection
FmT	Formation temperature
FTIR	Fourier Transform Infrared Spectroscopy
HCl	Hydrogen Chloride
Hg	Mercury
HL	Hydrated Lime
MW	Megawatts
PRB	Powder River Basin Coal
SBC	Sodium Bicarbonate
SCR	Selective Catalytic Reduction Technology
SO ₂	Sulphur Dioxide
SO ₃	Sulphur Trioxide
VFD	Variable Frequency Drive

REFERENCES

Guisu Liu; Baiyun Gong; Mike Klump; Alan Chadwick; Craig Paquette; Gregory Archer, SORB MIX to reduce sorbent usage by enhancing mixing in dry sorbent injection applications, 2015

Nick Evans; Mitch Lund; Jason Brown; Haley Turner, Sorb-Tec Lance-Less Injection Technology | Reduced costs and improved performance for your DSI and ACI systems, 2016

*For further information contact
Mitch Lund at mitchlund@nol-tec.com*

BIOGRAPHY



Mitch Lund is a Product Manager for Sorbent Injection with the Business Development group of Nol-Tec Systems. Mitch has managed all aspects of Nol-Tec's DSI/ACI rental program, including equipment development, scheduling, staffing, and reporting. He has worked extensively with customers onsite during testing and final installation processes. Mitch's responsibilities include developing new business in all markets, both new and old. Mitch has a Bachelor of Science in Chemical Engineering from the University of Minnesota and has been working at Nol-Tec since May 2012.



**Check Out
the WPCA Technical
Library at
www.wpca.info**

WPCA Corporate Sponsors

WPCA Chairman

Susan Reinhold,
CEO
Reinhold Environmental Ltd.
3850 Bordeaux Drive, Northbrook, IL 60062 USA
Email: sreinholt@reinholdenvironmental.com

WPCA Secretary

Sharon Sjostrom,
Chief Product Officer, Market Strategy
ADA-ES, Inc.
9135 S. Ridgeline Blvd., Ste 200,
Highlands Ranch, CO 80129 USA
Email: sharons@adaes.com

WPCA Treasurer

Robert Mudry,
President
Airflow Sciences Corporation
12190 Hubbard Street, Livonia, MI 48150 USA
Email: rmudry@airflowsciences.com

WPCA Vice President

Nate White,
Director, Business Development of APC
Haldor Topsoe, Inc.
5510 Morris Hunt Dr., Fort Mill, SC 29708 USA
Email: tnw@topsoe.com

David Novogoratz,
Manager of Environmental Products
Babcock & Wilcox

20 S. Van Buren Ave., Barberton, OH 44203 USA
Email: dmnovogoratz@babcock.com

Clayton Erickson,
Manager, Process Engineering
Babcock Power Inc.
5 Neponset Street, Worcester, MA 01606 USA
Email: cerickson@babcockpower.com

Allen Kephart,
President
CleanAir Engineering
110 Technology Dr., Pittsburgh, PA 15275
Email: akephart@cleanair.com

Mike Mattes
CEO
Steag SCR-Tech
304 Linwood Rd, Ste.102, Kings Mountain, NC
28086 USA
Email: m.mattes@steagscrtech.com

Tim Stark,
Director - Industrial Filtration Sales
CLARCOR Industril Air
11501 Outlook St., Ste. 100,
Overland Park, KS 66211 USA
Email: timothy.stark@clarcor.com

Michael Hatsfelt,
General Manager
Southern Environmental, Inc.
6690 West Nine Mile Rd., Pensacola, FL 32526
Email: mhatsfelt@sei-group.com

Blake Stapper,
Business Manager
AECOM
9400 Amberglen Blvd., Austin, TX 78729 USA
Email: blake.stapper@aecom.com

Curt Biehn,
Director of Marketing
Mississippi Lime
3870 S. Lindbergh Blvd., St. Louis, MO 63127
Email: crbiehn@mississippilime.com

Paul Ford,
President
Redkoh Industries
300 Valley Road, Hillsborough, NJ 08844 USA
Email: paul.ford@redkoh.com

Erik Johnson,
Executive Vice President - CMO
Nol-Tec Systems, Inc.
425 Apollo Drive
Lino Lakes, MN 55014 USA
Email: erikjohnson@nol-tec.com

Mike Volker
Business Development
Stock Equipment Company
16490 Chillicothe Road,
Chagrin Falls, OH 44023 USA
Email: m.volker@schenckprocess.com



WPCA Officers

WPCA President

Melissa Allen, Environmental Systems
Manager,
TVA

WPCA Vice President

Michael O'Connor, Program Manager
Dynege

WPCA Advisors

Greg Betenson,
Principal Engineer,
PacifiCorp

Melanie McCoy,
Superintendent
Sebewaing Light & Power

Ebrahim Patel,
Senior Consultant - APC,
ESKOM-GTD

Bruce Salisbury,
Engineering Supervisor,
Arizona Public Service

Scott Williams,
Principal Engineer,
Duke Energy

Darren Hanby,
Principal Engineer,
AEP

Brandon Bettinger
Chemical Engineer
East Kentucky Power Cooperative

Kayla Pauvlinch
Engineer IV
FirstEnergy

Logan Waller
Chemical Engineer
Louisville Gas & Electric