Dynamic Particle Control:

The Impact on Air Quality and Fugitive Dust Accumulation

By Robert Alexander & Brad Carr

AN OVERVIEW OF DYNAMIC PARTICLE CONTROL TECHNOLOGY:

There are two primary methods of engineering solutions for control of combustible dust within industries that utilize gravity-fed blending operations - *Local Filtration (capture of dust at the source*), and *Dynamic Particle Control* (DPC). Both of these engineered approaches typically require an enterprise-wide engineered solution that work in concert with other compliant housekeeping efforts.

Enterprise-wide solutions often combine various technologies, depending on the size of the gravity-fed facility, and the type of material being blended or compounded (food, grain, plastics, petro-chemicals, etc.). The primary enterprise-wide technology utilized in almost every gravity-fed system is localized filtration.

Localized filtration equipment collects the combustible dust particulate by either vacuuming or suctioning when and where fugitive dust is produced. Most plant operators stop here hoping to capture greater and greater percentages of dust at the source – with diminishing returns (See Figure 1.) This approach is often needed, but the reality is that such a technology cannot be used in isolation since localized filtration will never capture every particle. In most applications, regular daily and weekly manual housekeeping schedules are also employed to sweep or vacuum particulate that localized filtration fails to capture.

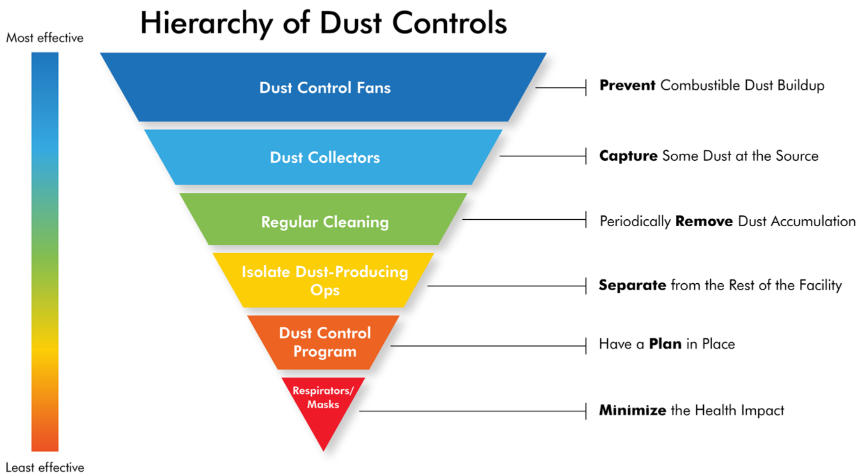

FIGURE 1:
Heirarchy of Dust Control Technologies

An additional measure of dust control is what SonicAire refers to as *Dynamic Particle Control (DPC) technology*. With DPC, a robotic dust control fan cleaning system automatically maintains OSHA dust compliance throughout the plant, preventing accumulation on plant equipment and structures. With this approach, there is a one-time deep clean of any dust built up on any existing plant structures and equipment in operation (in comparison to a lack of need for a one-time cleaning in new facilities).

Once this initial cleaning has been performed to remove existing dust layers, DPC accelerates particulate removal through particle agglomeration, which is the process of encouraging smaller dust particles to develop cohesive attraction, along with turbulent airflow to prevent new dust from ever accumulating in these areas again. Often, there is synergy between filtration and DPC technologies when used together in a facility to ensure ongoing compliance. Each solution reduces the labor requirement for compliant manual housekeeping.

With both engineered methodologies, there are higher one-time costs for implementation. But these one-time costs are offset by the reduction in ongoing costs and headaches of managed or reactive cleaning solutions. The largest potential benefit of an engineered approach utilizing DPC is the production uptime and minimized (reduced) labor utilization created by running a robotic engineered system concurrently with process equipment. While some shutdown time may be periodically required, this can be dramatically shortened. Depending on the sophistication of the system installed, DPC delivers consistently higher levels of cleaning for constant compliance with government regulations and greater employee safety and health.

FIGURE2:
A Dynamic Particle Control (DPC) Fan in an Agricultural Blending Operation.

THE PROBLEM

Limitations of Existing Dust Control Technologies:

Modern processing plants often use central filtration systems to capture dust particles generated by various processes (cutting, sanding, compressing, transferring, pressing, forming etc.). The ability to surround and enclose a process often determines the efficiency of collecting the particles created in product processing. Many processes cannot be tightly enclosed and therefore large amounts of fugitive particulate is released into the manufacturing plant as a byproduct of the operation. This particulate creates a painful housekeeping necessity for an industrial facility.

If the particles are combustible they can create dangerous fire and explosion hazards for the plant and its employees. Historically, this type of housekeeping has been a reactively managed process using a significant labor force equipped with manual tools (brooms, shovels, vacuum cleaners, and compressed air). In many cases, operations need to be shut down during the manual housekeeping process, which creates significant hidden cost to the plant. Because of this large labor cost and lost production cost, many, if not most, plants are frequently out of compliance with OSHA, NFPA, and other industry standards. This reality leads to an opportunity to create engineered housekeeping systems that eliminate the need for manual labor and the necessity to stop plant production.

THE SOLUTION
Enterprise Wide Dust Control Technology:

DPC is the applied science of using dynamic air streams created by strategically placed high velocity and high-mass airflow fugitive dust control fans in a manufacturing facility to control the movement and eventual resting position of fugitive dust particulate. When engineering a DPC robotic fan system the engineering designer takes into account the size and shape of the area to be maintained in constant compliance, the type, size, and properties of the dust created, as well as the location of obstructions, process equipment, and any other hard-to-reach buildup areas. In designing a system, the final desired resting place of any particulate must also be considered and agreed upon for ease of access and inspection of regular buildup/cleanup.

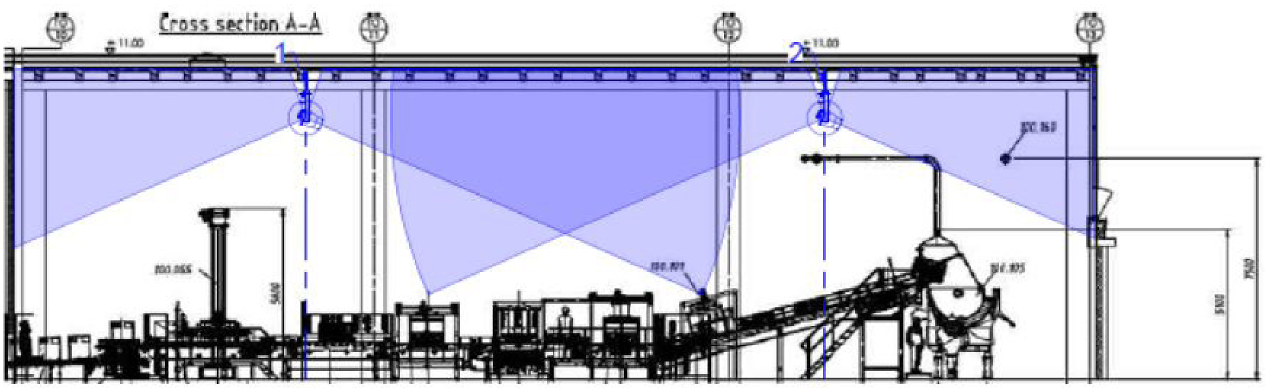

FIGURE 3: Typical horizontal application of a DPC robotic fan system.

Every plant is different and many factors will determine the effectiveness and extent of the system needed for controlling fugitive dust. Especially critical is establishing how much dust is generated and where it is generated. Other variables include particulate material and size, particulate density, particulate surface and profile, airstream velocity and mass, changes in direction of the airstream in the plant, as well as the need for change in direction and variations of airflow mass and velocity over time - based on obstructions in the plant environment.

Historically, DPC science led to the development of what SonicAire calls a BarrierAire© Technology which prevents dust particulate accumulation in the hard to reach overhead areas near dust-generating processes and areas of 'horizontally oriented' industrial plants (See Figure 3). This systematic approach to particle control is designed to disrupt thermal currents in the upper atmosphere of an industrial plant, which then prevents dust particulates from rising in the ambient atmosphere and settling on overhead structures. The dust particles simply fall to the floor to be easily picked up by the plants existing floor cleaning process or cleaning personnel.

Most recently the application of DPC to gravity-fed vertical processing equipment has resulted in similar successes. In these environments the robotic fan system is engineered, not just to disrupt thermal currents, but more importantly to drive airstreams and particulate off equipment to settle on the ground floor of the processing environment – off horizontal surfaces, through grates, and around processing equipment – where it can simply be removed through existing floor cleaning processes, similar to SonicAire's approach to a horizontally oriented process environment.

In addition to the automation of cleaning and reduction of personnel time in the dust-laden atmosphere, an unexpected benefit was the overall reduction in total particulate load in vertical plant layouts.

The subjective reduction in particulate levels in horizontal DPC applications is well documented by plant managers and personnel. There is a clear and visible difference in particulate levels before and after the use of SonicAire fans when the fans are aimed towards the ceiling - above the plant floor and equipment. In contrast, there has been insufficient hard data on vertical applications.

After engineering and installing several initial vertical DPC applications for customers in the agricultural and plastics industry sectors, SonicAire found a willing partner to assist in particulate measurement, The Azek® Company[1] in Scranton Pennsylvania. Azek agreed to assist SonicAire in helping quantify benefits found in its vertical gravity-fed/tower blending application.

Azek was scrambling to keep up with an unprecedented increase in demand for composite lumber brought on by the global pandemic of 2020. Because of consumer demand, they needed to find the best solution for eliminating combustible dust (which can lead to fire and explosion events in plastics manufacturing environments) while minimizing production impacts - all within a constrained labor market.

Its two facilities had similar vertically oriented blending operations where they manufacture and extrude deck, rail and outdoor trim, and accessories. The Corey Street facility had a custom-engineered SonicAire fan system installed and operating to mitigate the risk from combustible dust generated in their production environment, and the second facility - Keyser Street - planned to install fans, but had not yet put them into operation.

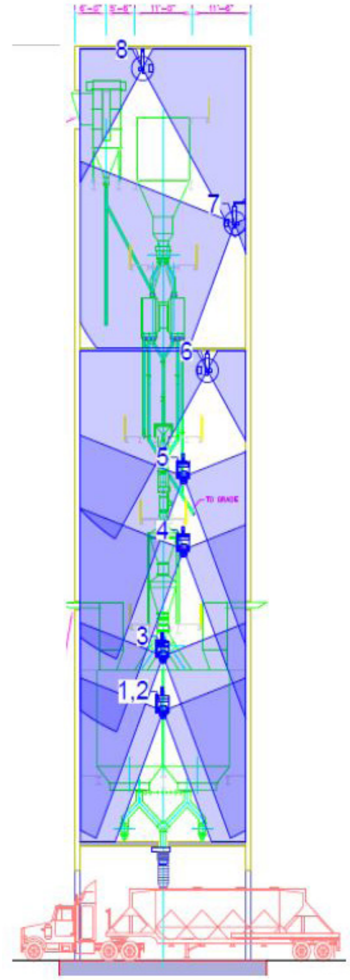

FIGURE 4:
Typical layout of a vertical DPC robotic fan system in an agricultural application.

Azek knew there was a difference with SonicAire fans from the subjective experience of their plant personnel. Employees knew that when cleaning the upper elevations of their facility they were required to go through significant Environmental, Health, and Safety (EH&S) protocols. This included wearing respirators, building scaffolding, and using ladders in precarious locations, all so they could get into hard-to-reach areas.

After installing a DPC system, the cleaning schedule and production schedule now work independently of one another. The fans work non-stop while the facility is in operation, maintaining the compliance and cleanliness of the plant automatically. Plant management enjoys being able to focus on production without thinking about housekeeping. With the fans running around the clock, Azek has kept the blending tower area compliant and running at maximum productivity. These were all expected benefits. The unexpected benefit was the measurable effect on indoor air quality from employees who worked in the plant environment. This also promoted employee satisfaction, increased productivity, reduced turnover, and created a healthier working environment.

[1] Azek is a leading manufacturer of beautiful, low maintenance building products - committed to accelerating the use of recycled materials through its Azek Exteriors, Versatex, Ultralox and TimberTech brands. The company manufactures products using recycled materials for the outdoor living and construction markets.

SonicAire worked with Azek to help quantify the differences in air quality between two plants, bringing in Adam Butler (CIH, CSP), a professional environmental health and safety partner with Resolution LLC, to quantify airborne particulate concentrations. Particulate counters were placed at a variety of levels throughout the two facilities. Readings were taken at each location for equivalent time periods under equivalent operating conditions, and compared. What was found was significant.

His analysis of the data found that the installed and operational robotic fan system was able to keep total airborne particulate levels low - in the upper atmosphere of Azek's Corey Street plant - where the fans had been installed and were running continuously. In contrast, in the upper levels of the Keyser Street plant where fans were not yet operational, Azek was seeing 'microbursts' of dust in the atmosphere in and around equipment when the blending tower system was operating - creating piles of dust - both on the floor and in the plant environment. Incursions were measured over 40mg/m3 at times.

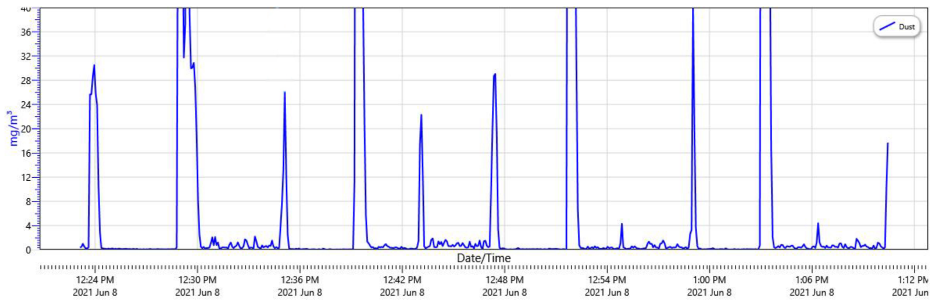

FIGURE 5: Measured total particulate levels WITHOUT robotic fan system in operation.

In comparison, the similar blending tower setting at the Corey Street plant where fans were already operating, levelized particulate loads were around 2mg/m3. On an integrated basis at the various sampling locations at the Corey Street Plant the airborne concentrations of total particulate were much lower - between 1/3 to 1/4 of the total particulate load seen at Keyser Street.

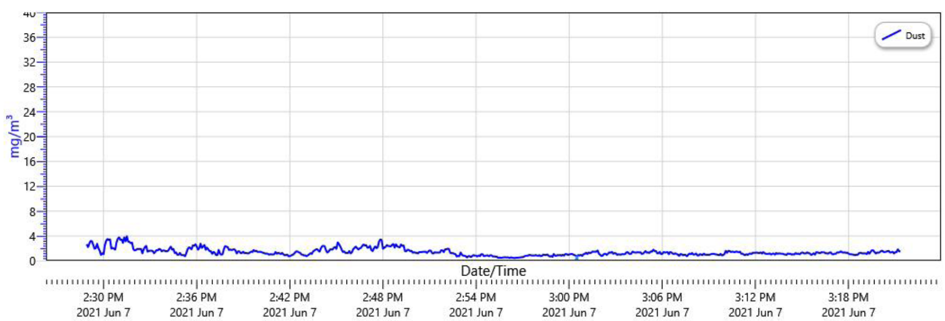

FIGURE 6: Measured total particulate levels WITH SonicAire fans in operation.

SonicAire's DPC Technology introduced turbulent airflow into the vertically oriented plant atmosphere, which had a side effect of *agglomeration*. Agglomeration in processes often "can be unwanted, resulting in uncontrolled buildup, caking, bridging, or lumping. However, it can also be a beneficial process, utilizing the controlled enlargement of particles"[2] when and where increased size and weight are beneficial - such as in fugitive dust control. When kinetic energy is added to the plant environment, depending on the dust type and other environmental factors (relative humidity, airflow etc.), the smallest-sized dust particles (under 10 micrometers) often get physically or molecularly "sticky", adhering to other particles in the environment.

As primary particles are attracted to one another, larger-sized particles called agglomerates (See Figure 7) gain in volume and weight, and when heavy enough, in turn, fall to the floor and are swept up into floor cleaning systems which can also either be manual or automated. This is the DPC science behind every robotic fan application - getting the particles out of the environment and onto the floor where they can be easily and safely removed.

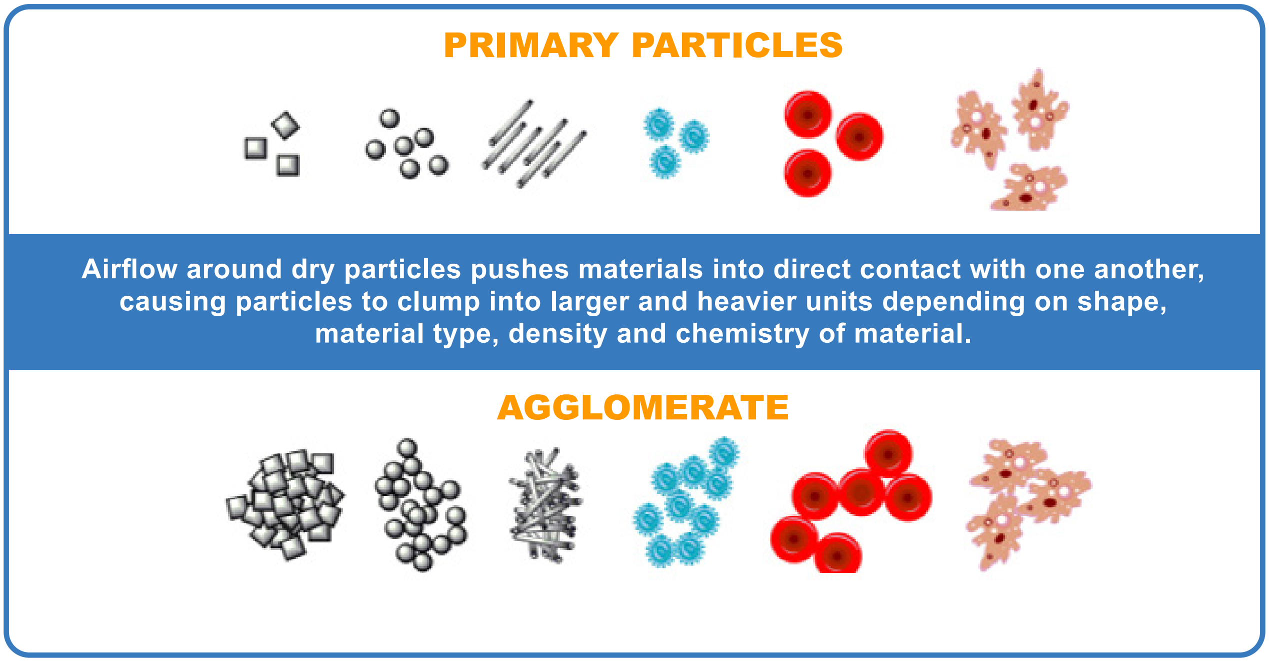

FIGURE 7: The effect of turbulent airflow on a variety of dust materials[3]

[2] From Peitsch, Wolfgang in *https://www.powderbulksolids.com/particle-enlargers-formers/what-agglomeration*

"Agglomeration, the sticking of particles to one another or to solid surfaces, is a natural phenomenon. For powders and bulk solids, agglomeration (in processes) can be unwanted, resulting in uncontrolled buildup, caking, bridging, or lumping. (However,) it can also be a beneficial process, utilizing the controlled enlargement of particles to improve powder properties and obtain high-quality products. (A)gglomeration… involves combining particles to create products with new particle sizes...size enlargement through agglomeration is done to obtain a product with larger particle dimensions. The resulting entity is only apparently a new unit. The original solid particles are still present in the structure—often with completely unaltered shape and size—and are held together by binding mechanisms... Agglomeration also changes the bulk characteristics of particulate solids—usually for the better. Larger particles have less dust, exhibit improved flow behavior, and feature reduced sticking tendencies.

Storage, handling, and feeding of materials with large particles are less risky, even for difficult materials. Three methods enlarge particulate solids through agglomeration: growth agglomeration, pressure agglomeration, and agglomeration using heat … In growth agglomeration, the adhesion of particles to one another is controlled by the competition between volume-related separation and surface-related adhesion forces. To cause permanent adhesion, the sum of all separation forces in the system (e.g., gravity, inertia, drag, etc.) must be smaller than the attraction forces between the adhering partners… ***If solids are in the micron, submicron, or nano range (starting at approximately 10 µm), adhesion occurs naturally even when the agglomerate-forming particles are dry."***

Wolfgang Pietsch, PhD, senior consultant at Compactconsult Inc. (Naples, FL) holds a PhD in agglomeration. A researcher, teacher, process developer, designer, vendor, and user of mechanical process technologies, Pietsch holds nine patents and is the author of more than 170 papers and five books, including Size Enlargement by Agglomeration, Agglomeration Processes—Phenomena, Technologies, Equipment, and Agglomeration in Industry—Occurrence and Applications.

[3] Modified from Valiulin, Roman, https://cheminfographic.wordpress.com/2016/12/20/agglomeration-aggregation/

Every plant is unique and uses various materials with differing agglomeration points which could impact results. However, the physical principles at work within the manufacturing environment are the same for industrial plants blending ingredients in vertical tower type ‘gravity-fed’ applications. The same technology can be applied differently in various industries based on the dust type and application.

In addition to keeping the upper atmosphere clean and compliant as guaranteed - robotic fans helped the Azek Company keep total atmospheric particulate levels down and helped reduce exposure time to total particulates by minimizing required housekeeping activies. By keeping employees focused on production rather than cleaning, a safer, healthier, and more efficient working environment was created for everyone.

Ultimately, the rapidly developing new science and body of knowledge surrounding Dynamic Particle Control (DPC) will contribute to technology that creates safer, healthier, and more efficient operations for dust-generating facilities.

CONCLUSIONS:

DPC is an expanding applied engineering technology for many industrial plants. The body of knowledge specific to and dependent upon the type of dust particles produced by plant processes is leading SonicAire to new insights and breakthroughs using dust control fans in new applications. There are a variety of benefits to applications with combustible and non-combustible types of dust both in horizontally oriented and vertically oriented processes.

1) LABOR: First and foremost benefit of DPC is an offset to labor costs and risks. There are both direct benefits and secondary benefits when considering labor savings. Most plants hire dedicated cleaning personnel and often send those personnel into dangerous or hard-to-reach areas. They have to locate, onboard, train, and supervise those personnel as well as inspect their work for compliance. All of this is in addition to the compensation and benefits that must be provided. With dust control fans these labor costs are virtually eliminated. These financial savings are in addition to inspection, supervision and oversight energies being channeled elsewhere. A related risk is health and safety exposure to both contractors and plant personnel. Having additional employees on-site only compounds the additional health risks. Those health risks can be eliminated through robotic cleaning. If a facility utilizes cleaning and maintenance labor at the same time, workers can often be redeployed from cleaning staff to maintenance staff, in order to focus on higher-skilled work. If a facility is already performing compliant cleaning, the payback on labor alone is often in a two- to three-year time frame.

2) GREATER PRODUCTION AVAILABILITY: If cleaning and maintenance work prevents a facility from manufacturing their product, the implementation of an automated DPC engineered system can result in paybacks under a year. After a robotic fan system is installed, facilities are sometimes able to modify production schedules to add one day a week or one shift per week in production time.

3) AIR QUALITY BENEFITS: As illustrated in this paper, one of the remarkable side effects of the implementation of a robotic fan system is the fact that the air in a facility becomes cleaner and healthier. In the vertically oriented DPC application studied, total particulate load was reduced by 65 to 75% compared to the load of its non-controlled counterpart. The benefits are not just for cleaning and maintenance employees who now spend minimal amounts of time in the production environment, but also for production staff and managerial staff as well. Cleaner air can often mean less sick time, greater employee satisfaction, lower health costs, and minimized employee turnover.

4) HARD-TO-REACH CLEANING AREAS: Although the overhead area of a plant can be and usually is extremely difficult and expensive to reach with vacuum cleaners, brooms, and compressed air for cleaning, it is not the only hard-to-reach area in many plants. Often, the hard-to-reach area is built into the process - under a conveyor or piece of equipment. Hard-to-reach areas also exist in vertical towers, requiring dust particles to be moved through multiple grate floor levels where it accumulates on top of equipment or within caged equipment areas, which requires shutting the equipment down for intermittent housekeeping. SonicAire's specialty fan series can often be used to keep these same hard-to-reach areas dust-free and operational. This eliminates the labor requirement for both checking on and hand cleaning these areas, while also increasing production uptime because areas are cleaned simultaneously with process operation.

5) LOWER SPEED MODES: Another ancillary benefit of DPC fans to consider is the possible use of a SonicAire Command control system with variable frequency drives (VFDs). Not only do VFDs allow variable movement of air within the facility - thereby doing a better job of cleaning around obstructions and equipment - but they can be utilized to maintain the clean plant environment by intermittently running fans at lower speeds, saving money and increasing efficiency. The fan energy consumed in cleaning is reduced and varied when in partial load VFD operation. The amount of reduction possible depends on the type of (dust) particles and the rate of production of fugitive (dust) particles. Typical usage of a variable speed control can reduce total operating cost by nearly 30%.

6) COMPLIANT CLEANING: Thousands of SonicAire DPC systems have been installed around the world. The main benefit of such an installation is the lifetime value of compliant cleaning that reduces the risk and costs of fires and explosions. In addition to the assurance of having a compliant facility, many insurance companies give reduced rates for the installation of robotic dust control fan systems.