Designing a cartridge dust collector for better filter cleaning and reliable performance

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In this article, a dust collection consultant explains how one commonly overlooked design factor for pulse-jet cartridge dust collectors, called the *filter-periphery airflow velocity,* can lead to poor filter cleaning and, eventually, a high pressure drop. As an example, he describes what he discovered about this design factor while investigating the source of an excessively high pressure drop in a glass-making plant's cartridge collector. He also explains how you can prevent high pressure drop and other problems by considering the factor when designing your own cartridge collector.

Poor cartridge dust collector performance often shows up in the form of a high pressure drop. Pressure drop (also called *pressure differential* or ΔP) is the difference between static pressures upstream (on the dirty side) and downstream (on the clean side) of the collector's cartridge filters. When the collector is performing properly, the pressure drop is typically below 5 inches water gauge. When the pressure drop rises, it makes sense to check that the collector meets traditional design standards. But if the collector checks out correctly, there's often more to the story than first appears.

High pressure drop points to filter-cleaning problems

Recently, I investigated the source of a puzzling pressure drop problem in a glass-making plant's cartridge dust collector. The cartridge collector was part of a dust control system designed to limit emissions of extremely fine, lightweight silica dust. The collector was equipped with a pulse-jet cleaning system that cleaned one row of filters at a time with continuous online 100-psi air pulses. The ductwork leading to the collector included capture hoods at pickup points over belt conveyors, hoppers, chute inlets and outlets, and a furnace inlet.

Before I was called in, the system operator had started up the collector and a plant technician had made opacity tests of the plant exhaust to confirm that the collector effectively controlled stack emissions. The collector not only controlled these emissions but operated at a pressure drop under 5 inches water gauge. But shortly after startup, the pressure drop rose to about 11 inches water gauge — way over the system's acceptable range. While the system was still controlling stack emissions, it was exhausting just 36 percent of its design airflow volume, and some dust was escaping into the plant area.

The plant technician made several inspections of the entire dust control system. Because the cartridge filters were dirty, it appeared that the pulse-jet cleaning system was ineffective. After the technician had plant maintenance workers check the cleaning system's operation and manually vacuum-clean the filters, the same problem rapidly recurred. Now the workers replaced the cartridge filters. But only 2 weeks after the workers completed this costly step, the collector's pressure drop again became too high.

At this point, the plant hired me to check out the dust control system. But when I inspected the system, I was puzzled: Everything appeared to be working correctly. A physical check of the dust collector exposed no problems, the pulse-jet cleaning system was performing properly, and the unit's traditional design factors were correct for the application (2.5-to-1 air-to-cloth ratio, 53-fpm can velocity, and 112-fpm interstitial velocity, as defined later in this article). I asked the maintenance workers to vacuum-clean the filters before the collector was operated again.

Just after the collector was restarted, the pressure drop was 3 inches water gauge. But by the third day, the pressure drop had again risen to 11 inches water gauge, and I also observed during this time that no collected dust was discharged from the collector's outlet into the receiving bin below it. The plant technician visually inspected the cartridge filters and found that, while they were in good shape, their external surfaces were blinded — that is, coated by a thick dust layer — because of the cleaning system's inability to fully clean the filters.

I realized that the excessive pressure drop couldn't be explained by analyzing the collector's traditional design factors. So what factor had the collector's designer overlooked that resulted in this pressure drop problem? For the answer, it's helpful to take a look at how dust collectors and their cleaning systems have evolved from the first baghouses.

Dust collector evolution and traditional design factors

In the early days of industrial ventilation, a dust collector was always a baghouse that enclosed rows of bag filters cleaned either by shaking or reverse air pulses. A baghouse is sized to provide enough filter media surface area to allow the dust-laden air to pass through the filters and be cleaned without creating an excessive pressure drop. The required amount of filter media surface area is determined by the baghouse's optimal filtration velocity, commonly called the *air-to-cloth ratio.* This ratio — the airflow rate versus the filter media area — represents the average airstream velocity through the filter media. The air-to-cloth ratio for a given baghouse depends on many factors, such as the dust concentration in the entering airflow, the dust's release characteristics, the dust cake's porosity, the filter type and media surface finish, and the cleaning system type and cleaning interval. Because the bag filters are cleaned offline, when the baghouse isn't operating, the airflow velocity pattern inside the unit isn't critical to the filter-cleaning efficiency.

Next, a pulse-jet baghouse was developed. This collector also uses bag filters but cleans them by injecting a short, high-pressure jet of compressed air from the top to the bottom of each filter, creating a shockwave that knocks the dust particles loose. While each section of bag filters is taken offline in sequence for cleaning, the other filters remain online so the baghouse can continuously filter the air. Because the baghouse cleans the filters while it operates, the dislodged dust must fall from the filters through the dust-laden airflow that typically enters at the baghouse bottom and moves upward toward the filters. The larger and denser the dust particles, the more easily they fall into the dust hopper below the filters. Fine, lightweight particles are re-entrained by the dust-laden airflow and redeposited onto the filter media until the particles stick to other particles, forming *agglomerates,* and become large and dense enough to fall into the dust hopper.

Thus, to correctly size the baghouse for effective filter cleaning requires knowing the airflow velocity in the baghouse. This means calculating two dust collector design factors: can velocity and interstitial velocity. *Can velocity* is the airflow's upward velocity in the baghouse's chamber, below the bag filters, and is calculated by dividing the airflow rate by the chamber's cross-sectional area. *Interstitial velocity* is the airflow's upward velocity between the bag filters and is determined by dividing the volume of dust-laden air entering the baghouse chamber by the net flow area available in the airflow's direction. The net flow area is determined by subtracting the total axial cross-sectional area of all bag filters from the baghouse chamber's total cross-sectional area. If either the can velocity or interstitial velocity in the baghouse is too high, the dust released during filter cleaning can be re-entrained by the dust-laden airflow and redeposited on the filters. (Be aware that can velocity isn't a factor in sizing a baghouse where the dust-laden air enters at the baghouse side or top [called a *side-* or *top-entry baghouse*], because the entering air flows downward.)

The next development was the cartridge dust collector. Instead of bag filters, this collector uses pleated cartridge filters. Each cartridge filter is a one-piece molded cylinder of pleated media with a top or bottom end cap. The media typically has 7 to 14 pleats per inch (inside diameter), with a maximum of 18 pleats per inch, thus increasing the filter surface area by 100 to 200 percent over a comparably sized bag filter. A cartridge collector can have up to three times more filtration area than a baghouse with the same housing size. The cartridge collector also operates more efficiently and requires less maintenance. It's typically cleaned by a pulse-jet system, which is even more effective with the cartridge collector than with a baghouse because the cartridge unit uses fewer filters.

But early pulse-jet-cleaned cartridge dust collectors didn't always perform well. Many were improperly engineered or undersized for their applications, and some of these remain in operation today. One common problem is a side effect of one of the cartridge collector's major advantages: The cartridge filter's pleated media can filter more air while consuming a much smaller area than bag filters and providing a comparatively lower air-to-cloth ratio than bag filters, *but* this makes the airflow velocity at each cartridge filter's periphery much higher than at a bag filter's periphery. This velocity, which for this article will be called the *filter-periphery airflow velocity* (although other users may call it by other names), can interfere with the free fall of dust particles released during pulse-jet cleaning, thus preventing effective filter cleaning.

Filter-periphery airflow velocity's effect on filter cleaning

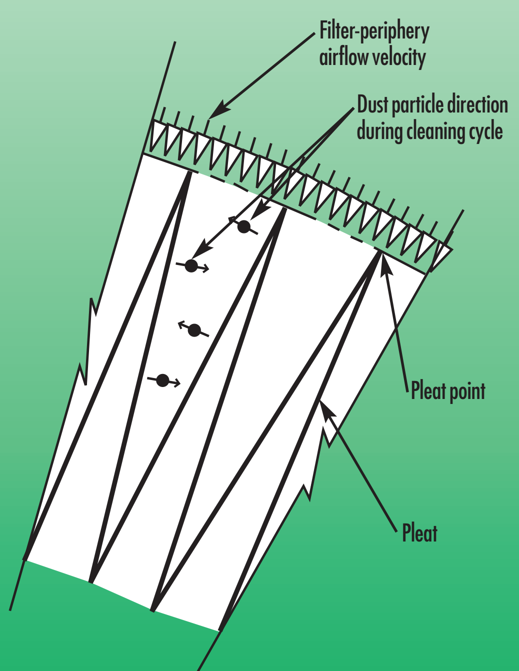
High filter-periphery airflow velocity can exacerbate an inherent problem in pulse-jet cartridge filter cleaning. In response to each cleaning pulse, the dust particles fly out perpendicularly from the surface of each cartridge filter pleat and toward the surface of the adjacent pleat; the adjacent pleat is also ejecting dust particles, as shown in Figure 1. The pleats obstruct the free outward flow of dislodged dust particles. When the filter-periphery airflow velocity is too high, the dust particles' outward flow is even more restricted.

High filter-periphery airflow velocity can exacerbate an inherent problem in pulse-jet cartridge filter cleaning.

This high-velocity airflow prevents finer, lightweight particles from flying out from the media surface and easily falling into the collector's dust hopper. Instead, dislodged

Figure 1

Direction of dust particles dislodged from cartridge filter pleats



fine particles are blown back onto the media surface after the cleaning pulse ends. Thus, high filter-periphery airflow velocity prevents dust from being removed during the cleaning cycle. This continues until a thick dust cake forms on each cartridge filter and increases the filter's resistance to airflow, which causes a high pressure drop. The airflow through the collector then decreases, in turn reducing the filter-periphery airflow velocity enough to allow some dust particles dislodged during pulse-jet cleaning to flow outward and then fall downward. This allows the filters to be partially, but not completely, cleaned.

In addition to high pressure drop, insufficient filter cleaning can lead to inadequate ventilation at your dust collection system's pickup points. To prevent these problems, you need to consider the often-overlooked filter-periphery airflow velocity when designing a pulse-jet cartridge collector.

Calculating filter-periphery airflow velocity

Determining the correct filter-periphery airflow velocity and air-to-cloth ratio for your cartridge collector will help you establish what design airflow volume, or capacity, the collector must have to ensure that it runs continuously and reliably.

The filter-periphery airflow velocity is a ratio of the airflow volume passing through a filter to the filter's *face area* and expresses the dust-laden air's *face velocity* as the air approaches the filter media surface. The filter's face area can be real or virtual. For a bag filter, the face area is the bag's real filter media surface area, as shown in Figure 2a, so the face area is equal to the filter's media surface area; for a baghouse, this makes the filter-periphery airflow velocity and the air-to-cloth ratio (that is, filtration velocity) equal. However, for a pleated cartridge filter,[1] the filter surface is the virtual surface formed by the point of each pleat around the filter's periphery, as shown in Figure 2b. This means that the cartridge filter's face area is much smaller than the filter's total media surface area, so that in a cartridge collector the filter-periphery airflow velocity can be much higher than the filtration velocity.

So how can you calculate an acceptable filter-periphery airflow velocity for your cartridge dust collector? There's no easy answer. Just as with a collector's air-to-cloth ratio, you can't precisely calculate the filter-periphery airflow velocity but must choose it by establishing several selection criteria. You can start by comparing your application with others in which a cartridge dust collector successfully controls the same dust. Factors that affect the filter-periphery airflow velocity are the airflow in the collector, your dust's characteristics (especially bulk density in weight per unit volume, typically expressed as pounds per cubic foot), and the dust collection system's operating conditions (such as operating temperature, airstream humidity, and batch or continuous operating mode).

These general guidelines are helpful:

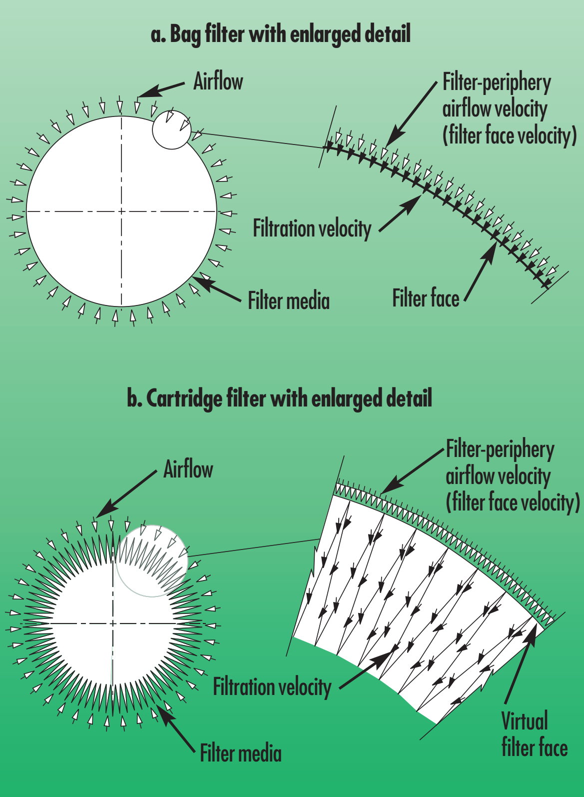
- For a fine, lightweight free-flowing dust, use a lower filter-periphery airflow velocity.
- For a coarser, heavier dust, use a higher filter-periphery airflow velocity.

I recommended replacing the collector with a larger unit with a lower design airflow volume and, hence, lower filter-periphery airflow velocity.

For help, have a qualified environmental consultant's lab or other qualified lab test your dust in different cartridge collector designs and sizes with varying filter-periphery airflow velocities, air-to-cloth ratios, media types, and other operating factors. Based on the results, you can calculate a filter-periphery airflow velocity that will allow the collector to effectively clean your filters and keep the pressure drop across the collector at an acceptable level so you can meet your performance goals.

Figure 2

Comparison of filter-periphery airflow velocities for bag and cartridge filters



Calculations for the glass-making plant's collector

The dust collector in the glass-making plant was designed to operate with a 68-fpm filter-periphery airflow velocity. I calculated this value based on data already known for this application, using the following equation:

$$FPV_d = \frac{Q_d}{(\pi \times D) \times L \times N}$$

where FPV_d is the filter-periphery airflow velocity (in feet per minute), Q_d is the dust collector's total designed airflow volume (in cubic feet per minute), D is each cartridge filter's outside diameter (in feet), L is each filter's length or height (in feet), and N is the number of filters.

However, based on my previous cartridge dust collector experience with fine, lightweight silica dust, I knew that the dust couldn't be efficiently cleaned from the cartridge filters if the filter-periphery airflow velocity was greater than 25 fpm.[2] To clean the cartridge filters properly, this dust collector should have only 37 percent (that is, 25 fpm/68 fpm = 37 percent) of its current design airflow volume. This explains why the collector's actual airflow volume was only 36 percent of the design airflow volume. As a result, I recommended replacing the collector with a larger unit with a lower design airflow volume and, hence, lower filter-periphery airflow velocity. This collector would be able to control the plant emissions to the desired levels while allowing effective filter cleaning and maintaining an acceptable pressure drop. **PBE**

Endnotes

1. The same is true for pleated bag filters.
2. No limits for filter-periphery airflow velocity for various dusts have been published, making this an area of dust collection technology that requires further research. In the meantime, you, your dust collector supplier, or your consultant will probably have to run tests or rely on experience with similar dusts to determine the filter-periphery airflow velocity limit for your dust.

For further reading

Find more information on cartridge dust collectors and cartridge filters in articles listed under "Dust collection and dust control" in *Powder and Bulk Engineering*'s comprehensive "Index to articles" (in the December 2002 issue and at www.powderbulk.com).

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