Optimizing Dust Collection System Design for Process Variances

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Designing dust collection systems to effectively handle process variables such as particle size range differentiations, excessive loading conditions, and non-standard air conditions are some common variables that must be properly accounted for to achieve optimal system performance. This article describes some of the most common contaminant or process variables, explains how each of them influence dust collection systems, and applies professional design considerations that will optimize system performance.

Approaching dust collection applications generally involves gathering detailed information regarding the collected contaminant, the operational parameters, and the system design requirements. Making sense of the variables that impact dust collection system design can be a challenging task. Contaminant particle size, loading conditions, operational duty cycle, and airstream conditions are just a few of the variables that influence the overall performance of dust collection systems and need to be accounted for when developing an optimal solution to meet performance expectations.

To understand how certain variables impact optimal system performance, let's review the four fundamental components of dust collection system design as shown in Figure 1.

- **Hood Design** — Method of contaminant capture and entry into the dust collection system.
- **Duct Design** — Method of transporting the contaminant from the hood to the next stage of the system, typically the dust collection equipment.
- **Equipment Design** — Equipment type, sizing, and configuration of the dust collection system — including the filter media technology.
- **Air-Moving Device** — Establishes the vacuum to transport dust-laden air from the source to the dust collection system.

If any one of these components is overlooked or incorrectly adapted to the application variables, the entire system may not be capable of meeting performance expectations.

Due to the unique dust characteristics and conditions present in highly variable processes, specific

Figure 1

Four Fundamental System Components that Impact Optimal Dust Collection Performance

considerations must be made in order to design a proper dust collection system that achieves optimal performance.

Design Considerations for Common Application Variables

Condition #1: Heavy Loading Conditions

Loading conditions refer to the concentration of dust as part of the air volume and are typically expressed as a mass per volume in units such as grains/ft.^{3} or mg/m^3. Moderate loading conditions for cartridge dust collectors are typically between 1 and 2 grains/ft^3. When the loading conditions exceed this amount, the following dust collection system design considerations are recommended:

- Increase the capture velocity at the hood to ensure that a high percentage of the contaminant is being collected.
- Utilize a more conservative air-to-media ratio when sizing the dust collector. Heavier loading accelerates increased filter pressure drop, which reduces airflow and filter life. Lowering the air-to-media ratio will offset this increase and allow the filter pulse cleaning system to work more effectively.
- Ensure that the dust collection system has "down-time cleaning" capability, which means pulse cleaning the filters when the airflow is not present. The additional cleaning will allow the filters to recover more effectively and maintain operational pressure and design airflow.
- Utilize pre-filtration to decrease the concentration of dust reaching the dust collection equipment. Examples of these devices include cyclone pre-filters (centrifugal separators) or air distribution modules. Figure 2 shows examples of each of these devices, which will mechanically reduce a large percentage of the dust volume based on particle size from reaching the filters, thus allowing the dust collector to operate more effectively.

Condition #2: Particle Size Distribution

In order to select proper filter media technology capable of filtering the full particle size range and configure the system design for optimal performance, understanding the particle size distribution is essential. Particle size distribution represents the percentage of the total particles as a function of particle size. This is typically presented by mass but can also be presented based on total particle count. The following needs to be considered based on the particle size distribution information:

- When dealing with broad particle size distribution, use the momentum of the larger, heavier particles to separate them from the fines with a cyclone col-

Figure 2

Examples of Dust Collection Solutions for Heavy Loading Conditions

Air Distribution Module

Cyclone Pre-Filter

lector, abrasive inlet, air distribution module, or dropout box.

- For larger particulate, such as wood chips or stringy / curly contaminant, use cartridge filters with wide pleat spacing. This will reduce the chance of contaminant becoming lodged in the pleat and allow it to release more effectively during pulse cleaning.
- When dealing with submicron contaminants, utilize filtration technology capable of collecting particulate in this difficult range. The filter minimum efficiency rating value (MERV) is a useful tool to help ensure proper selection. Figure 3 shows the relationship of particle size distribution and MERV ratings for many common contaminants.
- For submicron particulate (< 1 μm), utilize more conservative air-to-media ratios. Conversely, for larger particulate (> 5 μm), more aggressive air-to-media ratios can be used.

Condition #3: High-Density Materials

Material density is the mass per volume of collected contaminant used to calculate the necessary hood capture and duct transport velocity. Heavier dusts can also be abrasive to filters, which can shorten filter life and reduce the collection efficiency if the following system design elements are not considered:

- Consult experts or reference materials for the proven capture and transport velocities for given applications, hood types, and dust characteristics. The American Council of Governmental Industrial Hygienists (ACGIH) "Industrial Ventilation Manual for Recommended Practice" is a good source for this information, as are regulatory agencies such as the Occupational Safety and Health Administration (OSHA) or the National Fire Protection Association (NFPA). If you cannot find your specific process or contaminant, identify a material with a similar bulk density to utilize as a reference.
- For abrasive applications, configure the dust collector equipment with mechanical separators or abrasive inlets that reduce the contaminant velocity as it approaches the cartridge filters. Examples of these are expansion chambers or abrasive inlets as shown in Figure 4.

Figure 3

Particle Size Distribution and MERV Rating Relationship

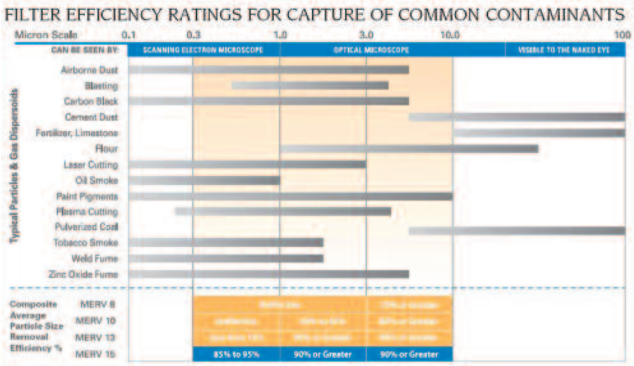

Figure 4

Dust Collection Solutions for Handling Abrasive Materials

Extended Dirty Air Inlet Plenum

Abrasive Inlet

Condition #4: Moisture-Laden Airstreams

Moisture entering the dust collection airstream through the process, the contaminant, or in the ambient air can pose a significant design challenge. As the airstream cools, the suspended moisture may begin to condense, resulting in liquid droplets. These liquid droplets can react with the contaminant, making it agglomerative and/or corrosive, which will negatively impact certain filter medias. Therefore, if moisture is present in the airstream or contaminant, the following design parameters need to be considered:

- Design the system to maintain a 50°F spread between the wet bulb and dry bulb airstream temperatures to reduce the possibility of condensation buildup. Utilize the worst-case ambient conditions as part of the calculations.
- Consider selecting a synthetic-based filtration media that has resistance to moisture, such as spunbond polyester. For added filtration efficiency and improved filter cleaning properties, consider ePTFE membrane technology.
- Insulate the ducts or even the dust collector itself as a way to maintain design airstream temperatures for outdoor systems and to avoid crossing the dewpoint.
- Airstreams with high levels of moisture have increased density over standard air, requiring airflow calculations to be corrected. This is especially important in selecting the air-moving device as most published fan performance is based upon standard air conditions.

Condition #5: Elevated Airstream Temperature

When collecting contaminants from processes with elevated temperatures, the resulting airstream in the dust collection system can be significantly higher than standard air temperatures. High temperatures change the physical properties of the airstream and may require changes to the materials used to construct the hoods, duct, dust collector, and/or filters. If your process produces elevated temperatures, consider the following in your dust collection system design:

- Decrease the recommended air-to-media ratio by 10-20 percent. As temperatures increase, some filter medias can soften or open up, which can lead to increased emissions. Lower air-to-media ratios work to offset this.
- Ensure that the entire filter construction is suitable for higher-temperature operation, including the filter media, gaskets, and any system sealing compounds that may be used.
- A general rule is that if the temperature is greater than 100°F, you will need to correct airflow calculations for the reduced air density. These calculations include the capture velocity, transport velocity, and air-to-media ratio. Making the necessary adjustments will help ensure that the fan performance has been corrected for the actual conditions as applied.

Summary

Through proper evaluation of the dust characteristics and variances in the customer's process, the design of a dust collection system can be optimized to meet performance expectations. Having an optimally designed system can decrease emissions, extend filter life, lower operational costs, and increase reliability. Consult a dust collection expert who understands how application and operational conditions influence proper dust collection system design. He or she can most accurately evaluate your specific process to determine the appropriate use and requirements for capture hoods and also design a complete air pollution control system to achieve optimal performance. **APC**

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