The dusts generated by tablet coating operations are like snowflakes: No two are alike. The operations themselves also vary widely. This article reviews the variables and standards that you must consider when selecting a dust collection system for tablet coating operations.

Because of the complexities and the unique nature of different coatings and coating systems, it’s impossible to apply a cookie-cutter solution to every dust collection challenge. Rather, we must drill down to details during the planning phase, and tablet coating and dust collection equipment suppliers must work together. That cooperation, coupled with a thorough, upfront examination of the coating system requirements, will lead you to the best options in dust collection components.

Why is it so important to go through this process? As a pharmaceutical manufacturer, you’re naturally concerned with employee safety, optimizing product quality, and minimizing downtime. At the same time, the dust collection system must satisfy:

- The FDA, whose overriding concern is patient safety;
- The National Fire Protection Association (NFPA), which sets standards for fire and explosion protection, especially important when the coating uses solvents;
• The Occupational Safety and Health Administration, which assesses indoor air quality, combustible-dust explosion risks, and other employee safety concerns; and
• The Environmental Protection Agency, which monitors the air exhausted outdoors.

Because tablet coating operations can involve toxic or potent materials, as well as potential fire and explosion hazards, the risks must not be taken lightly. Review the following questions and discussion for guidance in selecting a dust collection system for your tablet coating operation.

What is the proper air-to-media ratio?

The air-to-media or air-to-cloth ratio is defined as the volume of airflow (cubic feet per minute) that flows through the dust collector in relation to the square footage of cartridge filter media within the collector. The recommended air-to-media ratio for cartridge filters used in most tablet coating applications typically ranges from 1.5 to 2.5 cubic feet of air per square foot of media, a very conservative ratio. The actual ratio will vary with the particulars of each application and should be discussed with the coating equipment supplier.

The single most important factor in determining air-to-media ratio is whether coating is done in batches or continuously. Continuous coating systems are associated with very heavy dust loading. They can also introduce large amounts of moisture into the system because the coating is sprayed over longer periods.

Other variables in the equation: How many layers of coating are applied to the tablets and at what intervals? How many spray guns or nozzles are used? How big is the coating pan? Are solvents involved or are aqueous solutions used? Will the dust collector be adjacent to the coater—where moisture will be a bigger concern—or will dust travel to a more remote collector? All these factors should be considered.

An air-to-media ratio that is too high may lead to frequent (excessive) pulse cleaning, shortening the service life of the filters and impeding dust collection efficiency, which will cost you more money over time. Worse still, a high air-to-media ratio may lead to blinded filters and thus unscheduled system shutdowns. These unexpected shutdowns are very costly, and opting for a conservative air-to-media ratio is a better approach. In the most demanding or “worst-case” scenario—i.e., a large, continuous coating operation that includes a wash-in-place/clean-in-place (WIP/CIP) system—even a 1.5-to-1 ratio might not be conservative enough.

A conservative (low) air-to-media ratio reduces the risk of serious operational problems and will allow you to operate longer between filter changes. Yes, the initial expense of the dust collector will be higher, but the payback in operational and maintenance savings can be very short. Plus, the system will be much more reliable.

On average, airflows and pressures are higher in dust collectors serving coating operations than in those serving dry processes, such as tablet manufacturing. As a result, the dust collectors are typically larger, especially when coating is continuous, a case where the heavier dust loads and additional moisture may require more frequent filter changes.

What is the best filter media?

Tablet coating operations generate fine, potentially hazardous hybrid dusts that require high-efficiency filtration media, usually with some degree of moisture-resistance and/or other special properties. The type and duration of the coating process will have an impact on media selection (Figure 1).

The two basic, most common media for coating operations are nonwoven cellulosic blends and spun-bonded polyesters or polyester-silicon blends. The cellulosic media are the most economical for dry dust collection at operating temperatures to 160°F. Sometimes cellulosic media will incorporate a coating that enhances moisture resistance,

![Figure 1](image-url)

**Figure 1**

Cartridge filter media commonly used in tablet coating dust collection systems

a. Conductive media for use where conveyed dusts generate electrostatic charges that require dissipation, and/or for hybrid mixtures that include solvents in the airstream

b. Synthetic spun-bonded media for high moisture environments

c. Nano-fiber-treated media for better performance and longer filter life
but they do not, as a category, resist moisture as well as polyesters. Both spun-bonded polyester media and polyester-silicon blends are lightweight and washable. In dry applications, they can operate in temperatures of 180°F to 265°F. They can recover from a moisture excursion, but they are not intended for continuously wet applications.

Both cellulosic and polyester media can include a surface layer of nano-fibers to boost their efficiency and provide other benefits. The main benefit: better surface loading of fine dust to prevent it from penetrating deeply into the base media. That translates into better dust release during pulse cleaning cycles and lower pressure drop readings over the life of the filter, which extend filter life and reduce energy consumption.

In batch coating processes, particularly those with small coaters and in less demanding applications, both types of media are used, either as standard versions or with a nano-fiber layer.

Both media can also include conductive elements that dissipate electrostatic charges that can build up when dusts are conveyed. Typically, static dissipation is achieved by impregnating a cellulose filter with a carbon coating or a synthetic filter with an aluminized coating. Conductive media are often required when solvents are present in the airstream or when the application must meet requirements issued by the NFPA or ATEX, a European directive that governs explosive environments.

If the coating operation uses a WIP/CIP system, a spun-bond polyester media with an oleophobic treatment might be warranted. This oil- and water-repellent finish allows filters to withstand moisture from the cleaning system. A bypass damper can also reduce or eliminate moisture in the airstream before it reaches the collector, allowing you to clean in place without shutting down the dust collector. For the most demanding high-moisture applications, such as a very large continuous coating system with WIP/CIP, consider using heavy-duty, spun-bonded oleophobic media.

Filter service life varies a lot, but high-efficiency, long-life filters in a properly sized collector will last 3 to 6 months on average. One year is probably the maximum service life in a coating application. Many pharmaceutical manufacturers prefer to change filters more frequently, however, usually to coincide with other cleaning and maintenance tasks at the end of a coating cycle. They don’t wait for the filters to reach the maximum allowable restriction.

What kind of dust testing is needed?

There are two types of dust testing: 1) explosibility testing, which determines whether a dust is combustible; and 2) bench testing, which assesses the physical properties of the dust.

Explosibility testing. These tests are required to determine the degree of risk that a combustible dust could lead to an explosion. Conducted in accordance with ASTM methods (as stipulated by the NFPA), the tests determine a dust’s $K_{St}$ (the rate of pressure rise), $P_{max}$ (the pressure developed inside the collector), and MIE (minimum ignition energy).

Unless the dust is completely inert ($K_{St} = 0$), some form of explosion protection must be incorporated into the dust collection system. Coating operations often generate hybrid dusts and dust-solvent mixtures, and the concentration of solvent can have a dramatic impact on $K_{St}$ values. The NFPA Standard 68, “Explosion Protection by Deflagration Venting,” states: “Where test data are not available for hybrid mixtures with gases that have combustion characteristics similar to those of propane (fundamental burning velocity $\leq 1.3$ times that of propane) and St-1 and St-2 dusts, the design shall be permitted to be based upon $P_{max} = 10$ bar and $K_{St} = 500$ bar-m/s.” In this situation, the dust collection equipment supplier will use a worst-case scenario and incorporate a very high level of explosion protection. To avoid over-designing the system, it is always preferable to test samples of the actual dust that the dust collector will capture.

Bench testing. Testing dust samples in a laboratory is a long-established practice for making informed decisions about filter media and other dust collector components. It’s not always necessary but if there is anything at all unusual about the process and/or the dust—as is the case in coating applications—it’s a very useful practice.

Bench testing encompasses a series of tests that reveal valuable information about a dust’s physical characteristics. With a dust sample gathered from waste material, it’s possible to determine the dust’s particle size distribution, particle shape, moisture percentage by weight, the dust’s ability to absorb moisture, and other characteristics. Some dust collection equipment suppliers offer bench testing, often at no charge, because it generates very useful information. You can also have it done at an independent lab.

Is contained dust collection required?

Sometimes an inert coating is sprayed onto an active tablet core; sometimes an active coating is applied to an inert core; in other cases, both coating and core are active. The specifics of the application determine whether containment equipment is needed to prevent hazardous dust from being released into the environment.

In operations where the coating machinery is fully contained, and/or where cross-contamination of manufacturing processes is a concern, a contained dust collection system should be used. It will incorporate bag-in/bag-out (BIBO) technology for the filter cartridges to ensure filters are replaced safely (photo, page 12). It will include dual-valve continuous liners at the system’s discharge to capture and contain the dust that releases from the cartridges and enters the hopper during pulse cleaning. High-efficiency particulate air (HEPA) after-filters—sometimes called safety-monitoring filters—are also typically specified for hazardous dust applications, and these also incorporate BIBO technology.

If the dust is deemed not to be highly hazardous, containment may not be necessary, but HEPA after-filters are often used as backup protection to the dust collector. HEPA filters put a final “polish” on the air after primary filtration in the dust collector, allowing it to be released.
directly outdoors or recirculated into the building.

Which type of equipment to use depends on whether the dust is potent, toxic, and/or allergenic. These properties will, in turn, help determine the Occupational Exposure Limit (OEL) of the active pharmaceutical ingredient. The OEL is the maximum air concentration to which a worker can be exposed over an 8-hour shift (40-hour work week) without suffering adverse health effects. This concentration is expressed as a time-weighted average in micrograms per cubic meter of air. A risk-based exposure evaluation should be performed to determine what level of filtration and containment is needed for a specific application.

**What are the negative-pressure requirements?**

In a typical coating operation, air cycles through the coating pan at specific volumes, temperatures, humidity levels, and other parameters, and all these parameters can change throughout the process, creating additional dust-collection challenges. Typically, air moves through the system at negative static pressures that can reach 45 inches water gauge. The coating pan must remain under negative pressure (partial vacuum) throughout the process to maintain a controlled environment and ensure dust remains in the housing. Using a dust collector that is properly sized (correct air-to-media ratio) and contained (if required) will create and maintain the proper negative pressure environment and enable you to operate the coating system at peak performance without interruption.

It is also critical that you control the dust collector's reverse-pulse cleaning system. Otherwise, you risk creating positive pressure that can lead to a containment breach, improper operation of the coating equipment and, ultimately, downtime while you correct the problem.

**Where will the dust collector be located?**

Dust collectors for tablet coating applications are usually located indoors (photo), either in a maintenance or mechanical area adjacent to the Good Manufacturing Practice (GMP) space, or within the GMP space itself. If located within the GMP space, the dust collector must meet strict FDA requirements, just as all equipment in that space must, which may raise the costs of the collector.

Less often, usually due to space constraints or local requirements, collectors are placed outdoors. If a combustible dust is involved, the collector will likely be equipped with an explosion vent, and you will need to calculate the explosion vent area required and how to properly direct the explosion to a safe location. Outside installations typically have longer duct runs, and thus correctly configuring them takes on added importance to ensure consistent airflow from the coater to the collector. If incorrectly configured, the ductwork will lead to shorter filter life or blinding, which will cause the dust collector to malfunction and the coating system to fail.

**What is the best type of explosion-protection equipment?**

Explosion venting is the most basic and economical form of explosion protection, but it may not be an option if the collector is located within the GMP space and/or deep inside the building. In fact, that is where most coating operations and associated dust collectors are, and that makes venting an explosion to an outside wall difficult. In these situations, and/or if the dust is harmful or toxic (particularly if solvents are used), the only option may be a chemical suppression system, which is much more costly than venting. See Figure 2.

A chemical suppression system detects an explosion hazard within milliseconds and releases a chemical agent that extinguishes the flame before a deflagration can occur, protecting the dust collector from explosion. The inlet and/or outlet ductwork itself must also be protected from explosion. If chemical suppression is used on the dust collector, chemical isolation is typically used for the ductwork. Installed on the inlet and/or outlet ducting, it creates a chemical barrier that suppresses and isolates the explosion within the ducting and reduces the propagation of flame. It also minimizes the pressure rise within connected process equipment.

Mechanical isolation is another option. In these systems, passive dampers or fast-acting valves prevent a deflagration from reaching upstream equipment.

Determining which explosion-protection and duct-isolation methods are best for your coating operation requires conducting a risk assessment. Because of the importance and complexity of the task, hire an independent professional engineer and have him or her work with your dust collector supplier. That’s the best way to ensure compliance with the applicable standards and the requirements of your insurance carriers.

You can also conduct real-world destructive testing to help make decisions. The NFPA uses relatively conservative calculations in developing its standards for explosion-protection equipment, which is understandable. But the NFPA also allows you to use real-world destructive test data instead of its textbook calculations, as long as the equipment supplier’s
data proves that the design of the dust collection system meets a specific set of criteria for a given situation.

But few people use real-world destructive test data, probably because it is not required and can prolong the project and add cost if your equipment supplier hasn’t already conducted similar testing. Still, many equipment suppliers recommend gathering the real-world data because it can pay off very quickly by preventing you from paying for an overdesigned system.

The dust collector’s vessel strength is another factor that can only be verified by physical testing. A heavy-duty dust collector—made with a thicker metal and bearing a higher pressure rating—will better withstand a dust explosion and may allow you to specify a simpler and less costly explosion-protection system. Stronger vessels also increase the options for equipment placement because they allow longer explosion vent ducting, potentially saving space inside your facility if you can locate the dust collector in a more remote location. Find out if your dust collector supplier can provide real-world test data to assist with this strategy.

**Is air recirculation an option?**

If you operate in a region where it gets very hot or cold, consider air recirculation downstream of the dust collector. By recirculating heated or cooled air through the facility, you eliminate the cost of replacing that conditioned air, and the energy savings can be dramatic. Most dust collection equipment suppliers have software that can estimate the savings based on system airflow, climate, utility rates, and other factors.

When recirculating air downstream of the collector, adding a HEPA after-filter is recommended and, if you’re filtering hazardous or toxic dusts, it’s required. HEPA filters provide backup protection and a final scrub of the air before it returns to the facility. Ductwork and transition sections are usually required to connect a secondary filter module to the dust collection system. But in some applications, an integral HEPA after-filter module mounts on top of the collector to save floor space and eliminate the need for transitional ducting, saving money.

For contained coating operations, safe-change containment HEPA filter systems are available, and the design and selection of after-filter components should be based on a risk assessment and the specifics of the application.

If the collector is handling an explosive dust, HEPA after-filters—as well as the collector and ductwork—must comply with NFPA standards for combustible dust handling.

**Figure 2**

Explosion-protection methods

- a. Explosion vent
- b. Chemical suppression
- c. Chemical isolation
- d. Passive isolation valve (active mechanical isolation valves also available)
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