Making informed choices – Understanding the role of cyclone separator efficiency for maximum overall system efficiency

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Today's powder systems typically use one of two major types of recovery systems – cartridge filter systems or cyclone separator systems. New powder system customers may often explore the pros and cons of both types of designs when deciding what type of system to purchase. With the trend toward more colors, more frequent color changes and faster color-change times, more and more, new and existing, powder coaters want to understand the differences between the two types of systems. Note that this discussion assumes a one-to-one cartridge system vs. cyclone separator system comparison. It does not intend to discount the possibility of multiple systems, power-and-free conveyors, or roll on/roll off systems.

With the possibility of many different system configurations, the economic advantages or disadvantages of any single-or-multiple-system configuration would need to be comparatively analyzed relative to desired throughput, number of colors, frequency of color changes, operating costs, initial capital expenditure and return on investment. At some point, however, a cartridge filter type system with its associated cost of additional color modules and/or the cost of spraying to waste and not reclaiming, plus the added operating cost of relatively longer color-change times, may exceed the initial capital expenditure and operating costs of a cyclone separator system.

Nordson Sure Clean™ System with Compact Twin Cyclone Separator

Relatively recent technological advances in powder booth and recover designs have shown that cyclone separator systems can achieve color-change times ranging from 8 to 20 minutes with two operators. This capability provides finishers spraying numerous colors a potential economic advantage – resulting in reduced operating costs and higher throughput.

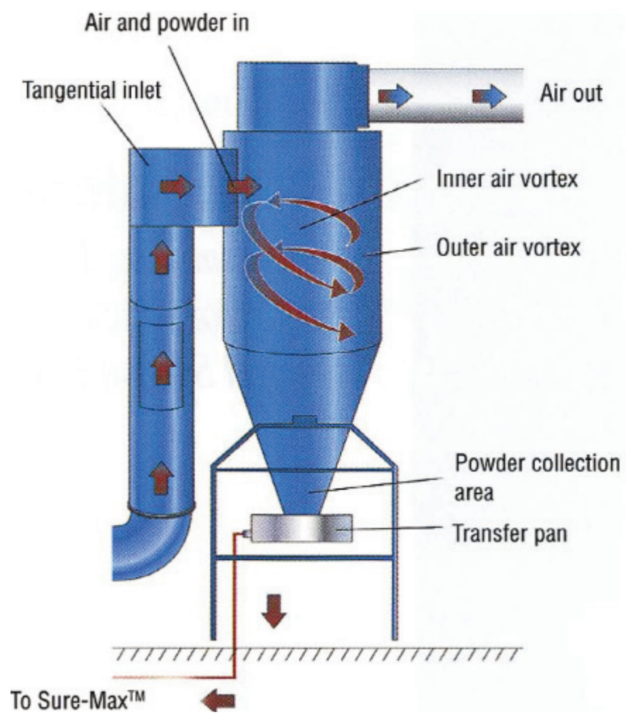

Figure 1: Conventional Cyclone Separator Theory of Operation

Cyclone separators – theory of operation

Relative to powder system operations, a cyclone separator is a device used to separate powder particles from an incoming air stream within a conical cylinder, using the principle of centrifugal acceleration. (See Figure 1) The air stream is injected at high velocities into the inlet pipe, which is positioned tangentially to the body of the cyclone. The shape of the cone induces the high velocity air stream to spin, thus creating a vortex within the conical cylinder. The larger particles within the air stream are forced outward toward the wall of the cyclone, where the drag of the spinning air and ensuing gravitational forces cause them to fall down the sides of the cyclone into an outlet at the base of the cyclone. Simultaneously, the smaller, lighter particles are captured within the center of the spiral-like air stream and are drawn out or discharged through an outlet at the top of the cyclone.

This separation process requires a continuous, steady flow of air, free from fluctuations or intermittent variations in flow rate. Therefore, the finer particles that exit the top of the cyclone are drawn by and extracted to an after-filter with exhaust fan and motor, downstream of the cyclone separator. This after-filter is the source of the high-velocity air stream that is drawn into the spray booth and through the cyclone, ensuring adequate containment of oversprayed powder within the system. Another separation process occurs with the after-filter, whereby the fine particles that were extracted from the cyclone separator are captured by primary cartridge-style filters in the after-filter. Finally, the air stream is then exhausted into the room through final HEPA style filters.

TABLE I: Cyclone Separator Efficiencies

	Powder 'A'	Powder 'B'	Powder 'C'
Cycle 1	94.6%	98.6%	91.3%
Cycle 2	98.3%	98.9%	97.7%
Cycle 3	99.6%	99.3%	98.3%
Cycle 4	99.9%	99.9%	99.9%

TABLE II: Particle Size Analysis

Powder	Median Particle Size (Micron)	Volume Percent Under 9.82 Microns	Volume Percent Under 5.43 Microns
Cycle 1 - Virgin			
A	38	9.9	2.1
B	84	4.0	0.2
C	33	18.8	7.9
Cycle 2			
A	37	6.1	0
B	80	3.0	0
C	39	6.5	0
Cycle 3			
A	42	2.0	0
B	83	2.1	0
C	41	4.0	0
Cycle 4			
A	43	1.4	0 under 6.3
B	86	1.1	0 under 6.3
C	42	2.2	0

Cyclone separator efficiency

The purpose of measuring cyclone separator efficiency relative to powder spray systems is to understand the ratio of separated powder particles. In other words, what percentage of larger powder particles are being extracted at the based of the cyclone and reclaimed for re-spray? And, what percentage of finer powder particles is being extracted at the top of the cyclone and ultimately collected by the after-filter?

The amount of powder particles captures within a truly efficient cyclone separator and conveyed back to the spray guns should be in the high 90-percentile range. As stated previously, the powder particles that are extracted through the top of the cyclone are finer particles. The powder particles captured at the base of the cyclone are relatively larger particles.

It has been claimed that larger powder particles tend to take on an electrostatic charge better than finer powder particles. In addition, it has been claimed that finer particles do not fluidize well, and consequently do not pump and convey as effectively as larger particles. Therefore, it is important to remove or separate the finer particles from the powder spray system to improve overall system efficiency.

An important design feature included in the design of experiment that affects cyclone separator efficiency, as well as system efficiency, is the method used to extract powder from the base of the cyclone and the speed it is removed. For maximum cyclone and system efficiency, it is required to remove the powder captured within the cyclone separator at a high rate of volume.

Efficiency test parameters

Efficiency testing was performed using three powders from various sources. The following equipment developed by Nordson Corporation was used for the test –

- Sure Clean® Powder Spray System with rotating floor and Apogee™ canopy
- Sure-Max® Powder Transfer System
- Spectrum® Powder Feed Center
- Sure Clean® Compact Twin Cyclone Separator (Figure 2)

Each test began with a 15-lb charge of powder that was poured onto the rotating Sure Clean booth floor while the booth was in operation. The Sure-Max Powder Transfer System was also in operation at this time. As the booth floor rotated underneath, the extraction duct suspended above it, the powder was then drawn into the duct and through the cyclone. Any powder that was recovered in the cyclone was then extracted at the base of the cyclone by the Sure-Max powder transfer system, and conveyed from the cyclone separator to the Spectrum Powder Feed Center. The floor was allowed to make several revolutions to ensure that all the powder had been recovered. An air lance was also used to remove any residual agglomerated powder on the booth floor that occurred when powder was dumped, rather than sprayed, into the spray booth.

The system after-filter was then turned off as the Sure-Max powder transfer system continued to run. Several foam cylinders were then run through the Sure-Max transfer line to remove any residual powder that was contained within it. The feed center was then turned off and the Sure-Max conveyor was disassembled. The filter was weighed and any remaining powder residue in the body of the Sure-Max transfer system was brushed into the recovery container. Powder in the recovery container was then weighted and added to the weight of any powder captured on the Sure-Max filter. This total weight represents the yield of the cyclone and was divided into the starting weight (15 lbs) to determine cyclone efficiency. See Table I for results.

Further analysis

Three powders were run through the system for a total of four "cycles" each. No virgin powder was added to any of the individual test runs. The yield weight was included in each subsequent efficiency calculation. Particle size analysis illustrates the role of the cyclone separate as classifier, with almost all particles under five microns removed from the recovered powder on the first cycle (See Table II). The result in subsequent cycles was an increase in cyclone efficiency, typically exceeding 98% in the first cycle and 99.5% within three cycles when tested with virgin powders containing less than 10% of their mass under 10 microns and a median particle size of 29 microns.

Conclusion

Cyclone separator efficiency plays an integral role in overall system efficiency. To achieve optimum overall system efficiency, it is also important to have the highest possible first-pass transfer efficiency – greatest level of powder particles attracted to the part. Furthermore, the amount of powder "in process" during operation plays a key role in system efficiency. In other words, all powder systems will have some amount of overspray. The key is to first minimize the amount of overspray, and to keep any overspray circulating through the system, without allowing it to reside in either the spray booth or the cyclone separator. Achievement of these goals will result in optimum overall system efficiency. To define your system needs and understand them better, it is recommended that you contact a knowledgeable powder equipment supplier to determine the most economical and efficient system configuration for your operations goals.