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Understanding Powder Coating Equipment and Application

There are many ways to apply powder coating materials; however, the material that is to be applied must be of a compatible type. For instance, if the application method is fluidized bed, the powder coating material must be a fluidized bed grade. Conversely, if the method of application is electrostatic spray, the powder material must be an electrostatic spray grade.

Once the material is correctly selected, the application method is chosen by part design and production goals. There are two forms of application methods: fluidized bed application and spray application. These vary as widely as the applications they suit.

FLUIDIZED BED

This application method was the first one used to apply powder coating materials. It is still used on many applications where the cured-film thickness is above 5.0 mils. Typical items are wire products, electrical bus bars, etc.

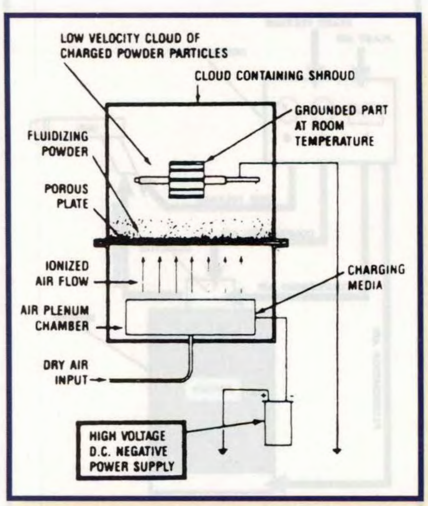

Figure 1. Electrostatic fluidized bed for powder coating

The fluidized bed application method can be performed in two ways. One way is the nonelectrostatic fluidized bed. This process requires preheating the part so that powder will melt and adhere to it. The hot part is placed into a fluidized bed of powder for coating. The amount of powder that is applied to the part is a function of how hot the part is and how long it is in the bed. It should be obvious that tight film-thickness control is not of primary concern when this method is used, as the total coating thickness often exceeds 10 mils.

To gain more control of film thickness on the part, with a fluidized bed system, the principles of electrostatics are introduced. As shown in Fig. 1, the part is transported above the fluidized bed and the powder is attracted to it. The part requires no preheating prior to being placed above the bed. Powder is attracted to the part by an electrostatic charge on the powder particle. This electrostatic charge is developed in an electrostatic field either above or in the fluidized bed.

Film thickness on the part now is controlled within tighter tolerances not only by the amount of time the part is in the fluidized bed but also according to how much electrostatic charge is on the powder particle. Sometimes, heat still is used in this process to overcome Faraday cage problems caused by part configuration. This process routinely applies powder from 5 to 10 mils thick.

Electrostatic fluid bed application is used for coating electrical motor armatures. These require a high dielectric strength coating with close film-thickness control to allow the wire to be wound properly.

SPRAY APPLICATION

Applying powder coating with electrostatic spray equipment is broken down into two types. In each case electrostatics must be used to attract powder to the part. There is no mechanical attraction or adhesion to hold powder to the part as seen in liquid spray systems. The two types of electrostatic spray equipment are corona-charged spray guns and tribo-charged spray guns.

Corona Guns

This device uses an electrostatic generator to create an electrostatic field between the gun and a grounded part. Powder is sprayed through the field, picks up an electrostatic charge, and is attracted to the part. The amount of charge that is transferred on the surface of the powder is a function of electrostatic field strength and the amount of time the powder particle is in the field. Also of importance is the surface area of the powder particle, as finer powder particles hold less electrostatic charge. The following equations (see Fig. 2) best explain how the powder is charged:

Field Strength: E=V/d

Charge on Particle: Q= 1/2 CEt2

Notice that some factors are more important that others. For instance, electrostatic field strength is directly proportional to applicator electrode voltage. Also, the distance between the part and the applicator (sometimes called the target distance) will directly affect electrostatic field strength.

The charge on the powder particle (which causes the attraction) is most affected by the amount of time the

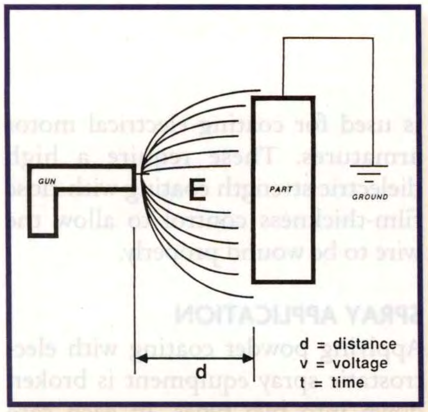

Figure 2. Principle of corona charging.

particle is in the field (by its square). The time and field strength will determine how much powder is attracted to the part (i.e., first pass transfer efficiency). The time the powder particle is within the electrostatic field is most easily controlled by adjusting the velocity of the powder pumped through the gun, or applicator, and reducing the speed of the applicator motion. It is a known fact that systems that use reduced powder velocity and slow gun motion will provide the best coating efficiency with the least effort.

The powder coating process is most often used to apply a charged dielectric material (powder coating) and onto a conductive (grounded) part. However, electrostatic powder coating on nonconductive materials (i.e. plastics, rubber, glass, etc.) can be performed using a conductive primer or aiding powder attraction by heating the surface to be coated. Additionally, electrostatic charging of conductive materials (i.e., blended metallic powders) can be difficult since they can short-circuit the applicator's charging circuit. However, most equipment manufacturers provide electrodes outside the powder path to overcome this problem.

Both positive and negative polarity electrostatic guns are available from most manufacturers to provide efficient charging of widely divergent coating materials. It is worth noting that 98% of all applicators used in powder coating operations are negative polarity devices.

Code requirements insist that certain protection circuits be part of the system. Among these are current limitation to control arcing and grounding of all equipment and products that are coated to dissipate stored charges. System interlocks are required for automatic equipment. Guidelines for this equipment are listed in National Fire Protection Association Code (NFPA) 33.

Tribo Guns

Tribo-charged spray equipment uses the principle of frictional electrostatic charging. This type of charging is best explained by the following analogy: When you shuffle your shoes on a carpet in the winter, you create an electrostatic charge that is stored in your body. This charge is usually dissipated when you come into contact with a ground, such as a light switch. This phenomenon will only occur in a dry (not humid) environment. This is why we are not bothered by static electricity in the humid summertime, but only in the dry air of winter.

Tribo-charge spray equipment will direct the powder stream through a path that it will tumble and rub against a dielectric surface within the applicator, yielding a frictional electrostatic charge on the powder particle. This path is accomplished by lengthening the powder route through the spray equipment in either a straight, radial, or oscillating path. The amount of electrostatic charge that builds up on the surface of the powder particle is a function of several variables, including (1) the amount of time the powder particle is subjected to the frictional charging apparatus; (2) surface area of the powder particle; (3) dryness of air the powder is transported with or comes into contact with; and (4) the type of resin material from which the powder is made.

Controlling these variables is important to assure that the powder particle will be properly charged. Remember: if the powder is not charged, it will not adhere to the part unless the part is hot enough for the powder to stick on contact.

The amount of electrostatic charge that typically is developed by this apparatus is less than that produced by corona equipment. The polarity of the tribo charge is a function of the material being sprayed and the material that it is rubbed against. If the same two materials are used, the polarity will always be the same.

Tribo-charge applicators can often be used to overcome Faraday areas on difficult-to-coat parts, as there is no electrostatic field used to charge the powder. This flexibility, however, is often overshadowed by the additional process and coating materials controls that are required to ensure successful coating.

Powder Bells

This device uses an air turbine to rotate a conical cup used to atomize the powder coating. Powder is pumped to the cup where the rotational forces cause complete powder atomization. The feed system used to support this device is similar to that of spray guns. These devices employ the corona charging method, described earlier in this article.

Powder bells are capable of dispersing a large quantity of powder coating over a large area. Therefore, the typical applications for this device are large flat components, such as appliances and automobile bodies.

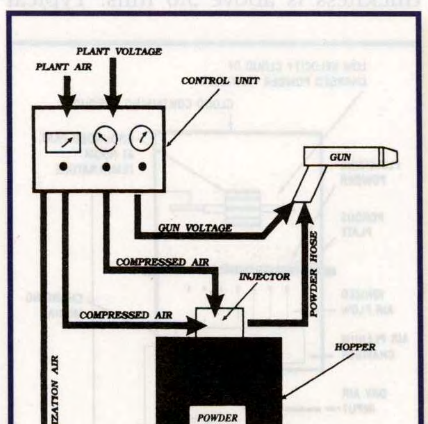

Figure 3. Powder delivery system.

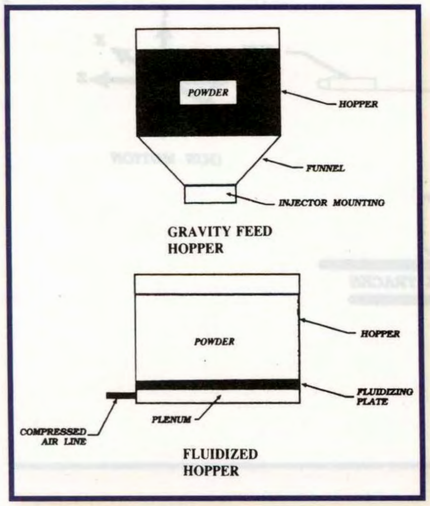

Figure 4. Hopper designs.

POWDER DELIVERY

All spray application equipment requires a delivery system (see Fig. 3). This delivery system consists of a feed hopper, a powder pump, and a powder feed hose.

The feed hopper can be one of two types (see Fig. 4). The first type is called a gravity feed hopper. As the name suggests, this feed hopper uses gravity to move powder to the powder pump located at the bottom. This hopper usually is conical in shape to funnel powder to the pump. Sometimes a mechanical stirrer or vibratory assist is used to maintain an even powder flow. Frequently, without a mechanical assist, powder will bridge across the bottom of the funnel causing uneven feed to the pump. Since there is no air mixed with the powder in the hopper, this device is often employed when spraying blended metallic powders that can be stratified within a fluidized hopper.

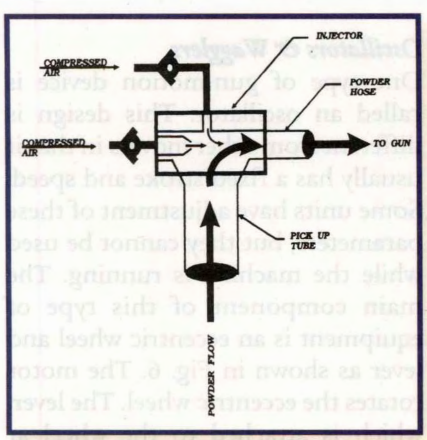

Figure 5. Powder pump.

The second type of powder feed hopper uses a fluidized bed. It is the same as the fluidized bed system described previously. A compressed-air supply is connected to the plenum chamber below the fluidizing plate. The fluidizing plate causes the air to fluff powder in the hopper to a state resembling water. Now the powder can be drawn out by the powder pump. Since powder is mixed with compressed air from the plenum, the powder within this device is very homogeneous in nature.

Powder pumps are mounted on the hopper and are connected to a pick-up tube to draw powder out of the hopper. These pick-up tubes usually are positioned an appropriate distance into the fluidized bed to assure that the turbulence usually present on the surface of the fluidized plate is not drawn up into the powder pump. This turbulence can cause inconsistent powder feed to the applicators.

Box Feeders

Powder equipment manufacturers also provide methods of pumping powder coatings directly from their shipping containers (box or bag) to the spray gun. This method is called the box feeder and utilizes a tilted vibrating table to support the box of powder. A powder pump connected to a pick-up tube is inserted in the lowest portion of the box. A compressed air jet is employed at the end of this tube to assist powder flow into the tube. Powder is then pumped directly from the box to the spray gun without the need of a feed hopper. This approach makes color change cleanup quick and easy, as only the pick-up tube, pump, and hose need to be cleaned. Changing the powder box completes the color change task.

PUMPS

Most powder pumps are designed to work by the venturi principle. Compressed air is directed perpendicular to the venturi pickup, causing a differential in pressure, or vacuum, that siphons powder out of the feed hopper or box feeder. When the powder enters the compressed air stream, it is pushed through the powder hose toward the applicator. An additional compressed air supply is introduced at the point where the powder enters this air stream (see Fig. 5) to dilute the powder and increase its velocity. Increasing powder velocity ensures that the powder stays within the air stream as it proceeds through the hose, reducing surging or pulsing problems. Surging occurs when the powder lays at the bottom of the hose until enough air pressure builds behind it to push it out with a burst. Both air supplies have check valves to force the air to go through the powder hose, allowing independent control of both powder quantity and speed through the feed hose.

Powder hose can be made from several materials, including urethane, vinyl, and certain rubber compounds. Hose diameter and length are critical. Diameter is dictated by the powder pump used; it always should match the manufacturer's recommendation. Length always should be as short as possible to reduce back pressure to the powder pump. This reduces surging of the powder stream to the gun. Avoid bends and kinks in the hose routing.

The more powder you pump using venturi style pumps the faster it travels through the electrostatic field. Consequently, transfer efficiency will be lower at higher feed rates. Applications requiring highly controlled powder flow at a wide range of output rates use high density - low pressure (HDLP) powder pumps. These devices deliver a column of powder to the applicator without having to mix it with compressed air. Reducing the compressed air within the powder stream decreases the velocity of the powder delivered from the applicator, slowing powder speed, increasing powder density, and eliminating aerodynamic issues that may cause coating difficulties on box-shaped parts. Since these pumps employ significantly smaller diameter feed hose, the hose is much easier to clean with compressed air purging, making these pump the preferred choice for "fast color change" systems.

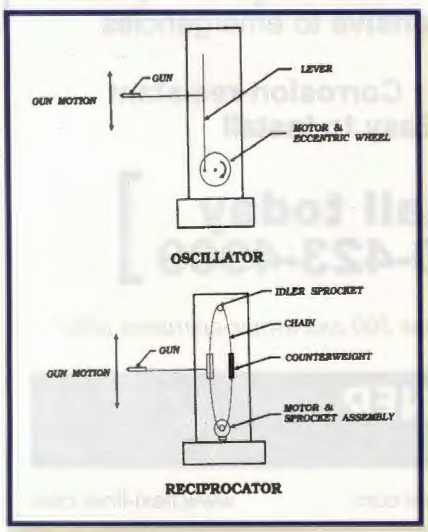

Figure 6. Gun motion devices.

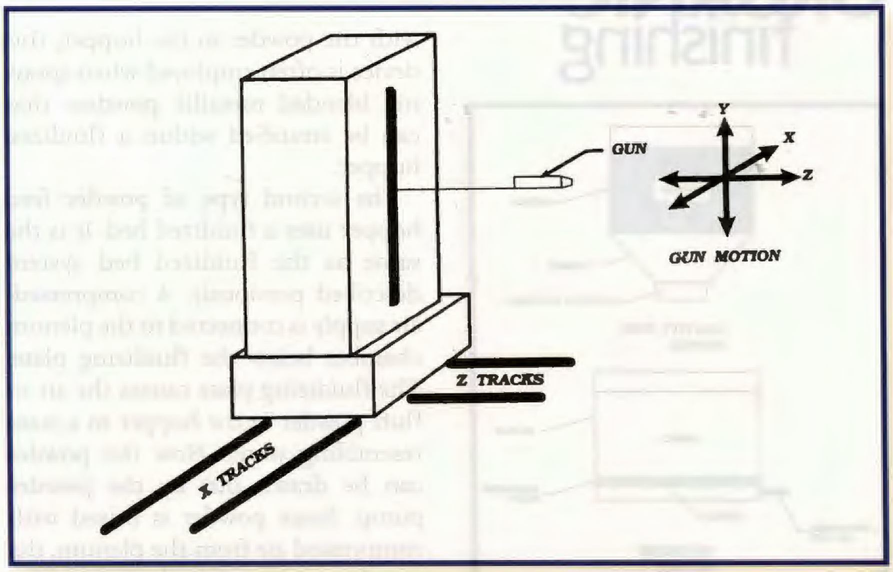

Figure 7. Multi-axis movement.

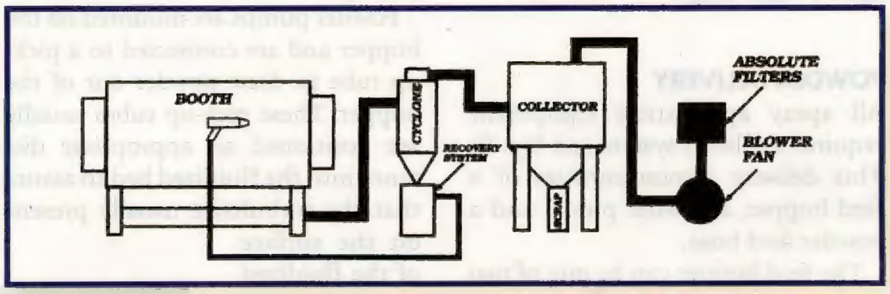

Figure 8. Conventional powder booth system.

GUN MOTION

Automatic spray devices are often accompanied by some ancillary equipment used to produce spray gun motion. Gun-motion equipment can be broken down into four general categories: oscillators, reciprocators, multi-axis machines and robots.

Each of these gun-motion systems has a different design and is used to fill a specific coating requirement; however, all have one common feature. They are designed to move the spray gun(s) in one or more planes to coat a larger area than a fixed spray gun. Thus, the number of spray guns required to coat a given area can be reduced. This makes for a more efficient and economical system design

Oscillators & Wagglers

One type of gun-motion device is called an oscillator. This design is different from other movers in that it usually has a fixed stroke and speed. Some units have adjustment of these parameters, but they cannot be used while the machine is running. The main component of this type of equipment is an eccentric wheel and lever as shown in Fig. 6. The motor rotates the eccentric wheel. The lever, which is attached to the wheel at some distance from the center, will translate this rotary motion to a vertical motion.

Stroke length is determined by the position at which the lever is attached to the eccentric wheel and by the diameter of the wheel itself. It can be adjusted by locating the lever at different points on the wheel radius. Speed is dictated by the motor and gear reducer used in the design. Sometimes, there are clutches and adjustable belt sheaves that will provide some speed adjustment; however, neither speed nor stroke adjustment can be changed while the unit is running.

Wagglers (radial oscillators) pivot the gun through an arc, where straight oscillators provide vertical gun motion in a straight line. Gun-to-part target distance is affected with radial oscillators, while straight oscillators will not have this problem.

Reciprocators

Reciprocators (see Fig. 6) use a variety of electronics to control both stroke and speed. In these machines, the mechanical linkage between the motor and guns is fixed; therefore, speed and stroke control must be adjusted electrically. These adjustments are sometimes made at the control panel and sometimes at the unit itself. For instance, stroke adjustment can be made by moving electrical limit switches in the unit or by adjusting an electronic feedback loop variable in the control panel.

Speed control is accomplished by a variety of methods depending upon the type of motor used. For instance, those designs that use a DC motor will provide speed control by varying voltage to the motor. Reciprocators that use AC motors have variable speed-control circuits to adjust speed. Both types allow adjustment during operation. This offers some flexibility over the oscillator design when different stroke lengths and speeds are required to coat different parts during the production cycle.

Multi-Axis Machines

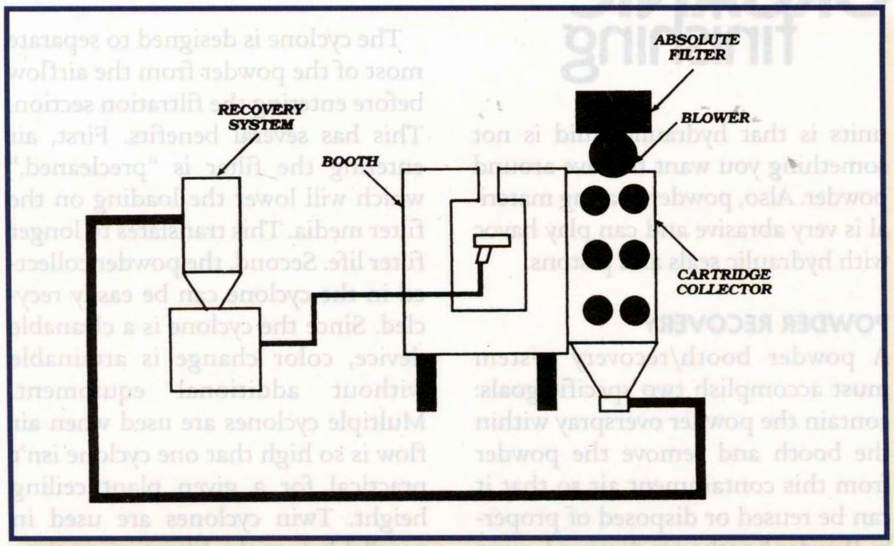

Figure 9. Cartridge booth system.

Both oscillators and reciprocators provide movement in one plane only. Multi-axis machines were developed to provide increased coating flexibility and meet a demand for total automation. Multi-axis machines have been successful in eliminating some or all of the manual touch-up necessary on some products. Though costly, this increased automation often will pay for itself by providing consistent part coating with minimal, if any, touch-up.

The multi-axis machine design is made up of two or three reciprocators that will move the gun(s) in two or three planes. The convention used to label the three axes of motion is as follows (see Fig. 7).

X = parallel to the conveyor travel
Y = up and down
Z = in and out

The design of these units is the same as reciprocators with respect to the control of speed and stroke adjustment; however, because the units must track parts moving along the conveyor, the addition of a programmable logic controller (PLC) is required.

The PLC will accept inputs from encoders (that determine conveyor speed) and photo cells or limit switches (that determine part position). This information is used to determine at what speed the multi-axis machine must run to track the part and when the multi-axis motion program is to be executed. The purpose of this complex tracking and motion system is to provide gun dwell time and powder pattern direction.

Robots

Most robots provide six axes of gun motion by adding wrist movement. Robotic machines can be electrically or hydraulically driven. Because of their cost and complexity, these units are rarely used in powder coating systems. Another detriment to these units is that hydraulic fluid is not something you want to have around powder. Also, powder coating material is very abrasive and can play havoc with hydraulic seals and pistons.

POWDER RECOVERY

A powder booth/recovery system must accomplish two specific goals: contain the powder overspray within the booth and remove the powder from this containment air so that it can be reused or disposed of properly. Powder booths are designed using several filtration techniques to separate the overspray powder from this containment air stream depending upon if the system will reclaim this powder or employ a spray-to-waste strategy, the number of reclaimed powders, and the time available to perform the color change.

Cyclone Booth System

A cyclone powder booth system, as pictured in Fig. 8, is made up of a spray booth, cyclone(s), a cartridge collector, and possibly ductwork.

The spray booth can be made of metal, plastic, or composite sandwich designs. Metal booths provides strength and durability but attract more powder that will prolong color change time. Plastic will allow more light into the booth and will attract less powder, reducing color change time. Composite sandwich designs offer strength and attract the least power, significantly improving color change time. All powder booths should provide a smooth interior to facilitate easy and thorough cleaning.

Ductwork connection(s) can be at one of several locations. The preferred method is to locate the ductwork connection in the base of the booth as this provides a down-draft air flow inside the booth helping to keep it clean.

The booth may have devices, such as baffles, to help control air flow within the booth, touch-up openings to provide access for manual spraying, and gun slots to provide access for automatic equipment.

The cyclone is designed to separate most of the powder from the airflow before entering the filtration section. This has several benefits. First, air entering the filter is "precleaned," which will lower the loading on the filter media. This translates to longer filter life. Second, the powder collected in the cyclone can be easily recycled. Since the cyclone is a cleanable device, color change is attainable without additional equipment. Multiple cyclones are used when air flow is so high that one cyclone isn't practical for a given plant ceiling height. Twin cyclones are used in parallel before the filtration section. Cyclone efficiency can vary by manufacturer and design with some systems delivering in excess of 90% of the powder into the reclaim device.

The filtration section used with a cyclone booth is a cartridge collector, given its name for the cartridges used to separate powder from the air flow. These paper cartridges are cleaned with a "back pulse" of compressed air to shock the powder from the cartridge surface. The cartridges will separate most of the powder out of the air flow from the booth (up to 99% efficiency). These are not cleanable devices for color change. The blower fan that produces the air flow in the booth typically is located on the clean air side of the filtration device. Final filters are used after the fan to remove powder particles, down to 0.3 micron in size, before the air is returned to the work environment.

All of these devices–booth, cyclone, collector, fans, and absolute filters–can be connected by ductwork. The velocity of air within this ductwork usually is above 4,000 fpm and the ductwork is designed to promote laminar flow to assure "self-cleaning" during operation.

Some powder booth manufacturers have taken the approach of reducing the ductwork in this type of booth. This design has numerous smaller cyclones attached directly to the powder booth wall. The booth airflow enters the cyclones directly and without ductwork. These cyclones are much smaller than those used in standard cyclone booths, allowing for simpler cleanup. The blower, filter pack, and final filters are downstream from, and attached to, the cyclones, allowing the air to be returned directly to the plant.

Cartridge Booth System

The cartridge booth system (see Fig. 9) answers the same technical needs that all powder recovery systems must address: safe containment and separation of powder coating overspray. In a cartridge booth system, this is accomplished by filtration of powder from the containment air using a cartridge collector attached to the booth. There are no external filtration devices (or ductwork to connect them) with this system.

The cartridge collector is usually located in the wall of the booth (side draft) or in the base of the booth (down draft). The powder-laden air flow enters the collector. The air passes through the cartridge filter and the powder is deposited on the filter surface. Periodically, cartridges are back-pulsed with compressed air to shock the powder from their surface and deposit it in the collector base. Powder in the base is pumped to a reclaim stand for reuse or to a container for disposal.

The cartridge filter pack can be removed from the blower pack for color change. A separate cartridge pack is required for each recoverable color. Cartridges are made of a paper filter media. The blower pack houses the blower fan and filter assembly. The blower is on the clean-air side of the cartridges. Air from this powder booth system is returned to the plant.

The booth may have touch-up openings and/or gun slots depending upon the application for which it is used. The booth is typically of metal construction, though some manufacturers prefer plastic. This type of powder booth system is known for its compactness. Safety is another important benefit to this design. Since there are no "enclosed" devices the need for explosion venting is eliminated.