1. Introduction

The process of finishing metal surfaces with dry powder coatings is not new. It has been used since the mid 1950's. It began with the coating of pipe, for corrosion protection, and electric motors, for insulation. With the growing need to reduce air pollution, including that associated with thin film liquid coatings, powder coating developed further. Meanwhile powder coating is making a major impact in the finishing industry. By utilizing the natural principle of opposites attract, this finishing technology offers manufacturers increased economic benefits and superior quality. From equipment to surface area covered per dollar of material applied, the costs of powder coating are comparable to those of liquid coating. Powder coating has been referred to as a "dry painting process". That's because powder coating is a modern technology. For the first time, end-use manufacturers are able to engineer their finishing operations to a degree only dreamed of heretofore, while eliminating many of the problems that have been traditional in the finishing operation. There are distinct advantages to powder coating when compared to solvent based liquid coating:

Powder coating material is received by the applicator in ready-to-use state, thus eliminating any variable in mixing.

Spray booths can be cleaned with a simple air jet as opposed to harmful solvents.

Absolutely no solvents are used, eliminating the need for expensive air pollution control equipment. The absence of solvents virtually eliminates the fire hazard associated with liquid paint shops.

With the use of a powder recovery system, overspray can be collected for reuse. Liquid paints cannot be reclaimed.

A 1 to 3 mil. film thickness will be obtained in one powder application. Wet spray may require 2-3 coats to attain this thickness, greatly increasing the processing time and expense when a higher film thickness is needed.

Powder coatings are cured at elevated temperatures (300 F to 425 F) as compared to wet coatings. This generally results in a tougher, more chip resistant coating. The high temperature, and greater film thickness allow powder coatings to achieve adequate bonding and coverage over less than ideal materials, resulting in less stringent precleaning and metal preparation requirements.

A full palette of colors is available to serve any market. An almost infinite range of properties can be chosen from, including resistance to ultra-violet rays, greater durability, better corrosion resistance plus any of a dozen other properties, depending on the particular needs of the user. Each can be accomplished either by control of the powder formation or special measures during the finishing process. Since the powder coating environment is much safer due to the elimination of solvents from the process, the employee and environmental safety is increased and insurance and permit costs compared to those of the wet spray industry are reduced.

Because powder coated parts are fully cured when they leave the oven, unlike many wet coatings which have post cure aging requirements, the total processing time is shorter with powder coating. This results in shorter turnaround time. The process is simple in concept and operation. Dry powder is pneumatically fed from a supply reservoir (generally called: hopper)to a spraygun where a low amperage(about 160 mA), high voltage (about 100KV) charge is imparted to the powder particles.

The powder used in the powder coating process is comprised of resins and pigments and in its dry, formulated state is then sprayed onto a part to be coated. Parts are generally presented to the coating operation while they are at ambient temperature, the charged particles will be attracted to and accumulate on the grounded article surface.

The powder particles approach the surface being attracted to the grounded part because of their electrical charge. The parts to be coated have to be electrically grounded so that the charged particles projected at them are firmly attracted to the part's surfaces and held there until melted and fused into a smooth coating in the baking ovens. This is possible, because upon contacting the surface that portion of the charge in contact with the surface leaks off to ground through the article and its support.

Since the powder particles, generally speaking, are plastic and are poor electrical conductors, they will retain a portion of their charge and thus will continue to be attracted to the surface. The particles will be held in place even over extended periods of time. The coating process can be done manually or it can be a highly sophisticated automatic operation, where computer programmed robots can perform the spraying in booths up to and over a hundred feet long.

The wide variety of equipment available makes powder coating feasible for the small end-use manufacturer, as well as for the very large user who may require an extensive finishing operation for multiple products. In recent times even the car manufacturing companies in part switch from liquid to powder coating. The charged powder particles will be attracted to the surface of the part whether the part is cold or heated.

If the temperature of the part during the coating process is above the melting point of the powder, that material attracted to the surface will melt and adhere immediately and loose most of the electrical charge to ground. The molten material already on the surface will then attract additional powder particles equally as well as the bare metal, so material will continue to accumulate on the part surface-so long as there is sufficient heat at the part surface to melt the newly arriving particles. By means of this hot coating method very thick film thicknesses can be produced. The material selected is important in this application. The powder selected must allow the high film thickness to polymerize and cure without sagging or gassing. The powder and process technique must remain constant in order to maintain a given thickness.

Proper attention to preheat and post heat dwell times are a must. Recovery of oversprayed powder is difficult if not impossible with this technique.. For parts to be coated at normal ambient temperatures and because the powder is dry when sprayed, any overspray can be readily retrieved and recycled regardless of whether the finishing system is manual or highly automated. Several methods are available depending on the application equipment in use and the size of the finishing operation. All however operate on the same principle: the unused (oversprayed) powder is removed from the spraybooth by a ventilating air stream and then separated from the air stream by various vacuum and filtering methods and returned to a feed hopper for reuse enabling efficiency-use rates to approach almost 100 percent.

Besides lower material and equipment cost in comparison to liquid finishing systems, additional savings can be achieved in energy, labor, production, waste disposal, and meeting environment protection standards, making the real, bottom line costs of powder coating systems less than liquid finishing systems.

Energy - Because venting of fumes from wet spray paint solvent systems is not necessary, the need for air makeup - and the high costs for heating the air in colder climates is lessened, resulting in considerable energy savings.

Labor Costs - Labor costs are often substantially lower in plants using powder coating because automatic systems require less manpower and worker environment is more favorable, plus faster clean-up time and fewer clothing problems.

Efficiency - Because no drying or flash off time is required and the powder coating application process permits parts to be racked closer together on a conveyor, more parts can speed through the production line resulting in greater operating efficiency and lower unit costs. Despite the increase line speed, the reject rate is normally significantly lower when using a powder coating system than when a wet solvent system is utilized.

Waste Disposal - With a dry powder coating system, there is no liquid paint sludge to haul away to a burial site. That means more dollar savings and a major reduction of an increasingly difficult disposal problem.

Pollution - Air and water pollution problems are virtually eliminated with a powder coating system, which in turn, reduces the high costs of anti-pollution equipment and the time and money spent in dealing with federal and state regulatory agencies.

Today any quality powder coating plant is geared up to finish the widest variety of part sizes and configurations. To be successful the application specialists of WAGNER know every aspect of how to apply a quality finish in the most cost effective manner. Utilizing our knowledge of powder application processes and procedures enables maintaining the highest level of service.

However, it is essential that especially the job shop finisher know all the possible variables that could cause problems before they occur (both long and short term problems). There is a line between what can and what cannot be accomplished with powder. In most cases, a job shop is contacted when a new requirement is called for. For that reason, it is essential that the job shop finisher keep up-to date on the latest developments and changes within this rapidly growing industry.

This Powder Coating Guide is intended to provide the necessary background information for selecting the optimum technology for a wide range of standard powder coating requirements.

Powder coatings are used on an increasing variety of products and components. Industries with multiple applications include appliance, automotive, electrical, medical and office furniture, building and architectural, farm, garden and industrial machinery, fabricated products and miscellaneous products.

Besides the choice of the appropriate powder to be used, choosing the method of application is critical to achieve optimum coatings. In general the powder supplied from the manufacturer is placed in a powder feed system which enables it to be delivered, mixed with air (this mixture is called: fluidized powder), to an application device.

The spraygun or application device has the ability, by various methods, to apply an electrical charge to the powder particles. The application device usually is an electrostatic manual or automatic spraygun. It requires uniform controlled powder feed from some type of hopper incorporating a fluidized bed or a special means for fluidizing the powder in front of the suction unit.

The powder booth where the powder is sprayed in has controlled air extraction to prevent powder spillage into the surrounding area and to suck the overspray-powder into a cyclone or filter system, for recovery.

The oven may be gas or electrically heated and may be a recirculating air or radiant type depending on the component to be coated and the coating used.

When running a powder plant some of the most important aspects be observed are color or material changes and the effects of contamination. This is, because the greater the number of colors or types of powder which are to be applied, the more often changes are likely to be made. This will establish the fact that contamination is the most significant threat to quality.

Powder delivery and recovery systems which provide fast changes will have to be considered and these will be a must, for example, in contract coating operations. However, successful powder coating always requires good operator training and disciplined housekeeping for maximum benefit to be achieved.

If large volumes of components need to be coated, automation is necessary. Small quantities of components of varying size and shape will mean that manual application is more likely to be used. This means that for instance the "white goods" manufacturer is the typical user of automated systems, whereas most contract coating operations will use a manual approach, or at least an automatic installation with a provision for extensive manual touch-up.

So, for example a sheet metal fabrication where all parts are coated with the same color the decision is very easy for automation. However, manual systems are needed for after coating of "difficult corners". Likewise, the contract coating scenario of not knowing, from one day to the next, what components and colors will be required is a typical case where flexible manual (touch-up) coating systems are required.

Another difficulty arises when similar components are to be coated in various colors, often to tight customer delivery needs, for example, in the architectural aluminum market. In these cases special fully automated systems with special means for an extremely fast color change are required. If the unit is to be used for multi-shift work, careful consideration will have to be given to the type of powder feed mechanism which will be best used to handle major amounts of powder. Given the need to avoid contamination, the dimensions of the powder feed system to be used (especially the hoppers or containers) should be sized for the length of run of the particular color or type of powder. Component handling will have a considerable bearing on the type of booth which should be chosen. Too often the jigging and handling is not considered in detail so that problems often arise after installation. Sometimes even a perfectly designed plant concerning the application is under utilized due to handling problems. If for example two sides need to be coated, the booth will have to have coating openings on both sides, unless the components are being rotated. This implies careful consideration of the required extraction rates and the related energy costs. And also special attention will have to be given to the application system. A need for heavy coatings may suggest certain application systems and might even mean a preheat stage. Similarly, thin film coatings are very depending on the powder which is applied as well as the use of high efficiency application systems. Special attention has also to be given to film thickness uniformity. Coverage into enclosed or recessed areas and manual touch-up often leads to a greater variance in film thickness.

2. Powder Container

This unit contains the powder which is vibrated and mixed with air in order to fluidize it. This is done by means of a suitable shaker motor and by sparkling compressed air through the powder. The powder container must be of an economical size to suit the application for which it is intended. Sizes can vary from 100 g in the laboratory, to tons in large volume automatic plants. Together with box feed systems, fluidized beds provide the usual method for handling powder. They are ideal for bulk users of powder, both on manual and automatic systems. Fluidized bed handling systems work by fluidizing the powder from the bottom of the container by blowing compressed air through a porous tile. When the system requires cleaning, remaining powder must be removed from the container and the unit thoroughly cleaned. The cleaning procedure must be made for every powder or color change and can take considerable time. Normally, 5 - 10 minutes are required just for cleaning the container or hopper system as it must be thoroughly performed to prevent contamination.

A drawback with powder coating used to be the time required to change colors, and the sheer difficulty of this. Direct or "powder from the box" systems such as the WAGNER Airfluid System have radically changed this. Color changes are very fast and almost as easy as wet paint changes, so far as powder feed systems are concerned. The WAGNER Airfluid powder delivery systems use powder straight from the powder manufacturer's own containers. This is a particular benefit for companies which apply a number of different colors during the course of each day. Powder changes with these direct feed systems are fast and the color changes are made in minutes. In addition, because powder does not have to be emptied from the hopper or the container these systems are generally very clean to use.

The WAGNER Airfluid systems work by lowering a "shoe" with a system of perforated air hoses into the powder which is supplied with compressed air and a suction system connected to a powder injector (venturi). The powder is fluidized only in the immediate vicinity of the fluidizing shoe. A rugged shaker motor helps to fluidize the powder by vibrating the system horizontally. These units are particularly suited for powders that are difficult to fluidize or tend to separate because of a wide range of particle weights and a broad particle spectrum. They are very fast to color change and can operate even with only a few kilos of powder.

3. Injector (venturi)

The delivery of powder to the gun is critical. It is important to understand how powder injectors (powder pumps) work and to appreciate their importance in the success of the powder coating process. The injector (or venturi) is operated by means of compressed air. Its purpose is to draw powder from the container in order to supply a powder and air mixture to the spray system (gun). Clean, dry air is essential for optimum operation of the powder feed injector. For effective powder application, powder must be supplied to the spraygun continuously in a delivery range of 40 - 500 g per gun per minute. Control is important, anything more than the amount that is strictly required will be waste powder. Anything less than the amount required may produce too thin a film. This will slow down the application. A good help for controlling the powder film thickness is the WAGNER LASER THERMOSCOPE.

The powder to air ratio must be adjustable; for this reason the WAGNER venturis have an additional air supply in the working part of the injector system. This is commonly called dosage air, which helps to provide an even distribution of powder inside the delivery hose and to avoid blocking. WAGNER powder injectors guarantees a smooth powder supply even if the system is started and stopped frequently. The amount of feed- and dosage air can be precisely controlled by the patented WAGNER AFC technology (air flow control).

The now available WAGNER powder metering device (PMD) allows for the direct measurement of the delivered powder in g/min. As powders are generally far more abrasive than is often thought, the powder guiding parts of the injector assembly are designed to wear evenly and made from a wear resistant, low friction material such as PTFE.

4. The Powder Guns

In general, the key to successful, cost effective powder coating is strongly related to the performance of the powder applicator, the electrostatic powder spraygun. Performance is directly depending on the method and effectiveness of the electrostatic charging method used for a particular type of gun. Powder application differs from wet spraying in one essential way. Wet paint finishing only uses electrostatic application to improve efficiency. Normally liquid paint adheres to any surface automatically even without any additional electrostatic charging.

Powder coating, however, could not be accomplished without the electrostatic charge which is given to the powder particles. This is the only way to make powder particles stick to cold components which are to be coated. Moreover, components must be electrically grounded for this to happen. The powder is given an electrostatic charge to make it adhere to an item long enough for it to be stoved. This is achieved by ensuring that the component to be finished is hooked onto a grounded point (hanger or hook) when the powder is applied.

4.1 Corona Guns

There are two different types of electrostatic charging, and one of them is Corona charging. Corona charging works through the application of a high static electrical charge to a corona charging electrode and powder is charged when passing through the area close to the electrode by picking up free electrodes from the electrostatic field. The charge is generated by a cascade built into the gun itself. Corona guns normally charge negatively. The high voltage discharged from the corona electrode sets up electrostatic field-lines to the nearest ground. Electrons, generated by the charging electrode, attach themselves to a number of powder particles in the powder cloud . The composition of any powder is important. Too many small particles will lead to overcharging and a build up of powder on leading edges of the component which is being coated. Too many large particles will attract a disproportionate amount of charge. This will cause undercharging and consequently poor coating thickness. Powders should, therefore, be well dispersed with optimum particle sizes, designed to maximize the charging characteristics.

Electrons which have not attached themselves to powder particles also travel in the air stream and along the electrostatic field lines to the item being coated. This is because it is grounded. The unattached electrons are attracted to the component together with the powder particles where they build up because of the isolating layer of the already deposited powder particles. If too many charges with the same polarity are deposited on the workpiece, the electrostatic force between the individual particles becomes so strong, that they repell each other and get pushed away from the surface. This is called back ionisation. Back ionisation causes discharges within the powder coat itself and also makes it difficult to coat complex shapes. Additionally, back ionisation causes the powder coat to be uneven and when stoved, the finished surface looks like orange peel.

The Faraday effect which prevents charged particles from going into deep recesses and corners can be overcome partially by increasing the velocity of the powder cloud for example by selecting a flat spray nozzle. If however, the speed of the powder cloud is too fast, it can blow powder off as fast as it is applied. By means of the WAGNER "Corona Star" add-on the free ions and electrons can be removed from the powder cloud to a large extend and therefore penetration is improved and "back ionisation" reduced by stripping off the ions through the grounded electrode placed adjacent to the spray nozzle. The Corona Star add-on kits can also be used to retro-fit existing WAGNER Corona guns.

In all WAGNER Corona spraygun systems a low dc voltage is supplied from the control box to the gun. This source of energy is then "multiplied" in the barrel of the gun through a cascade device. This unit is easily to replace if damaged, particularly since all WAGNER guns are of modular construction. The generation of the high voltage directly in the gun body avoids the necessity of heavy high voltage cables to be routed from the controllers to the guns.

Another helpful feature of all WAGNER Corona guns is that they are all equipped with a special electronic circuit to produce a stabilized or constant discharge current. Since the discharge current is stabilized, the voltage will automatically reduce as the gun is brought closer to the product (or ground). In this way the discharge energy when the gun is close to the product is very much lower. This will not only minimize the effects of back ionisation and orange peel, but the lower voltage levels will also reduce some of the effects of the Faraday Cage.

4.2 Tribo Guns

The second type of charging is through the Tribo charge gun which produces its electrostatic effect by passing powder through the gun. This has a "friction body" with a complex pattern of turbulators through which the powder passes. All powder guiding parts are lined with insulting materials such as PTFE. To ensure that maximum contact and mixing takes place, to expose the powder to friction, it must rub extensively against the insulating PTFE surfaces. This gives the best charge.

Tribo guns charge positively and this implies that the powders have to be specifically formulated for Tribo charging. Since there is no charging electrode there is also a very much reduced Farady cage formation making Tribo coating the optimum choice for recessed areas and undercuts for example when painting radiators.

5. Application and equipment selection hints

5.1 Transfer efficiency

An amount of powder can be weighed into a hopper and a number of weighed components including the hooks can be sprayed. After spraying, the component and hook, are re-weighed before curing. The results are noted.

After the test, the powder remaining in the hopper is weighed and recorded. A comparison is then made between the weight of the powder on the components and the weight of powder sprayed.

A percentage transfer efficiency can be calculated. Results can vary dramatically with different types of equipment and powder. Other variables are component profile, humidity, booth air velocity, spraygun settings (voltage, airs, powder output) and operator technique. During all tests it is advisable to note the operating conditions, particularly to ensure that the speed of application is the same for all tests.

Trial and adjustment can pay for themselves by minimizing the amount of powder lost into the booth and recovery units. Wrap around is NOT the definitive test for electrostatic performance. However, the most major parameter for a powder gun is that of transfer efficiency.

Recovering powder is costly and in a case where powder is sprayed to waste then the efficiency at which it is applied is even more important. Users should always satisfy themselves that an equipment optimization is made on the basis of powder actually applied to the component. A simple test of weight sprayed compared with weight on the component or recovered, reveals many interesting optimization possibilities.

5.2 How to choose the right manual gun

If you are thinking about manual gun powder application, the key to coating success is the selection of the gun itself. Efficient, user friendly (weight!), field serviceable with a complete range of accessories. These are the desirable features to look for when choosing the equipment for your operation.

There is, of course, the choice between Corona and Tribo systems. Depending on the components, simple or complex shapes, the optimum charging method should be selected. It is important to know that some powders are preferably charged positively (=Tribo) and some negatively (=Corona). Epoxies and polyesters are naturally negative whilst the nylons are naturally positive. Often powders are modified especially for Tribo charging techniques and the powder manufacturer will need to know which gun you use to provide you with the correct powder.

For work requiring the coverage of large areas and complex shapes the weight of the gun is an important criterion. The lighter the gun, the easier it will be to use for long periods and the better the coating quality on complex shapes because the guns can easily be positioned in an optimum way. The WAGNER manual sprayguns (PEA-C2 and PEA-T1)are the lightest high power guns on the market.

Accessories include nozzles of differing configurations and special fitments to provide a sampling system for testing. Transfer efficiency is often a function of the nozzle being used to spray a particular component. The WAGNER spray nozzle system provides for optimum coverage of all application needs.

A high voltage test meter like the WAGNER HV 200 is often useful to check if the equipment is performing correctly and in accordance with parameters being displayed at the control panel. The wider the range of useful accessories, the more flexible will be the range of work that can be undertaken. A wide range of accessories is available for WAGNER sprayguns to improve deposition and coverage. These help to ensure that the initial investment has the widest possible application capability.

Where cost is important and provided that the line speed is less than 1 m per minute, the cost efficiency of a pure manual system should be closely considered. Also in situations where a great number of colors are to be applied, manual guns offer optimum flexibility. The WAGNER manual guns provide simple, fast and accurate set-up procedures and can be altered easily (nozzles) to meet changing application conditions.

Manual guns provide substantial flexibility and with the WAGNER specific broad choice of deflectors or nozzles, manual guns can be used to coat a wide range of components irrespective of size and shape.

Consideration, however, must be given to the speed of the conveyor system. Manual guns can be used to coat small to medium work loads, on both batch and conveyorized systems. Transfer efficiency, speed, user friendliness and weight are the key points of all WAGNER manual sprayguns. For product comparison you should consider:

- weight with hoses and cables connected, weighed at arm height
- transfer efficiency with a particular nozzle

- speed with the same nozzle
- instrumentation and indications at controller
- feel - is the gun comfortable to use?

5.3 How to choose the right automatic gun

First of all there is (as with the manual guns) the choice of Corona or Tribo. Depending on the components, simple or complex shapes, the optimum method should be selected. The best possible scenario in an automated situation is to have a system that does require only minimum manual touch-up. Simple shapes, flat panels or tubes will be effectively coated with corona charging guns. For coating of complex shapes that include areas where some penetration is required, then Tribo guns will be advantageous.

The WAGNER Corona Star ion stripping technique together with the use of corona guns helps to overcome the problem of orange peel effects. Alternatively, multiple Tribo gun set-ups will give good penetration with reduced "back ionisation" problems. In case of coating inside a plastic booth even a combination of Tribo guns together with the Corona Star add-on can be the best solution.

In all cases an optimum decision for a special coating task can only be made after testing of the equipment for the specific part in the WAGNER test lab. As an additional result of these tests the factor of conveyor speed can be considered or related to the type and number of guns that will be required to meet the specific production requirements. However, at the point of decision about the most suitable equipment to buy following the results from the testlab, it is important to note the type of powder used for testing, since powder properties may change dramatically in actual production.

More than ever, automatic spraying systems which of course, involve the use of high quantities of powder, must be controlled intelligently to ensure efficiency of its use. Therefore instrumentation is important. In producing consistent quality, it is important to be able to return to the same set-up parameters after each clean down and shut down.

The WAGNER EPG Digiflow controller as part of the modular WAGNER EcoTech system provides for the possibility to store all relevant coating parameters in a built-in memory bank making the return to any previously optimized situation as easy as pushing a button. For rather complex powder coating systems as for example in the coating lines of the SMART city car (Mercedes-Benz / Swatch) WAGNER implements PLC control with touch screen or dockable Laptop process visualization.

Automatic guns may be fixed, reciprocating or attached to robots. Weight will be important if complex movement is required. Weight is calculated as the weight of the gun itself and the force necessary to move all the hoses and cables attached to it. Reciprocators or robot "wrists" can be severely stressed by complex movement and/or required force.

In choosing the correct nozzles, speed, transfer efficiency and cleaning will be important. Wear is also a factor that should be considered as large quantities of powder will stress the powder guiding parts accordingly. Color change necessitates different hoses, nozzles and set-ups if they are to be fast, effective and without the problems of contamination. The wider the range of useful accessories, the more flexible will be the range of work that can be undertaken. A wide range of accessories are available from WAGNER to improve deposition and coverage. These help to ensure that the initial investment has the widest possible application capability.

In relation to the total cost of an installation with a possible reduction in labour and increased productivity, the purchasing decision should be made on performance and NOT price as is so often the case. The gun itself is the center of the installation and should be reviewed as such. It should be remembered as being often the major component in establishing the success of the plant.

WAGNER automatic guns are easy to set-up, monitor and control. They provide simple, fast and accurate set-up procedures and can be easily altered to meet changing application conditions. They are easy to clean since they are especially designed to be used on coating lines that require frequent color changes. A special protection cover is available converting the gun together with the connectors for powder hose, electrical supplies and air hoses into a streamlined shape which can easily be cleaned-up by an external compressed air nozzle system. These automatic gun cleaning nozzle systems are standard features of the WAGNER ABC and FBC plastic spray booth systems.

WAGNER automatic guns provide substantial flexibility and with the wide choice of deflectors and nozzles, they can be used to coat a wide range of components irrespective of size and shape. Consideration must, however, be given to the speed of the conveyor system. Several guns usually are required simultaneously to meet production requirements. Present and possible future needs determine what possible accessories may be required but in the first instance these can only be established by tests in the WAGNER test lab together with the applications specialists in an in-depth evaluation of your special needs.

5.4 How to choose the right gun controller

The performance of the spraygun, automatic or manual, is only as good as the control system that is provided for it. All WAGNER control units allow fast and accurate adjustment, and clearly indicate settings and conditions for the guns. The control unit demonstrates all aspects of powder delivery from the gun. Meaningful calibration of the instrumentation is important. It is necessary to be able to return to the exact setting time and time again without creep or deviation. The WAGNER control units ensure that the powder / air mixture and the output of powder will provide the optimum coating efficiency and reproducibility. The flow of powder to the gun is depending, for example, on:

- The amount of feed air.
- The type of powder and dosage air.
- The length and diameter of the powder hose.
- The charge given to the powder.

The essential is to be able to set the gun to spray as required and to have repeatability. The conveying (or feed-) air adjusts the powder output from the injector, enabling the correct amount of powder to be applied by the gun.

The correct setting ensures that the minimum amount of powder applied is consistent with maximizing powder deposition. This air normally "powers" the venturi that sucks powder from the container or hopper. More feed air - more powder.

The dosage air stabilizes the powder output and determines the powder/air ratio together with the flow speed in the powder hose. More dosage air - less powder.

The combined total of the dosage and feed air should be in the region of 5 to 7 m3 per hour. This ensures that the powder flow is well defined and the spray cloud accurately directed to enhance deposition.

The additional Tribo air provides the necessary swirl movement and volume in Tribo (friction) charged guns.

The spiral flow (of air and powder) imparts a friction charge to the powder as it passes through the special barrel in the gun. The greater the amount of Tribo air, the higher will be the charge imparted to the powder.

However, Tribo powders are prone to variations in their charging characteristics due to shifts in the particle size distribution for recovered powder. Up to a powder specific limit it is possible to compensate for the reduced friction charging capabilities of the in general smaller sized recycled powder particles by increasing the Tribo air flow.

However, increased air flow means always also increased wear implying a maximum tolerable amount of Tribo air.

Each individual gun must be separately controlled to optimize powder deposition. In most instances, and especially in automatic powder coating facilities, the fine tuning that control units provide means that accurate commissioning is required and individual gun settings should be recorded once satisfactory results have been obtained.

For manual coating operations, settings can be noted so that settings can be repeated. As already stated, WAGNER offers for automatic coating plants computerized control-systems that will repeat the settings for each type of component mix.

5.5 How to choose the right nozzle system

There are mechanical deflectors and adjustable nozzle systems with a number of different powder cloud shapes that can be produced by each type. The purpose of the powder deflector is to produce a defined and efficient cloud of powder particles.

WAGNER deflector cones (or round spray nozzles) produce a slow moving powder cloud without causing the powder to lose too much forward momentum. Obviously if the speed of the powder is too low, the powder cloud will not reach the component being coated and will fall short, and be lost to waste in the recovery unit.

The WAGNER deflectors produce a cloud which is uniform in density and constant in shape so that coverage can be maximized and the settings reproduced easily. The advantages of the WAGNER deflector nozzle systems are that for a comparatively low expenditure, almost any round shaped powder cloud be obtained. Generally this is accomplished by putting a deflector with a special shape in the path of the powder jet and a wide range of these is available from WAGNER in different diameters.

For all standard nozzle systems adjustment of the powder cloud is possible by adjusting the amount of feed- and dosage air or by changing the deflector. A special atomizing air helps to avoid powder depositions on deflectors and also ventilates the deflector as well as forming a coherent powder cloud without the use of mechanical means.

A round spray nozzle (or deflector cone) produces a slow moving powder cloud but gives good wrap around on tubular components and good even coats on large flat parts. This nozzle system is excellent for applications which have to coat a wide range of different parts in mixed batches.

A flat spray nozzle produces a directional spray pattern that is quite fast moving. This assists in the penetration of awkward and recessed areas. However, the additional speed of the powder can cause previously deposited powder to be dislodged, if the guns are allowed too close to the component. The flat spray is ideal for large flat areas as long as the distance between the gun and the workpiece is not too short. Flat spray is not recommended for wire goods as the increased powder particle speed reduces wrap around and therefore increases overspray and waste.

6. The Powder Booth

Generally the purpose of a powder booth is to ensure that powder sprayed from the electrostatic guns stays within its confines. Then overspray can be transferred to a powder recovery system. For a manual booth the construction is box shaped, with an aperture through which operators can spray manually. In the WAGNER ID-booth system, the same booth type can also accommodate automatic sprayguns. Where this happens there is an aperture on either side. Components are either manually loaded into the booth or conveyed through the sides.

Materials of construction of the WAGNER spray booths vary from stainless steel to patented sandwich plastic materials used to improve transfer efficiency and cleaning down. Different powder recovery systems take oversprayed powder away and provide special systems for recycling it. The plastic powder spray booth plays a valuable part in maximizing transfer efficiency by not attracting charged powder or even by repelling powder. Added to this is the fact that less powder on the booth wall is much easier to clean off. This is provided that the correct cleaning techniques are used, i.e. air guns for the first step and mops for the fine cleaning. It is particularly important in the case of manual booths to safeguard the health and safety of the operator by making sure that air passes from the operator into the booth, diverting powder away from the spraying area. On all booths, manual or automatic, air velocities should be sufficient to prevent powder escaping and causing contamination of the work area. As a thumbrule the velocity of the air streaming into the booth should be 0.5 m/sec or higher at every opening of the booth. The conveyor and other auxiliary equipment should also be kept free of powder.

The booth and extraction equipment must be designed to keep powder from building-up too high concentrations. At high concentrations this could result in an explosion if the powder to air concentration is incorrect and a source of ignition added. The WAGNER spray booths together with WAGNER extraction systems guarantee that powder concentrations are kept in a safe range.

In addition, the powder / air mixture velocity in ductwork should be sufficient to ensure the ductwork is self cleaning. For every new installation exact calculations of WAGNER engineers guarantee that the powder / air mixture in any part of the booth and recovery units does not exceed 50% of the specified lower explosion limit. In case the lower explosion limit is not specified by the powder manufacturer the concentration is kept below 10g/m3.

WAGNER offers a variety of types of powder booths. Nonetheless, deciding factors affecting the suitability of a booth for particular types of powder coating work are simple: Stainless steel booths are best suited to the application of single, or at most, a few colors only. Plastic booths are ideal for companies using a wide color range. Clean down and change criteria are major factors in deciding for choosing a plastic booth with an automatic cleaning system.

The sizes of WAGNER spray booths vary from big enough to powder coat a car body, to small systems for coating for example toy car bodies. In all cases the same general principles apply. The booth must be large enough to accommodate the component and the sprayguns required to coat the work. Efficient transport of oversprayed powder into the recovery unit is essential, without incurring high velocities of air within the actual spraying area. The question of the fastest possible method for color changes is according to the specific situation either answered with multiple booths that can be used and then moved off-line for cleaning, or as in the advanced WAGNER plastic booth designs, the user is enabled to clean down automatically and change within a few minutes.

7. The Powder Recovery System

It is well recognized that one of the major advantages of powder is that it can be recovered after spraying and re-used. Certainly, from an economy point of view, one of the major concerns for a powder coater is to obtain maximum transfer efficiency and have to recover as little as possible. However, recovery is a must and very detailed consideration must be given to this subject. The WAGNER recovery systems divide into two major areas. The first of these relates to filters. The second to cyclones.

7.1 Filter Systems

These are ideal for manual booths and automatic booths which are generally dedicated to one color, or at most one or two changes of color per day, which can be cleaned down easily and with color change achieved simply by changing cartridges compartments. For automatic systems from WAGNER (ICF systems) the cartridge recovery unit is incorporated in the spray booth and takes very little space. Multiple cartridges, however, are required if a range of colors is to be used.

7.2 Cyclone Systems

The use of a single cyclone which is connected to the spray booth for powder recovery, has been one of the most widely used principles over the years. The extract air is passed through an after (cartridge) filter and then returned to the factory. The monocyclone unit recovers powder by centrifuging it from the air stream and depositing it in a container fixed at the bottom of the cyclone. If air velocities are correct in the ductwork, the system, apart from the container, is considered to be self cleaning. This obviously is more than useful when color change time is considered.

7.3 After Filter Systems

These units are placed after cyclone systems specifically to extract powder which the cyclone has been unable to capture. The unit is not cleaned after any color change and powder recovered in it is waste (fines). WAGNER after filter cartridge units are programmed so that they clean themselves at regular intervals, either by rotating cleaning devices or short sharp reverse compressed air pulses. The standard air capacities are 12000, 16000 and 24000 m3/h.

8. The Color Cycle

The color cycle has three major parts:

- The feeding of powder from hopper to gun
- The transfer of oversprayed powder to the recovery unit
- The return of oversprayed powder to the hopper for re-use.

Simply speaking this means that oversprayed powder is recovered through a cyclone or filter system, then dropped or sucked into an air stream to be transported, sieved and remixed with virgin powder. Finally the mixture is returned to the hopper for transportation to the guns for spraying. The cycle begins again.

Few controls are needed other than level sensors and the means to add virgin powder without risk of contamination. One important consideration has to be the selective recovery of powder particles with different sizes and their ability to be re-cycled. Fines may be lost in cyclone systems as they are carried into after filters. Heavier particles may be recirculated constantly. This means that there will be a point at which recovered powder is unusable due to the particle size distribution becoming unbalanced.

Process control becomes an important criterion in maintaining powder balance. It should, though, be borne in mind that generalizations about the operation of systems is difficult and misleading. Recycling systems are invariably tailor made for particular applications.

Nonetheless, principles are important, and seeing and understanding in the WAGNER test lab what can be done is a standard service for our customers. It can give a deeper understanding of powder coating and the adoption of good operating practice.

9. Process Automation

Totally integrated systems for powder coating are all more simple with powder than with liquid paints. Building a successful system can be very rewarding in terms of productivity and cost control. Profitability can increase significantly. The final step in powder coating is therefore, full automation.

The ability to apply powder more evenly than wet paint and without runs and sags is a great advantage. The absence of waste resulting from overspray is also a great benefit and therefore altogether powder coating creates a possibility to automate coating operations effectively.

The most important factor in effective powder coating automation is the control of the process. The powder coating must be applied evenly and to the specified thickness in the areas that are required to be coated, but it may be that less important areas need only be "dusted". A build-up of powder on horizontal surfaces is a common occurrence in poorly controlled installations. Excessive coating on non-critical areas is also a waste of powder.

Spraying into the area between components or into space within a component (for example frames or wire-goods) must be avoided to reduce the amount of powder that needs to be recovered and re-cycled. Spraying for maximum transfer efficiency must be the preferred method.

Powder recovery is necessary but the cost depends very much on the amount of powder to be processed. Therefore controls to prevent spraying excessive amounts of powder are highly desirable, hence, programmable controllers that will switch powder on and off and move reciprocators to enable work to be sprayed in the most transfer efficient way. All this can be achieved by the innovative computerized WAGNER gun movement and spraygun control system.

In addition a wide range of gun movers (-reciprocators) and programmable controls are available, or can be designed for specific applications.

Contamination is a serious risk to quality in powder coating. Since all standard hoppers operate with the aid of a fluidizing process and are exhausted to the factory environment. Therefore WAGNER offers a movable powder handling center ("powder kitchen") with a built-in extraction system to eliminate all unwanted emissions of powder.

10. Safety and general construction hints

10.1 Comparison with solvent based systems

Unlike conventional paints, powder coatings contain no solvents and are based only on an extruded mixture of pigments, extenders, reactive polymers, hardening agents and additives. Compared with conventional wet paints there is therefore a lower level of hazard when the powder coating technique is used. Dust clouds in air require 50-100 times the energy necessary to ignite a solvent vapour/air mixture, and are therefore basically much more difficult to ignite. Powder mixtures in air need to reach a certain concentration, known as "the lower explosion limit" before ignition or explosion can occur at all. Increasing use is being made of powders to give thinner films, which generally necessitates powders of lower particle sizes. Although this may not affect the conditions for an explosion, an explosion if it occurs may be more violent. Care must be given to maintain the concentration of powder below the lower explosion limit. However, certain hazards exist in using powders depending upon the conditions. Precautions must be taken to avoid them and such precautions are specially referred to here as safe working procedures. If these are well observed, they should minimize the risk.

10.2 Principle

The powder particles, fluidized with air, are pneumatically transported to the gun where they acquire an electrostatic charge from a Corona discharge electrode operating at typically 10 - 100 kV, or simply by friction along a suitable polymeric material (Tribo). The charged particles adhere to the substrate which must be properly grounded. The oversprayed powder is removed by an exhaust air ventilation system. The air is subsequently filtered and the recovered powder is re-cycled after mixing with fresh powder. The particles adhere to the substrate by electrostatic forces, until the items enter the oven where the powder melts and subsequently cures.

10.3 Explosion Hazards

In general terms the powder is combustible and within certain defined limits of powder-air concentration will form a potentially explosive mixture. The lower explosion limit of most commercially available powder coatings has been determined to be in the region of 35 - 90 g/m3 (DIN 55990 - 6 or ISO 8130-4). Providing the concentration of powder in air is maintained below this value, there is no risk of explosion. Equipment should be designed such that, in operation, half this concentration is not exceeded. In the absence of specified values, a figure of 10 g/m3 is taken. In order to prevent any risk of powder ignition in the vicinity of the guns, there is the thumbrule to install a maximum of one gun per cubic metre of booth volume. Spray booths designed and operated according to the technical specification

CENELEC SC Q31/8, will not cause any explosive hazard. All WAGNER spray booths are designed to meet all relevant safety requirements.

10.4 Health Hazards

Following the decision of the European Committee on Powder Coatings of CEPE, Brussels, the French "Institut National de Recherche et de Sécurité" (I.N.R.S.) has carried out toxicological investigations on different powder coatings. Results of this study are published in a brochure edited by the CEPE, "Results of the experimental toxicological studies on thermosetting powders", and the conclusion, as well as the advice for hazard prevention are given hereafter.

On the basis of this toxicological study, "it has not been possible to find any sign of local or systemic toxicity which can be attributed to the different samples". However, the inhalation of powders, even inert ones, should be avoided and it is recommended to maintain in the atmosphere of workshops as low a concentration of powder in air as possible, especially in the immediate vicinity of the workers, by means of efficient ventilation. According to published information, the respirable dust concentration in the breathing zone should not exceed 5 mg/m3 (O.E.L. - Occupational Exposure Limits for respirable dust). Allergic persons and workers with difficulty in breathing should not be employed in powder application. When the concentration of powder in air is higher than 10 mg/m3, it is recommended to supply personnel working there with efficient dust masks in conformity with local regulations.

The above mentioned tests have only been carried out on powders not containing any products classified as dangerous or poisonous (such as TGIC). In such cases where such products may be present, all the regulations relating to their use will apply without restriction. For liquid paints, the labelling regulations have been adopted in an EC directive. Manufacturers of powder coatings must equally conform to them and make reference to the hazards involved and the means of reducing them. The internal plant regulations must include the prohibition of smoking, eating and drinking in the workshop. In addition, all normal hygiene measures required by local regulations must be observed.

10.5 Safety

The average concentration of powder in the spray booth should be below 50% of the value of the lower explosion concentration. Where a figure for the lower explosion concentration is not available a figure of 10 g/ m3 of powder in air for the maximum concentration in the booth and the recovery equipment should not be exceeded. The concentration must be calculated by excluding the weight of powder already deposited. Powder deposits should not be allowed to accumulate in the booth, as dust clouds could be formed and cause mixtures capable of explosion which could lead to an explosive chain reaction. For that reason WAGNER offers and recommends the use of a moving floor belt in each spraybooth which automatically removes all powder deposits from the booth floor.

The following rules should be observed:

- The calculation of the concentration must be based on the total amount of powder introduced into the spray booth. The equipment should be constructed to minimize explosion and fire hazard.

- The intensity of a possible explosion should be minimized by explosion panels discharging to atmosphere and thus reducing the risk of any fire or explosion for personnel in the working area.
- The basic causes of ignition should be eliminated or controlled.
- Suitable fire fighting equipment as well as extinguishers must be installed. The most likely ignition hazard is located in the vicinity of the sprayguns, because there, two important parameters may play a role: concentration of inflammable material and a source of energy. It is advised to install safety equipment allowing instant detection and fire extinction, avoiding further propagation.
- Powder leakage from the coating area should be avoided.
- The ventilation system should be so constructed that the concentration of powder in air does not exceed the L.E.L. (Lower Explosion Limit).
- It is impossible entirely to avoid deposits of powder, but this should be minimized by having smooth surfaces easily accessible for cleaning. All powder should be removed regularly and as often as possible. A continuously running extraction floor belt is ideal to prevent deposits from building up.
- Recommendations related to maximum respirable dust concentration are found in paragraph "Health Hazards".
- The high voltage equipment must be installed and protected in accordance with the regulations of the individual country.

10.6 Construction of Plant and Equipment

10.6.1 Buildings

Regulations are already in existence for paint shops using conventional solvent based paints. Possible regulations for powder application plants will not be very different and are currently being prepared.

10.6.2 Application area

The high voltage equipment shall comply with the existing regulations in the individual countries. The following special safety measures should prevail:

- limitation of the energy of discharge between the electrodes and the workpiece
- in case of accident automatic cut-off of high voltage with simultaneous cut-off of powder supply
- the powder and spraying process shall be interlocked with the air extraction system to minimize the possibility of the recommended lower explosive powder concentration being exceeded. If possible a fire detecting device similarly linked with the powder and spraying process, and a release system for a fire extinguishing gas should be installed in an automatic booth.

10.6.3 Ground Connections

Safety regulations require all parts of a spray booth made from conductive material to be properly grounded. For plastic booths, this regulation cannot apply. The walls of a plastic spray booth should either have a minimum thickness of 9 mm or if thinner, should be designed in a way that no conductive part can get closer from the outside to the wall than 90 mm. This is to avoid sparking from electrostatic charges accumulated on the plastic parts. In any case the construction should guarantee that no electrical field or charge can be detected outside the booth.

10.6.4 Spray Booths

Spray booths must be designed and operated according to the technical specification CENELEC SC 31/8. Personnel may be present for "touching-up" or manual application and such operators should work in a clean atmosphere. There should be no discharge of powder into the working area. Personnel involved in application must be kept in an atmosphere containing a maximum of 5 mg/m3 of fine powder / air. The booth or cabin should be of sufficient size to cope with the spray dust, and the cabin should be of sufficient size to ensure a minimum distance (25 cm) between the articles and the gun and similarly between the gun and the walls assuming that these are properly grounded. The walls should be smooth and so constructed that accumulations of powder are avoided and also be easy to clean. The floor of the working area must be conductive to ensure that the operators are adequately grounded. This applies especially where the operator is not protected by the grounding of the spray booth or other equipment. Ensure that powder is only being sprayed onto workpieces which are effectively grounded. Avoid all accumulation of powder in the booth and particularly on the floor.

10.7. Recommendations for the Powder User

10.7.1 Maintenance

A regular maintenance program for the plant is essential. Regular inspection and removal of powder accumulations are necessary to ensure perfect cleanliness. It is important to check that there is adequate grounding of all conductive parts.

10.7.2 High Voltage

It is important to follow the instructions provided with each type of equipment. A weekly check of the safety equipment should be made.

10.7.3 Extraction

Precautions should be taken to ensure that there is no discharge of powder into the working area. Checks should be made to ensure that the extraction rate is sufficient and constant. If powder accumulates in any part of the booth, work should cease and the plant cleaned. When the minimum rate of extracted air volume is reached (which will happen after a certain time when for example the after filter in a cyclone system gets clogged) a signal should be given so that the cleaning of the extraction equipment at the right time is guaranteed.

10.7.4 Grounding

The electrical grounding of a manual installation should be checked regularly and also after any maintenance work. Electrical groundings on automatic plants should be checked weekly. The grounding of jigs on an automatic plant should be checked on each cycle of the conveyor. An alarm signal should be triggered when the resistance is higher than 1 mega ohm (control voltage 5 kV, energy content of article maximum 5 millijoule). If the grounding is insufficient the jig must be changed and cleaned.

10.7.5 Safety Valves, Explosion Panel, etc.

This equipment should be checked weekly, should not be obstructed and always be visible. Access must be free and nothing stored in such a way as to affect their efficient functioning.

10.7.6 Cyclones, filters

A daily check should be made to ensure that they are working well and that the exhausted air is clean. The after filters should be checked at least weekly.

10.7.7 Moving parts

The cleanliness of bearings (operating temperature) should be checked daily.

10.7.8 Lighting

Light fittings should be kept clear. Emergency exits and fire extinguishers are to be unobstructed and checked daily. Dust-tight electrical fittings should be used within 2.5 metres of the application and recovery system, in accordance with local regulations.

10.7.9 Stoves

Stoves should be cleaned every week to remove any fused powder and to ensure the correct functioning of the burners. Hint: the installation of infra-red heating devices at the entrance of the oven will slightly sinter the powder, avoiding the presence of dust in the oven.

10.7.10 Buildings

Measures should be taken to ensure that the floors are kept clean, particularly in the vicinity of the spraying areas. Smoking, welding or the presence of open flames is absolutely prohibited in the working area.

10.7.11 Personnel

Operators of hand equipment must wear leather-uppered antistatic footwear to the appropriate specification (i.e. BS 5451/BS 1870 or DIN 4843). Insulating gloves should not be worn. Overalls of low flammability should be worn and if necessary, masks with fresh air supply, glasses and gloves. Smoking and the use of open flames is prohibited in the vicinity of the coating system. Any necessary cleaning outside the booth should be done preferably with a special vacuum cleaner.

11. Trouble Shooting

11.1 Application

Problem	Cause	Remedy
film thickness variations	distance between gun and part too small	increase distance
powder delivery pulsating	wrong feed air/ dosage air ratio	optimize feed /dosage air ratio
high voltage too high / too low	workpieces with different shapes	optimize voltage settings
incorrect relation between conveyor speed and reciprocator speed		readjust reciprocator settings
incorrect powder grain size distribution	too much recycled powder in system	optimize grain distribution. Add virgin powder
powder level variations in hopper	loosened level sensor	readjust level sensor in hopper
powder falls from part	poor grounding of part	check ground resistance(< 1 Mega Ohm)
too low gun voltage setting	workpiece shape has changed	increase voltage
too much feeding air	nozzles or hoses have been changed	decrease feed air setting
incorrect grain size distribution	too much recycled powder in system	optimize grain size distribution, add virgin powder
guns "puffing"	powder hose too long	shorten powder hose
too much "fines" in sprayed powder		check recovery system, add virgin powder
feed air fluctuations		check main air supply
blocked nozzle system		clean nozzle
fluid air setting too low	powder type has been changed	increase fluid air flow
bad coating of recesses and Faraday Cages	voltage too high wrong nozzle system	decrease voltage setting use flat spray nozzle
Faraday Cage formation by Corona field		use Tribo guns

11.2 Powder delivery

powder sinters in hoses and/or injector	too much feed air setting wrong hose material	decrease feed air use PUR hoses instead of standard PVC hoses for critical powders
bad fluidization of powder	fluid air setting too low	increase fluid air volume
powder particle size too fine		add virgin powder with correct grain size
fluidization base clogged	(possible reason: oil or dust in air supply)	clean fluidization base from both sides
wet powder	storage time too long	use dry powder
ambient temperature too high	booth ventilation extracts hot air from oven	lower ambient temperature
lumps in fluidized powder	powder was stored too long powder was exposed to temperatures > 35 °C	use new powder

11.3 Coating Quality

low brilliancy/gloss	curing temperature not in specification range for special powder	readjust oven temperature according to powder manufacturers recommendations
crater formation	oil/grease residues on parts	check pretreatment
oil/grease/dust in air supply		check air purifier
pin holes	silicone in coating area	DO NOT USE ANY SILICONE
outgasing of substrates		use heat pretreatment for parts
back ionization		reduce film thickness and/or gun voltage
yellowing	oven temperature too high	reduce oven temperature
wrong curing time		optimize curing time
conveyor speed variations		check conveyor system
orange peel	free electron/ion deposition on part	use Corona Star add-on

craters in the film	incorrect pretreatment	optimize pretreatment
oil, grease residues on surface		change grease or cleaning agent
oil in feed and atomizing air		put oiler out of operation
silicone oil from chain		change to products free of lubrication
incompatibility with powders of other manufacturers		clean system
welding residues		grind welded seams
blisters in the film	rust/water on the part	Check drier after pretreatment
powder film too thick		reduce feed air

11.4 Powder recovery

wrong powder particle size distribution	to much overspray	optimize nozzle system, air and voltage settings
cyclone operates not efficiently		optimize cyclone air volume
metallic particles separation	metallic particles not bonded to epoxy particles	check with powder manufacturer for improved powder quality
impurities in powder and on part	damaged sieving machine	replace sieve

11.5 Oven

foaming of cured powder	oven temperature too high	reduce oven temperature
coating not completely cured	conveyor speed too high	reduce conveyor speed
object temperature too low		oven to short

11.6 Metallic Powders

no charging of powder particles	short circuit in gun because of metallic particles	use special gun for metallic powders