THE ELECTROSTATIC POWDER COATING

1. Introduction

This text introduces you to one of the most environmentally friendly and economical technologies for surface coating, which permits the carrying out of a wide range of applications, easily and cleanly. Powder coating has been used since the early Sixties. Initially, its production and application were not without problems. Today, however, powder coating is an established and acknowledged process, because powder paints are:

- environmentally friendly
- energy saving
- safe to process
- very economical

2. The basic principle

The elementary idea behind electrostatic powder coating is based on the fact that parts with opposite electrical charges attract each other. Therefore, most conducting, and thermally stable solids are suitable for powder coating. Above all today, metal objects are electrostatically powder coated in an ever increasing volume. The most usual examples are:

- Household appliances
- Office furniture
- Garden furniture
- Automobile accessories
- Fittings
- Wire goods
- Sections
- Cladding elements

Daily, everyone comes into contact with the results of this technology. The dry coating powder is filled into a powder hopper, fluidized and conveyed by means of compressed air to the spray gun. A low-voltage of 10 V is converted in the powder gun to high-voltage, according to the cascade principle. One or more electrodes on the front of the powder gun charges the powder to 60 - 100 kV when sprayed. An electric field is created between the powder gun and the grounded workpiece. The powder particles follow these field lines and remain adhered to the object due to its the residual charge. The so processed workpieces can then be conveyed either manually or automatically to the curing oven, where the organic powder is melted to a smooth film at 160 - 200° C (320 - 392° F) and then hardened. Because of its chemical characteristics enamel powder requires much higher temperatures, namely 780 - 830° C (1436 - 1526° F). The coating thicknesses with organic powder for decorative purposes are approximately 30 - 80 mμ and for functional purposes 200 - 500 mμ. Enamel powder can be used in a coating thickness range between 80 - 200 mμ.

ITW Gema

3. The organic powders

Epoxy/polyester powder:	It is the most widely distributed powder with the biggest market share. It has very good chemical resistance and excellent mechanical characteristics. Its gloss durability and its colour appearance are, however, mediocre. Its fields of application are industrial equipment panelling, office furniture, machine tools, water heaters, radiators and shelving.
Epoxy powder:	This powder has good chemical and mechanical characteristics, but renders colour and gloss only poorly. This if further diminished by the UV rays in daylight. It is used for the underfloor coating of automobiles, pipe coating, fittings of all types, in the food processing, and chemical industries.
TGIC polyester powder:	It has good chemical resistance and very good mechanical characteristics. Its gloss and colour durability are good. It is readily used for open-air furniture, farming machinery, air-conditioners, fence posts, and aluminium sections and architectural panelling.
Polyurethane powder:	The powder has good mechanical and chemical characteristics. Gloss and colour are very durable. Polyurethane powder is used for automobile wheels, panelling, playground equipment and fluorescent building parts.
Acrylic powder:	It is well known for its good mechanical and very good chemical characteristics and for its very good colour, and gloss durability. Washing machines, oven parts, microwave ovens, refrigerators and automobile bodies (clear coat) are coated with acrylic powder.
Structured powder:	Caution is required when normal and structured powders are used in the same plant. Contamination can severely affect the coating quality if the cleaning of the plant is not carried out very carefully when changing powders.
Metallic powder:	Basically, there are two types of metallic powders. With the first, the metal pigments are mixed together, dry. This powder achieves a very nice metallic effect, but a danger of segregation exists. This powder is inclined to give difficulties when being recovered. With the other metallic powders the metal pigments are extruded in/bonded. With these powders the metallic effect tends to be mediocre, but the powders do not have problems when being processed. Metallic powders must never be used with normal Corona powder guns, as this will lead to short-circuiting, without special metallic nozzles. The ion reducing accessory (SuperCorona®) is to be removed before using metallic powders. As a rule, working with Tribo systems is not recommended. Using the same metallic powders with different systems, different plant or also only with different nozzles give differing colour results!

Thin film powder:

As long as the plant is set correctly and carefully monitored, thin film powder does not give any processing problems. The coating results to be achieved depend, as with no other powder, directly on the care taken by the operating personnel when using thin film powder. Cleanliness in processing and care with the continuous monitoring of the plant parameters are a 'must' when using this powder.

Clear coat powder:

The best known, but also the most demanding example is the clear coat powder coating of the BMW car bodies. Clear coat powder is technically not more difficult to process than other powder types, but requires considerably cleaner conditions. Clear coat powder can be processed, by all means, without the clean room concept with no problems, when the personnel operate the plant with the corresponding cleanliness.

Enamel powder:

Enamel powder is due to its composition very abrasive and requires special coating equipment. After stoving at 780 - 830° C an enamelled surface is present, which can be heated to a temperature over 450° C (842° F), and which is colour-fast and scratch-resistant. Enamel has a limited colour palette, but the surfaces finished by this means display outstanding mechanical and chemical characteristics. That is why powder enamelling is enjoying an ever increasing popularity. The favoured applications of powder enamel lie wherever especially high requirements are placed on a surface for resistance, such as on cooker panels, kitchen equipment, bathtubs or shower bases.

4. The coating plant

A plant for automatic powder coating normally comprises the pre-treatment, water drier, coating zone, curing oven and conveyor system. Such complete Industrial plants are monitored centrally. According to the layout more booths with corresponding conveying circuits may be necessary. For small production volumes or for special colours a small booth for manual coating is often sufficient, which from the price, and space requirements can be fitted into any production workshop.

The conveying equipment:

Conveying equipment for workpiece transport serves to automate the coating process, whereby the primary distinction is made between overhead, and belt conveying. Many transport problems, especially with not too large or very heavy workpieces, can be solved with a single train or circular conveyor. When long, large or bulky workpieces are to be coated or narrow working spaces are present, the "Power & Free" conveyor is ideal, as this permits longitudinal, and transverse travel as an alternative. Because of the complicated design it is more expensive, but permits more flexible adaptation to continuous and automatic coating, in cyclic operation during loading, removal and other processes. A further advantage of the "P & F" conveyor is possibility of chain formation for optimum material flow. Even the lifting and lowering stations can easily be combined. A special observation must be made in connection with the lubrication of the conveyor system. Temperatures in the curing oven may reach 250° C (482° F), therefore heat-resistant lubricants or alternatively, externally ventilated chain protection channels must be used.

The hanger fixture design:

For smooth conveyor functioning suitably designed hangers are essential for efficient production. How the workpiece hangers should look depends on the application arrangement. Sufficient stability guarantees problem-free coating and safeguards the production process without notable faults. The hangers are partially coated by the electrostatic, for this reason round material is to be preferred. In order to coat rationally, two complete sets of hanger are required: If the coating on one set of hangers is too thick, the second set are to be used while the coating is being removed from the first set.

The pre-treatment:

Before the workpieces can be coated, they must be freed of all contamination such as grease, oil etc.. This takes place in the multi-zone pre-treatment plant. After cleaning follows mostly, according to material, the pickling, phosphating or chromatizing. Generally, a distinction is made between steel sheet, which is phosphated for corrosion protection, galvanized steel sheet which is pickled to improve adhesion, and aluminium sheet which is chromatized. Workpieces, such as steel containers, wire goods, turned, punched or pressed parts, bicycle parts and accessories pass through the different treatment zones on the chain conveyor. The pre-treatment must be accommodated to suit the workpieces. An over dimensioning means wasting of energy and raw materials. The final coating results depend significantly on the cleaning and pre-treatment. Measures for effective environmental protection, and recycling of the raw materials are to be principally integrated into the pre-treatment concept.

The residual water dryer:

When the workpieces have passed through all the pre-treatment stations on the chain conveyor, any residual moisture must be removed. This takes place in the residual water drier. This is similar to the powder dryer, but are designed only for temperatures up to 120° C (248° F). Depending on the type of workpiece, blowing with normal air with nozzles may be sufficient; but it always depends on individual cases, what outlay is required.

Pre-treatment for enamel:

A prerequisite for the successful use of powder enamel is absolutely perfectly pre-treated steel. In order to achieve the necessary level of quality, pre-treatment lines with up to 20 stages are possible. As a rule, working is reduced to 6 stages (3x degreasing, 2x rinsing, 1x soak cleaning), whereby, this saving is only possible through the choice of suitable coating materials, as only high quality steel can be pre-treated with only 6 stages.

5. The charging process

In principle three different charging processes are used for powder coating: electrostatic charging, low-grade ion charging, and Tribo charging. The air ion reduction is achieved by practically all powder gun manufacturer's through a special accessory (SuperCorona®) on the powder gun. A fourth possibility is fluidized bed coating, which, at any rate, operates without electrostatic and is to be classified as an exception.

5.1 The electrostatic charging

The corona discharge is the unimpeded discharge of free electrons from an electrical conductor. This process is only possible under a high electrical field strength. This increases with increased voltage and with decreased wire thickness, that is why a high voltage and a thin wire are required. The free electrons seek the shortest route to the next grounded part. They contact the powder particles and remain adhered to them. The thus ionised powder particles are attracted all grounded objects like the free electrons. In practical use is the workpiece the first grounded part that the powder meet and therefore, remain adhered to it. As soon as the ionized powder particles meet the grounded workpiece, a "counter-charge" is created on the workpiece. Both charges mutually attract one another. Because the powder is not electrically conductive, the charge cannot discharge and the attractive force remains. The discharging current, consisting of free electrons, air ions, and the influence current of the counter-charge, flows from the grounded workpiece.

To guarantee optimum charging of the powder, the electrons of the ITW Gema powder guns are rinsed with a small stream of air. Without this rinsing the powder will sinter on the electrode in the shortest time and its electron flow will be considerably reduce. The air stream increases the corona discharge on the electrode, because the electrons are flushed away. About 1 - 3% of the free electrons hit powder particles, the rest ionize in the surrounding air or remain free. These free electrons, and the ionized air are called space charge, and have an influence on the coatings quality. As already mentioned, the charged powder particles seek the shortest route to the next grounded object. The space charge amplifies this force and the powder particles have a problem to penetrate into cavities and deposit on the edges and in the corners of the workpieces.

We know that the charged powder particles repel all similarly ionized powder particles. This repelling force is also active with powder particles deposited on the workpiece. It limits the coating thickness and increases the even distribution of the powder. When the powder film on the object is too thick, an uneven surface, called 'orange peel' effect, is created. Another manifestation is, that powder is sprayed back, called back-ionization, whereby small craters are formed on the surface. When the high-voltage is reduced on the electrode, the charging, and space charge are also reduced, so that 'orange peel' effect and back-ionization can be combated. Due to this procedure the charging of the powder is also reduced, and its ability to penetrate into cavities also sinks.

5.2 The low-grade ion charging (SuperCorona®)

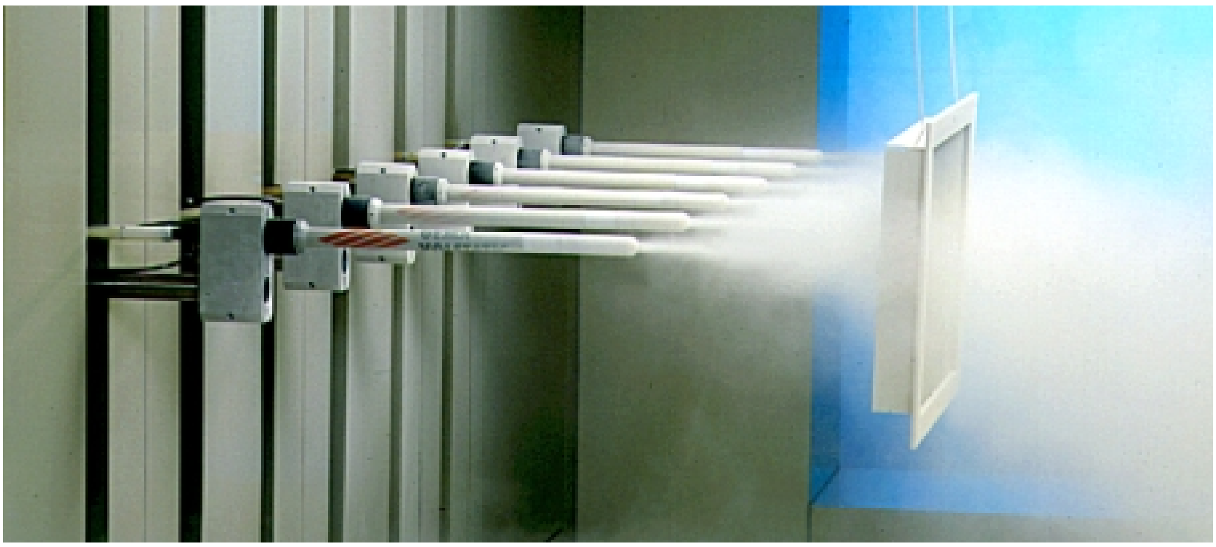
Low-grade ion charging, with the retro-fitting of a SuperCorona® ring, comes into use everywhere where thicker powder film and a high visual coatings quality is required simultaneously. It is not always possible to achieve a high surfaces quality with the usual electrostatic charging, where cavities are to be covered and the leading edges must be smooth simultaneously. Either the cavities cannot be covered, or the edges are too thickly coated, which coating thicknesses of 60 - 70 µ the notorious 'orange peel' form. This results from an excess of free ions, which cannot discharge through the object due to the too thick powder film and this leads to an uneven coating. The SuperCorona® ring prevents the free ions from reaching the workpiece, in that they are fed back, through the ring for grounding the powder gun. The ring consists essentially of a conductive ring with six electrodes and a connecting wire fixed to the grounded powder gun fixture. Typical fields of application for the SuperCorona® are the coating of drawers, wheel rims, and sections. Another field of application is also coating with structured powders, where the SuperCorona® leads to a considerably well-balanced pattern. In addition, it reduces back-ionization when coating manually.

5.3 The tribo charging

The tribo process utilizes charging through friction. We know that when 2 plastic foils are pulled apart, they mutually attract each other again. Both separating surfaces have charged themselves with an opposite polarity electrical charge, which after separation attract each other again. Tribo charging uses this phenomenon, only that the charge is drawn off. The powder particles are brought into contact with another plastic material and immediately separated again. This process can take place in a tube, hose or on a plate. Ideally it should take place at a high air velocity because turbulence is created in the tube, which increases the number of contacts. The plastic material used is teflon.

The tribo charging only has a limited adjustment. As with electrostatic charging the powder is fed through an injector to the powder gun. Because the conveying velocity of the powder is not sufficient to charge the powder with the required charge in the gun, the transit velocity of the powder through the gun is increased with supplementary air. Because of this, regulation of the air volume and with it the charging of the powder, regulation is only limited.

The advantage of tribo charging lies in its good depth of penetration. Tribo-charging does not create excess ions in the air. The space charge is insignificant. This is why the penetration of powder in cavities, such as post boxes, and wheel rims is better than with the Corona gun. The charge on fresh powder is higher than with electrostatic charging. The coated surfaces are smoother, and the 'orange peel' effect is less marked. The disadvantage of tribo charging is its limited flexibility and the recovery of the powder. Not every powder can be used with tribo guns, it requires a special Tribo additive (aluminium oxide). Today, of course, powder manufacturers can make most powders suitable for tribo use. Fresh powder charges best, and powder which has been recovered a number of times can no longer be used. The higher the fine particle content in the powder the less tribo capable it is.



5.4 Special process: Fluidized bed coating

With fluidized bed coating no charging of the powder is necessary. The workpiece is heated to the reaction temperature of the powder and dipped into fluidized powder. Fluidized bed coating is ideal for small parts, and wire type workpieces where thicker coatings are required, without requirements on the visual coating quality. Fluidized bed coating is an exception.

6. Types of equipment

Standard versions of electrostatic equipment always consist of a control unit, a powder container, and a powder gun. There is a differentiation between control units for one, two or more powder guns. The powder guns can be fitted with a number of different nozzles according to the application. The choice of powder containers consists principally among fluidized, vibrating or those with a stirrer. The manufacturer's container can also be used as a powder container, which is especially useful for frequent quick colour changes.

Manual coating:

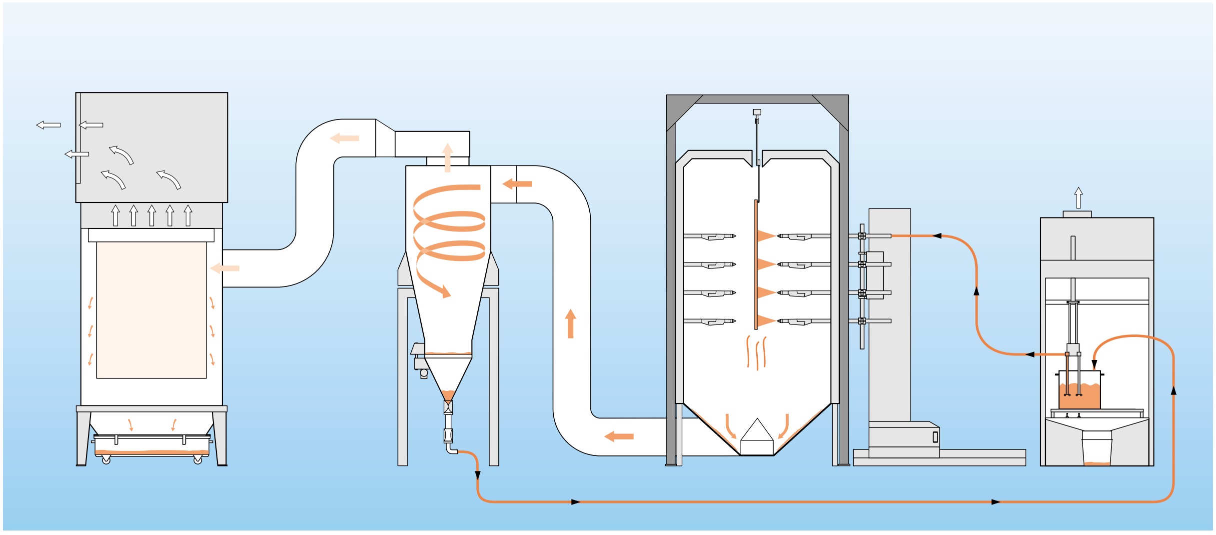
High-performance equipment for manual coating are ideally suited for small to medium production series. They should always be easy to clean because colour changes may be frequent.

Automatic coating:

High-performance equipment for automatic coating must the able to fulfill the requirements for production of large series. Individual modular systems, with standard elements, which permit a tailor-made solution for every paint shop, are predestined for such tasks.

7. The powder circuit

Even when the powder particles are properly charged, many miss their target, the workpiece. Electrostatic powder coating is so economical, because the overspray can be recovered, and reused. Individual booths operate with different recovery systems. Further information on this is found in the following text. What all have in common is, that the workpieces are coated in a booth, in a permanent, slightly lower pressure created by the exhaust suction. Overspray is prevented from escaping from the booth by the intake air flow created.



8. The reciprocators

In order to achieve an adequate rationalisation of the production process with the coating of medium and large series the procurement of reciprocators is indispensable. An exactly reproducible coating performance of standard uniformity, and coating thickness is first possible though the customer specific layout of the reciprocator stations. These automatic machines can be operated in up to three dimensions as required, whereby, in addition to the advantages already mentioned, manual touch-up coating will often be unnecessary. At any rate, larger series must be produced with multi-dimensional automation, otherwise the considerable programming effort will neutralize the coating advantages again. Today, in large paint shops several two-dimensional reciprocators, with about four powder guns each, are no longer uncommon, particularly because these are controlled from a single, compact control unit, which guarantees a uniform coating quality.

9. The Oven

After the application of the powder the workpieces can be transported directly into the curing oven without delay. The final finish depends on the accuracy of the temperature. The stoving temperature tolerance of the powder is about ± 5° C (± 9° F). Heating-up and holding times are influenced of the volume of the oven interior components such as partition walls, reinforcements or heat insulation. But also the workpiece type, concentration of hangers, and material thickness are important criteria for the design of the oven. Generally, there are various designs of oven on the market. Whether a continuous oven, a reversing oven or any one of the various other designs is to be recommended, will depend on the overall plant concept, and space requirements. A further important factor is the dwell time duration in the oven. With a continuous oven it is clear that for a planned workpiece flow rate the specified temperature, with an acceptable tolerance, must be guaranteed. Hardening is done at differing temperatures according to the type of powder.

Energy saving possibilities:

Heat energy is expensive, that is why economic measures in this area will always remain a topical theme. The designer with a sense of responsibility will integrate this problematic in his concept and know, with which measures the energy consumption is kept as low as possible. A few of the criteria listed below will help in making a decision:

- Direct or indirect heating? With direct heating about a 10 % energy saving can be made, however, only gas can be used as the heating medium.
- Opening losses are avoided with an A-Zone design.
- The heat insulation must be correctly designed, radiation losses must be avoided.
- Heat recovery systems lower energy requirements.

10. Summary

Electrostatic powder coating is becoming increasingly more important. The growth rate of this environmentally friendly technology is far above average. Floor space, and personnel costs can be keep low through compact plant design, and the possibility to automate extensively. Since coating takes place in a closed system, without solvents, there are no harmful side-effects. The efficiency of this technology, depending on the recovery system, is up to 99%. This makes powder coating one of the most economical of all surface finishing technologies. With the relatively new development of so-called quick colour change systems, a colour change can be carried out within fifteen minutes. Powder coating is becoming more and more a replacement process for wet coating, which is considerably less environmentally friendly.