ELECTROSTATIC PHENOMENA IN POWDER COATING

NEW METHODS OF IMPROVING FARADAY-CAGE COATING, FINISH QUALITY AND UNIFORMITY, AND RECOATING OPERATIONS

Introduction

Worldwide popularity of powder coating as a process has enjoyed steady, double-digit growth over many years. One of the forces driving this success has been continuous improvements in the application equipment used in the powder coating process. Since the early days of powder coating, powder coaters and application equipment manufacturers have faced several challenges, including: maximization of first-pass transfer efficiency; effective coating of Faraday-cage areas; better finish quality and uniformity; and recoating of rejected parts. Technology developments, however, have allowed leading equipment manufacturers to offer users new equipment features that more closely meet these challenges. Additionally, an understanding of the electrostatic phenomena involved in the powder coating process is equally important to equipment manufacturers and users. As equipment becomes more and more sophisticated, to offer more capabilities previously unavailable, it is important that powder coaters understand what features are worth the investment, in which applications, and why. This paper focuses on corona-charging application systems, and presents an overview of electrostatic processes utilized in powder coating technology in light of new equipment features now available.

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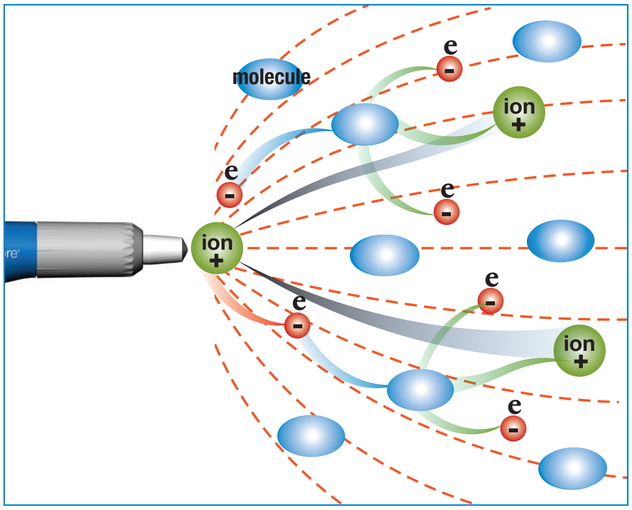
In corona-charging systems, a sharply non-uniform electric field is created between a gun and part by applying high (usually negative) voltage potential to a pointed electrode. Non-uniformity of this field is imperative since the field lines converge on sharp points and the density of field lines in any area represents the strength of the electric field. Therefore, if we apply a high-voltage potential to a single-point electrode and position a larger-size grounded object before the electrode, we will create an electric field whose strength is greatest at the tip of the pointed electrode.

There are always free electrons or ions present in the air. If an electron passes through a strong electric field, it will start moving in this field along the field lines and be accelerated by the field force. As the electron accelerates along the field lines, it will ultimately run into an air molecule (see Figure 1). If the field strength is adequate and the electron has gathered sufficient kinetic energy while traveling along the field lines, its impact on the air molecule will be strong enough to split that molecule to form two secondary electrons and one positive ion (the remainder of the molecule). Secondary electrons will instantly be accelerated in the electric field. Moving along the field lines, they will split new molecules and create more ions and electrons.

Figure 1



Because opposite charges attract, positive ions remaining from each split molecule will also be accelerated by the field force and move along the field lines. Their motion, however, will be in the opposite direction toward the gun's negative electrode. Once again, if the electric field is sufficient, positive ions can either split molecules on their way toward the negative electrode or, if they reach the electrode, impact it so hard that they will split new ions from the metal surface of the electrode.

This process is corona discharge. It is selfsustaining at field strengths equal to, or greater than, some starting level. Immediately after the ionization process begins, the space between the spray gun and grounded part becomes filled with millions of ions and free electrons. Henceforth in this paper, the term "free electrons" will be replaced with the more commonly used term "free ions[1]."

Charging Powder Particles

Figure 2 illustrates a powder particle in an electric field. The uncharged dielectric particle will distort the external electric field so that some field lines will extend toward the particle's surface, enter at a 90º angle, pass through it, and exit at a 90º angle. If free ions are present in the external electric field, they will follow field lines towards the uncharged particle and ultimately be captured by the particle's field of polarization[2], thus increasing the particle's own charge.

This process will continue until the charge accumulated on the particle, as a result of capturing multiple ions, is sufficient to create the particle's own electric field. This field will again change the alignment of the external field lines. This time, the external field lines will be pushed away from the particle (see Figure 3). When this happens, ions from the external field can no longer reach the particle because its own field repels them. In other words, the particle has reached maximum charge, given the external field strength, particle size, and material.

In electrostatic powder coating, we spray powder through an area of strong electric field and high free-ion concentration. Passing through this area, the particles are charged as discussed earlier. The process of powder particles' charging in the electric field of corona discharge is governed by Pauthenier's equation (see Figure 4). Charging is most strongly affected by field strength, powder particle size and shape, and the length of time the particle spends in the charge area.

Figure 2

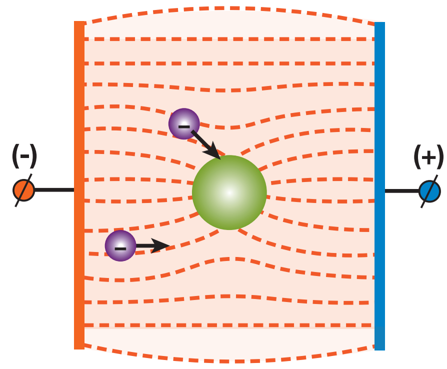


Figure 3

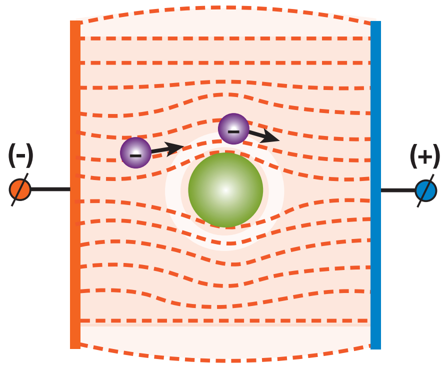
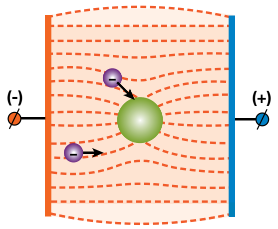


Figure 4



$$q_m = 4\pi\varepsilon_0 \left(1 + 2\frac{\varepsilon_r - 1}{\varepsilon_r + 2}\right) E r^2$$

For Conductors

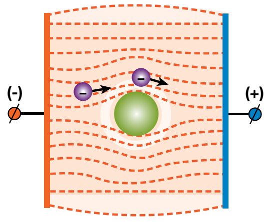
$$\varepsilon_r \rightarrow \infty$$

$$q_m = 12\pi\varepsilon_0 E r^2$$

$$q(t) = 4\pi\varepsilon_0 \left(1 + 2\frac{\varepsilon_r - 1}{\varepsilon_r + 2}\right) r^2 E \frac{enkt}{4\varepsilon_0 + enkt}$$

WHERE

r = Radius of the particle
E = Field strength
e = Charge of an electron
k = Electron mobility
n = Electron concentration
t = Time
ε_0 = Absolute permittivity
ε_0 = Relative permittivity of powder material



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[1] *"Free ions" are negative ions, produced by the corona ionization process, which do not get captured by powder particles and remain free in the space between the gun and grounded part traveling towards the closest ground along the field lines.*

[2] *The distortion of an external electric field by an uncharged particle is caused by the particle's own field of polarization, a detailed discussion of which exceeds the scope of this paper.*

Powder Deposition and Layer Formation

Figure 5 illustrates forces affecting a charged powder particle as it travels from the spray gun to the grounded part. It should be noted, however, that the only force pushing the particle towards the grounded substrate is the electric force equal to the charge of the particle, multiplied by the strength of the electric field.

The air stream delivers a particle to the part. However, if the particle is not charged or the field strength is not sufficient, the particle will bounce off the metal substrate and either be carried away by the air stream or fall down under gravity forces. The electric force helps the particle overcome aerodynamic and gravity forces, and remain on the part's surface to allow yet another force to be established. This new force is the attraction between the charged particle and grounded metal surface.

Most materials used for powder coatings are strong dielectrics. Once charged, they do not allow charge to "bleed off" quickly. In fact, most materials used for powder coating retain their charge for at least several hours, even if small particles of the material are placed on the grounded metal surface. When a charged powder particle is positioned next to the metal surface, it induces a charge of equal value but opposite polarity inside the metal (see Figure 6). In simple terms, this results because the conduction electrons inside the metal vacate the area close to the point of contact of the powder particle and metal surface. As electrons move out, what remains is the area with an excess positive charge equal in value to the negative charge on the powder particle. This positive charge is commonly called "mirror charge."

As soon as the mirror charge is induced inside the metal, two charges of equal value and opposite polarity exist next to each other, separated by the metal surface. These two charges will not only attract each other and hold the powder particle to the metal surface, but also create another electric field between themselves.

The larger the powder particle on the metal surface and higher its charge, the stronger the electric field is between the particle and its mirror image. Thus, the stronger the electrostatic attraction is between them (see Figure 6). The fact that larger particles experience a stronger attraction to the grounded metal provides one explanation as to why we are more likely to observe "orange peel" effect on thicker layers of powder coatings.

After the initial layer of powder coating is deposited on a metal surface, the particles of subsequent layers have to induce mirror image charges over the already existing layer of dielectric material to be deposited. The presence of the existing layer of dielectric powder coating dampens the induction process (since there is no direct contact of powder particles with the metal surface). Lower charges of smaller particles may not be sufficient to create an attraction force strong enough to retain the particles on top of the already deposited powder coating layer.

Figure 5

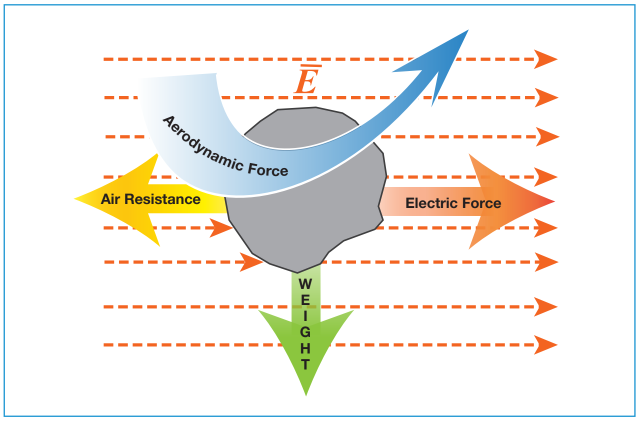
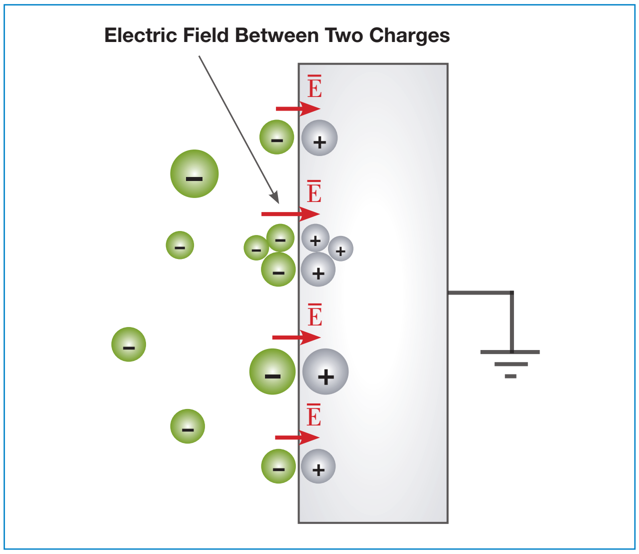


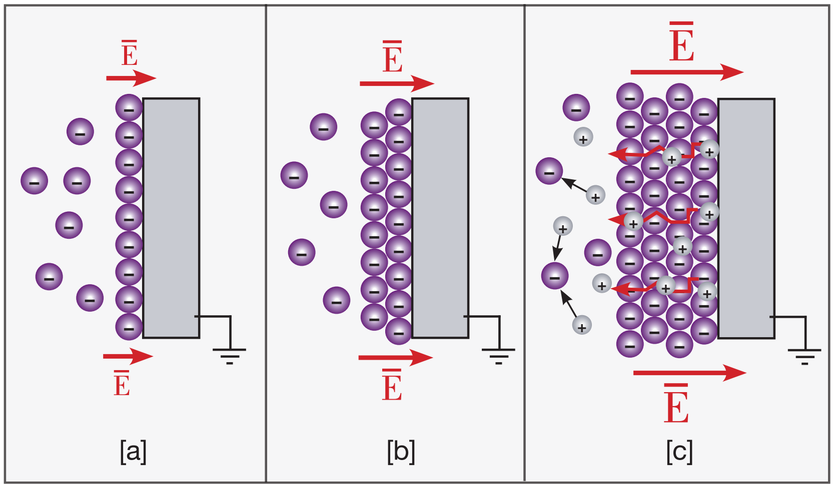
Figure 6



Larger powder particles usually accumulate stronger charges and, therefore, the attraction force between them and their induced mirror reflection is also stronger. As a result, larger powder particles are more likely to be deposited on top of the existing uncured coating. If one were to look at a cross-sectional view of uncured powder coating layer, the bottom portion (closer to the metal) would likely have a smaller average particle size than the top portion.

If a powder coating material does not flow well during the curing process, the larger particles comprising the upper coating layer may not flow out completely and will retain some of the surface profile of an uncured coating layer. This will result in lower-gloss, bumpy finishes and orange peel due to insufficient flow properties of coating material.

Figure 7



Back Ionization, Finish Quality and Transfer Efficiency

We have analyzed the process of powder particles deposition on a grounded metal surface. If we continue spraying charged powder on the same surface, back ionization will ultimately occur (see Figures 7a, 7b, and 7c).

When charged powder coating is applied to a metal surface, the strength of the electric field inside the layer of powder coating increases. Every new powder particle deposited increases: 1) cumulative charge of the powder coating layer; 2) cumulative mirror charge inside the metal; and 3) strength of the electric field inside the layer of powder coating.

As we continue applying charged powder, the strength of the electric field inside the powder coating layer ultimately becomes sufficient to ionize air trapped between powder particles. The ionization process inside the coating layer is very similar to the one that develops around the gun's electrode when high voltage is applied to it. Stray electrons, present in the air, accelerate in the electric field, split air molecules, and generate a great number of negative electrons and positive ions. Because opposite charges attract, negative electrons rush toward the relatively positive ground, and positive ions try to escape from the coating layer toward the gun's negative electrode. As a result of this intensive flow of electrons and ions, streamers develop through the layer of powder coating.

A streamer can be viewed as miniature lightning or a spark shooting through the powder coating layer. Inside a streamer numerous electrons and positive ions traveling in opposite directions. Once developed, streamers can be seen through image intensifying equipment as glowing dots on the surface of powder coating.

The process of streamer development through the layer of powder coating is virtually identical to corona ionization around the high-voltage electrode of a spray gun. Thus, it is commonly referred to as "back ionization."

Back ionization is another common cause of orange peel effect on the surface of powder coatings. It also is the driving force behind what is often called the "self-limiting" property of the powder coating process, because it greatly reduces transfer efficiency.

As positive ions produced by back ionization inside the powder coating layer move out of the coating layer, they neutralize the charge of powder particles adjacent to the streamer channel. Active, directed motion of positive ions along streamer channels also engages air molecules, resulting in a phenomenon called "electric wind." Electric wind rips powder particles that have been neutralized by positive ions off the powder coating layer. This action creates micro craters that can easily be seen on the surface of uncured powder coating in the form of "starring." If powder coating material does not flow well during the curing process, craters formed by back ionization will not flow over completely, resulting in a "wavy" surface appearance of cured powder coating.

Another important effect of back ionization is illustrated in Figure 7c. When positive ions find their way outside the powder coating layer, they become attracted to negatively charged powder particles which are continuously arriving on the surface of the grounded part. The collisions of positive ions and negatively charged powder particles result in powder particles losing their charge and, therefore, the ability for deposition. As back ionization develops, the ability to continue building the layer of powder coating is significantly diminished by the presence of positive ions in front of the grounded part. Transfer efficiency of the powder application declines dramatically with the onset of back ionization.

During the analysis of corona development at the tip of the gun, it was established that the space between the gun and part becomes filled with billions of free ions which, together with charged powder particles, form the space charge. Until now, our analysis of powder deposition and back ionization development has ignored the presence of free ions in any conventional corona-charging powder coating application. Let's analyze their effect.

We can compare the build-up of cumulative charge on the powder coating and ultimate development of back ionization to filling a bucket with water. If you take a bucket with a small hole in the bottom and try to fill it with water from a faucet, it will take some time for the bucket to overflow. In this analogy, the stream of water from the faucet represents the stream of charged powder particles building a powder coating layer, water in the bucket is the charge accumulating on this layer, and water leaking through the hole in the bottom of the bucket is the small amount of charge that can bleed off the coating. The overflowing bucket represents the onset of back ionization.

Following the same analogy, the presence of free ions in the space between the gun and part can be represented by adding a fire hose to fill the bucket. Just as the bucket would overflow almost instantly with the addition of a large hose, back ionization on the layer of powder coating develops much faster when free ions are present in the powder coating process.

Free ions are attracted to, and travel toward, the grounded part along electric field lines. As long as the part's surface is not covered with a layer of dielectric powder coating, free ions arrive on the metal surface and flow off to the ground. However, if the metal substrate already has a layer of powder coating, this layer partially insulates the metal surface, restricting the flow of the charge delivered by free ions to the ground. The charge that does not bleed off to ground dramatically increases the cumulative charge of the coating layer, resulting in rapid development of back ionization, significant reduction in powder transfer efficiency, and deterioration of finish quality and uniformity.

Faraday-Cage Effect

Let's look at what occurs in the space between the gun and part during the electrostatic powder coating process. In Figure 8, the high-voltage potential applied to the tip of the gun's charging electrode creates an electric field (shown by red lines) between the gun and grounded part. This leads to the development of corona discharge. A great number of free ions generated by the corona discharge fills the space between the gun and part. Some of the ions are captured by powder particles, resulting in the particles' being charged. However, multiple ions remain free and travel along the electric field lines toward the grounded metal part, mixing with powder particles propelled by the air stream.

As stated earlier, a cloud of charged powder particles and free ions created in the space between the gun and part has some cumulative potential called space charge. Much like a thunder cloud creating an electric field between itself and the earth (which ultimately leads to lightning development), a cloud of charged powder particles and free ions creates an electric field between itself and a grounded part. Therefore, in a conventional corona-charging system, the electric field in close vicinity to the part's surface is comprised of fields created by the gun's charging electrode and the space charge. The combination of these two fields facilitates powder deposition on the grounded substrate, resulting in high transfer efficiencies.

Positive effects of the strong electric fields created by conventional corona-charging systems are most pronounced when coating parts with large, flat surfaces at high conveyor speeds. Unfortunately, stronger electric fields of corona-charging systems can have negative effects in some applications. For example, when coating parts with deep recesses and channels, one encounters Faraday-cage effect (see Figure 9).

When a part has a recess or a channel on its surface, the electric field will follow the path of the lowest resistivity to ground (i.e. the edges of such a recess). Therefore, with most of the electric field (from both the gun and space charge) concentrating on the edges of a channel, powder deposition will be greatly enhanced in these areas and the powder coating layer will build up very rapidly.

Unfortunately, two negative effects will accompany this process. First, fewer particles have a chance to go inside the recess since powder particles are strongly "pushed" by the

Figure 8

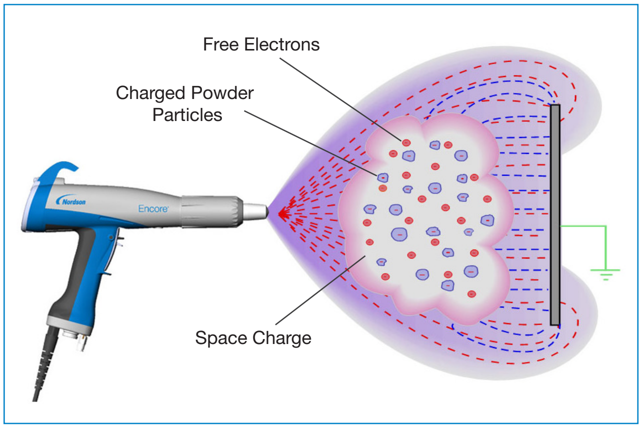
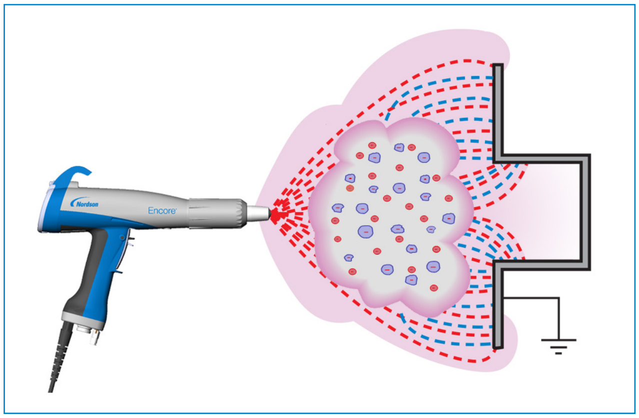


Figure 9



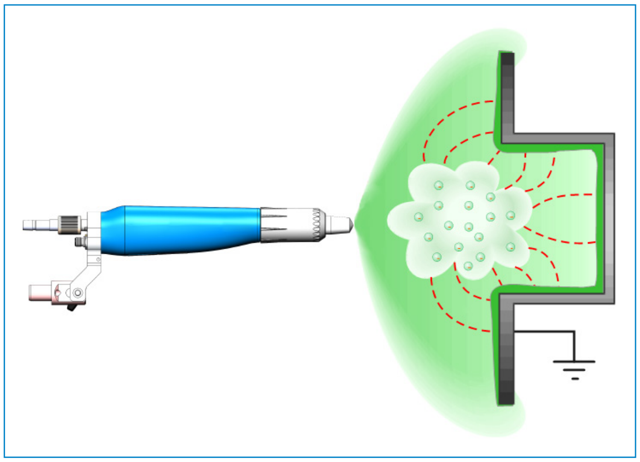
electric field towards the edges of Faraday cage. Second, free ions generated by the corona discharge will follow field lines toward the edges, quickly saturate the existing coating with extra charge, and lead to very rapid development of back ionization.

It has been established earlier that for powder particles to overcome aerodynamic and gravity forces and be deposited on the substrate, there has to be a sufficiently strong electric field to assist in the process. In Figure 9, it is clear that neither the field created by the gun's electrode, nor the field of space charge between the gun and the part penetrate inside the Faraday cage. Therefore, the only source of assistance in coating the insides of recessed areas is the field created by the space charge of powder particles delivered by the air stream inside the recess (see Figure 10).

If a channel or recess is narrow, back ionization rapidly developing on its edges will generate positive ions which will reduce the charge of powder particles trying to pass between the Faraday-cage edges to deposit themselves inside the channel. Once this occurs, even if we continue spraying powder at the channel, the cumulative space charge of powder particles delivered inside the channel by the air stream will not be sufficient to create a strong enough electric force to overcome the air turbulence and deposit the powder.

Therefore, the configuration of the electric field and its concentration on the edges of Faraday-cage areas is not the only problem when coating recessed areas. If it were it would only be necessary to spray a recess for a sufficient length of time. We would expect that once the edges are coated with a thick layer of powder, other particles would be unable to deposit there, with the only logical place for powder to go being the inside of the recess. Unfortunately this does not happen due, in part, to back ionization. There are many examples of Faraday-cage areas which cannot be

Figure 10



coated regardless of how long powder is sprayed. In some cases, this happens because of the geometry of the recess and problems with air turbulence, but often times it is due to back ionization.

Back Ionization and Recoating of Parts

The phenomena of back ionization complicates the process of powder coating with conventional corona-charging equipment by: 1) reducing transfer efficiency; and 2) restricting the ability to effectively coat Faraday-cage areas. Free ions are the major cause of back ionization in corona applications and, therefore, the excessive number of free ions is the reason for the above mentioned problems.

Recoating parts is another common in the powder application challenge where free ions have a negative impact. In this case, we try to apply a second layer of coating on top of the cured one. The difficulty arises because free ions generated by corona discharge travel between the gun and part with velocities much greater than those of powder particles. Free ions very quickly make their way to the part and increase the charge of the layer of the existing cured coating. A cured coating is a much better dielectric than an uncured one. So, the charge delivered by free ions to the surface of a coated part has no way to bleed off.

By the time the powder particles arrive at the surface of the part being recoated, the existing coating already has a lot of charge on it. Arriving powder particles and additional free ions rapidly drive up the cumulative charge on the coating layer almost instantaneously, resulting in back ionization. In fact, back ionization may already exist on the surface of the part before the first powder particles arrive there. As has already been shown, once back ionization develops, transfer efficiency declines quite dramatically. That's why we often experience difficulties when trying to recoat parts.

A traditional method of facilitating recoating operations and improving penetration of Faraday cage areas is to turn down the gun voltage. Reduction in the gun voltage reduces: 1) strength of the electric field in the vicinity of the part's surface; and 2) gun current.

Reduction of the field strength in the vicinity of the part's surface results in easier Faraday-cage penetration because the electric force pushing powder particles toward the edges of recessed areas becomes weaker. A lower gun current translates into a lower number of free ions in the space between the gun and part. This delays the development of back ionization and leads to easier recoating operations and Faraday-cage penetration, thicker film builds and better finish quality.

Unfortunately, manually turning down gun voltage is not always an acceptable solution. For example, it would not be an easy task in automatic applications. Additionally, how low should gun voltage be to accomplish our coating goals and still optimize process efficiency?

Difficulties associated with manual adjustment of gun voltage have led to the development of more advanced techniques of combating back ionization and achieving greater uniformity and quality of finishes. These techniques are: 1) automatic control of the gun current; and 2) free-ion collecting devices. Both techniques allow coaters to improve their finishing operations by eliminating or reducing stray ion current from the gun to the part.

Automatic Current Control

The principle of operation of automatic current control (ACC) is the automatic adjustment of gun voltage to maintain the gun current and field strength between the gun and part at some optimum level. To better understand why ACC brings improvements to the powder coating process it is important to comprehend Ohm's law (U = I x R) and the concept of "load line" of powder application equipment.

The load line is the relationship between the gun current and actual voltage at the tip of the gun's electrode. A load line of a conventional corona gun is shown in Figure 11. The closer the distance between the gun and part, the higher the current flowing through the gun and the space between the gun and part. What is important in our discussion is that as we move the gun closer to the part, the resistivity of the space between the gun and part becomes lower and the gun current higher. Given that the gun current directly translates into the number of free ions generated by the corona discharge, the number of free ions flowing to the part for a gun-to-part

Figure 11

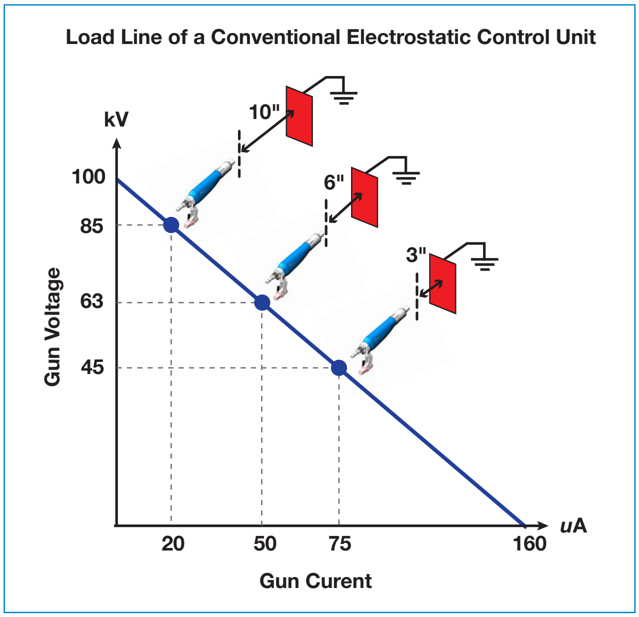
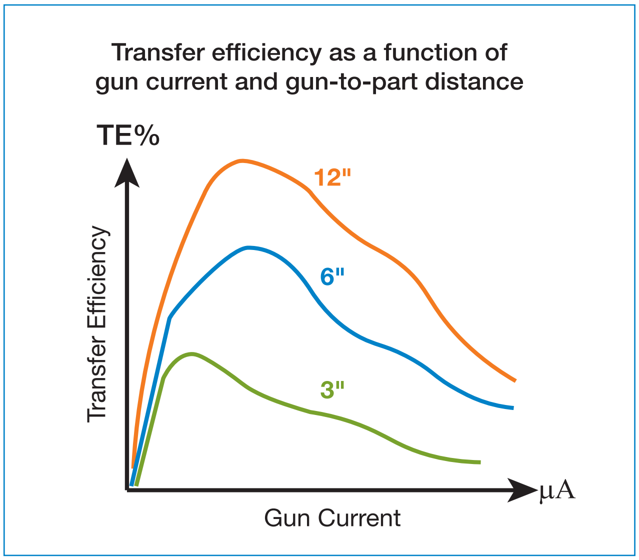


Figure 12



distance of 3 inches will be significantly greater than the number of ions flowing to the part at a gun-to-part distance of 10 inches.

Figure 12 shows a family of curves[3] approximately representing the relationship between the transfer efficiency of the powder coating process and gun current for a fixed powder flow rate and conveyor speed, and gun-to-part distances of 3, 6, and 12 inches. It is clear from the graph that for gun-to-part distances of 6 to 12 inches, maximum transfer efficiency is achieved at some current level. At the 3-inch distance between the gun and part, the maximum transfer efficiency was reached at a lower current setting. This difference can be easily explained using, once again, the example of a bucket of water.

If we take an empty bucket and try to fill it from a water hose positioned at a distance of 10 feet, the water spray coming out of the hose would fan out and only a portion of the water would get into the bucket. This way, it would take us some time to overfill the bucket. If we now try to fill the same bucket from the hose positioned three feet away, a much greater portion of sprayed water would get in and we would overfill the bucket more quickly.

Using the analogy in which the overfilling bucket represents back ionization on the layer of powder coating, we can say that when we apply powder coating from a gun positioned 10 inches from the part, field lines are distributed over a large area of the part, and the density of free-ion current per unit of the part's surface is low. Therefore, it takes longer to start back ionization. If we move the gun 3 inches to the part, two things happen using a conventional corona gun: 1) free

[3] *"Although the curves in Figure 12 are not the exact graphs constructed as a result of a series of experiments, they very closely represent the actual curves.*

Figure 13

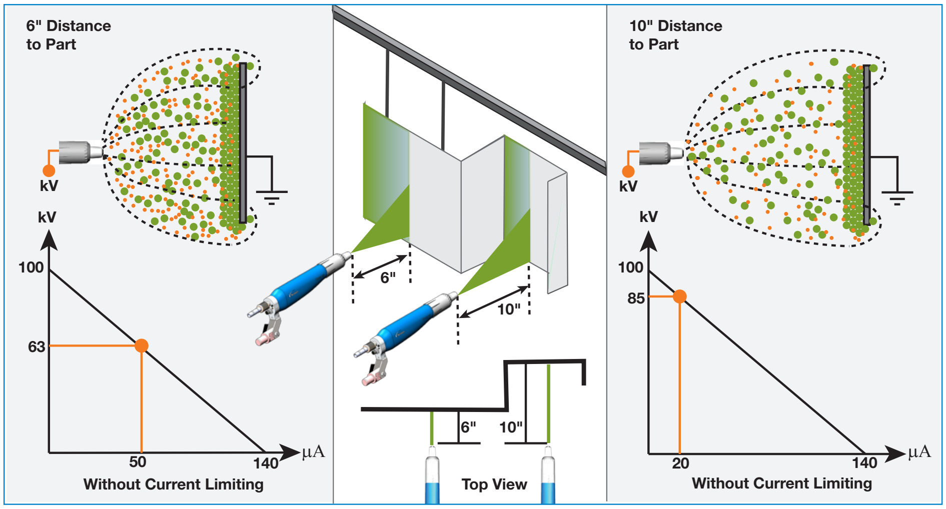
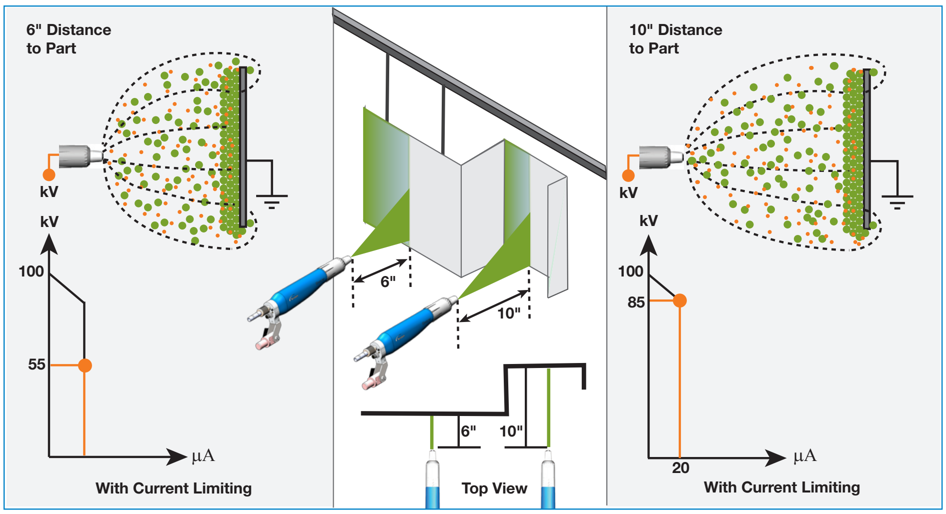


Figure 14



ions will flow through a narrower channel causing a higher current density per unit of the part's surface; and 2) a closer gun-to-part distance will result in a higher current level which, following our analogy, would be equal to increasing the volume of water flowing through the hose. Therefore, at a 3-inch gun-to-part distance, conditions are such that even a gun current which is optimal for 6 inches, is enough to cause rapid development of back ionization and lower transfer efficiency.

A good way to envision why overall transfer efficiency is lower at a higher current level is to imagine that each square inch of the part's surface gets exposed to the free ion flow for a certain period of time (depending on conveyor speed). Maximum application efficiency is achieved if we apply powder at the highest transfer efficiency possible throughout the entire time. If the current is too high, we may reach back ionization so quickly that only a part of the allotted coating time is used with maximum efficiency.

Results of experiments show that for a broad range of gun-to-part distances there is some current level that provides for maximum transfer efficiency. Therefore, if we had a tool that would allow us to automatically maintain gun current at this optimum level (regardless of the gun-to-part distance), we would optimize overall efficiency of the powder coating process. This tool is automatic current control (ACC).

With ACC, as the gun-to-part distance changes (either due to the complex part shapes or parts of different depths passing before the gun), the gun control unit automatically adjusts voltage up or down to maintain gun current at a preset level, which is optimum for a given operation.

For example, when a manual operator has to touch-up some part with a difficult recess on its surface, the operator almost inevitably will move the gun closer to the part in an attempt to "push" powder inside the Faraday-cage area. Without ACC, this would lead to an increase in the gun current, higher density of free ion stream per unit of the part's surface, and faster development of back ionization. ACC will automatically reduce gun voltage as the gun is moved closer to the part. As a result, ACC: 1) keeps the current at an optimum level to prevent generation of an excessive number of free ions; and 2) controls field strength in the vicinity of the part's surface, and facilitates penetration of Faraday-cage areas by reducing voltage at the tip of the gun in proportion to the reduction in gun-to-part distance.

Figure 13 shows two conventional corona guns coating different areas of the same part. Because of the part's profile, one gun is spraying from a distance of 6 inches and another from 10 inches. On the same figure, one can also see the load lines and current level for each gun. The gun spraying at a 6-inch distance draws more than double the current of the gun spraying at 10 inches. This results in: 1) a significantly greater number of free ions in the space between the gun and part; 2) faster development of back ionization; and 3) lower transfer efficiency, film thickness and finish quality.

Figure 14 shows the same two guns spraying the same part in the ACC mode. Notice that the current levels and number of free ions in the space between the gun and part will be equal for both guns. This results in optimum transfer efficiency and consistent finish quality and uniformity.

To summarize, automatic control of the gun current delays the development of back ionization and: 1) optimizes the powder coating process by controlling the number of free ions generated at the tip of the gun and the field strength at the part's surface; 2) results in the maximum attainable transfer efficiency over a broad range of gun-to-part distances; 3) facilitates penetration of recessed areas; 4) improves finish quality and uniformity; and 5) enhances recoating operations.

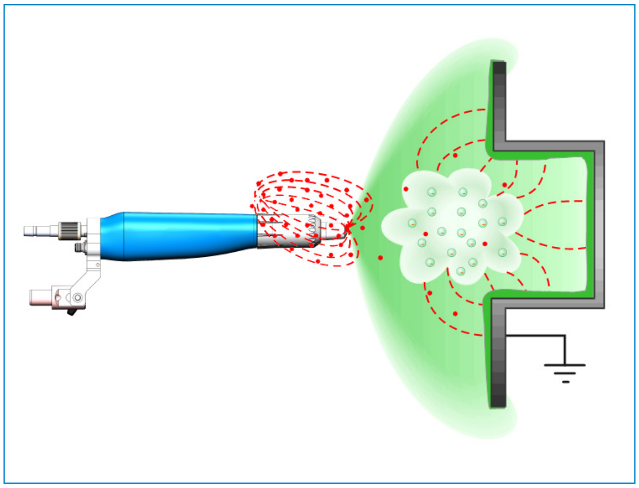
Although one current setting still may not be optimum for all applications, modern PLC process controllers further enhance the efficiency of powder coating operations by allowing automatic adjustment of the current settings depending on the powder flow rate, conveyor speed and other operating parameters.

Free-Ion Collecting Device

The principle behind the operation of ion collecting (IC) device is that it extracts free ions out of the space between the gun and a part, and draws them to a grounded collector electrode positioned behind the tip of the gun (see Figure 15).

When a conventional corona gun is equipped with an ion collector, a grounded electrode is positioned behind the end of the gun at a distance shorter than the one between the gun and part. The fact that a grounded IC device is closer to the tip of the gun than the surface of the part implies that the electric field, following the shortest path to the ground, will develop between the gun's electrode and ion collector, and not between |the gun and part. As a result, the electric field in the vicinity of the part's surface will be created only by the space charge of the cloud of charged powder particles. This field will be weaker than that is achieved with a conventional corona gun because we eliminate (or greatly reduce the effect of) the high voltage at the tip of the gun. However, if the powder is well charged, transfer efficiency will not suffer while the ability to penetrate recessed areas will be greatly enhanced.

Figure 15



Since the electric field created by the gun no longer goes to the part, free ions generated by corona discharge will follow the field lines to the grounded ion collector. This means that, depending on how the ion collector is set up, there will be either virtually no free ions in the space between the gun and part, or their number will be greatly reduced.

The ability to adjust the distance between the tip of the gun and the ion collecting device is very important. The easiest rule of thumb to follow in setting a free-ion collecting device is to place it behind the tip of the gun at no more than half the distance between the gun and part. Following this rule ensures that most of the electric field and free ions created by the gun's electrode go to the ion collector. If the ion collector is properly set up, it will often deliver impressive results in improving Faraday-cage penetration, and finish quality and uniformity. Multiple field installations also report dramatic improvements in the ease of recoating operations.

In many applications the use of ion collecting devices may be even more effective in reducing back ionization and coating recesses than the use of ACC control. However, caution should be exercised when deciding to use ion collectors since the range of gun-to-part distances at which ion collectors can be used with maximum effectiveness is limited. For the maximum effectiveness in collecting free ions, the ion collector should be positioned behind the tip of the gun at no more than half the distance between the gun and part.

Therefore, if the gun-to-part distance is 8 inches, the ion collector will not only be effective in collecting free ions but also produce maximum transfer efficiency if positioned at about 4 inches behind the gun's electrode (see Figure 16). For 10 inches between the gun and part, such performance will be achieved at 4 to 5 inches to the ion collector. But, if we are spraying parts with the gun-to-part distance of 4 inches, the ion collector would have to be placed only 2 inches behind the end of the gun. Unfortunately, at such close distances between the charging electrode and ion collector device, transfer efficiency of the application process is likely to suffer.

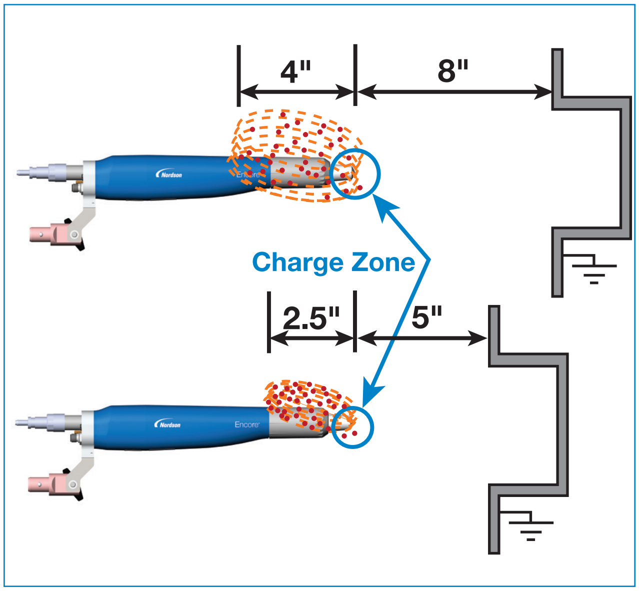
Reduction in transfer efficiency is likely to occur with ion collectors placed too close to the tip of the gun because of changes in the size of the charge zone. In conventional corona applications, powder particles and free ions travel in the same direction from the gun to the part. This extends the time during which powder particles can be charged by ions. With an ion collecting device in use, powder particles travel toward the part while ions go back to the collector. This motion in opposite directions produces a good blending of ions with powder particles when an ion collector is set up properly. In addition, closer proximity of the grounded ion collector to the charging electrode (compared to the part) results in higher gun current level, greater number of ions, and greater likelihood of each powder particle being impacted by them. However, the time powder particles spend within the zone densely populated by ions is reduced.

Figure 16 illustrates that the size of the densely packed ions area around the charging electrode gets smaller when the ion collector is moved closer to the gun. In other words, at very close distances the size of the charge zone will be so small that the time powder particles spend passing through it will not be sufficient for optimum powder charging. This will result in lower transfer efficiency.

Based on the arguments presented here, the use of free ion collectors may not be very effective at gun-to-part distances of less than 4 to 5 inches. In general, ion collecting devices are practical and highly effective when gun-to-part distance is relatively fixed and at least 5 inches.

The use of ion collecting device on manual guns is also limited due to human nature. Because of the fact that manual operators usually move the gun closer to the part when trying to coat recessed areas, the likelihood of the gun-to-part distance becoming shorter than the distance to the ion collector is very high. This leads to a great reduction or even cancellation of any positive effect of the ion collector. If the gun-to-part distance varies rather significantly either from part-to-part or within one part, automatic control of the gun current may represent a more effective and easy to use tool because of its automation.

Figure 16



Conclusion

In this paper we have established that the excessive number of free ions generated by conventional corona charging equipment is the reason behind such powder coating challenges as Faraday-cage penetration, recoating of rejects, and improvement of finish quality and uniformity. With the increasing demands for greater coating efficiency and finish quality, powder coating equipment suppliers continue advancing the technology by offering to the market new equipment features. Unfortunately, a single solution to all challenges that would work in every type of application has yet to be found.

Although automatic current control and ion collecting devices provide finishers with powerful tools to optimize their powder coating operations, such optimization can only be realized if the proper tool is used for the right application. Knowledge of the basics of electrostatic technology will help finishers make the correct decision about which features of equipment will bring them closest to meeting their optimization goals.

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