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Understanding Electrostatic Finishing

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Electrostatic finishing today, like television, is taken for granted. Every finisher knows that electrostatic paint application has many advantages, including transfer efficiency, VOC reduction and finish quality. However, many finishers may be unaware of some of the electrical principles behind electrostatic finishing. Modern electrostatic finishing equipment ranges from manual and automatic spray guns to high-speed rotary bells and disks.

How do electrostatic finishing systems operate? Why select an electrostatic system for a particular application? A knowledge of the basics of electrostatics can help answer these questions.

Electrostatic fundamentals

Electrostatic finishing got its start in the early 1950s. Coatings engineers needed an application method that would significantly increase transfer efficiency and reduce finishing costs. They reasoned that since unlike electrical charges are attracted to each other, the same would apply to charged spray coatings and a part to be painted. They discovered that by negatively charging the atomized paint particles and positively charging the workpiece to be coated (or making it a neutral ground), an electrostatic field is created that pulls paint particles to the workpiece.

The electrostatic field is similar to the magnetic lines created when metal filings are deposited on a piece of paper and a magnet is placed under it; the filings line up according to the lines of magnetic force.

With a typical modern electrostatic spray gun, a charging electrode is located at the tip of the atomizer. The electrode receives an electrical charge from a power supply. The paint is atomized as it exits past the electrode, and the paint particles become ionized (pick up additional electrons to become negatively charged) (Figure 1).

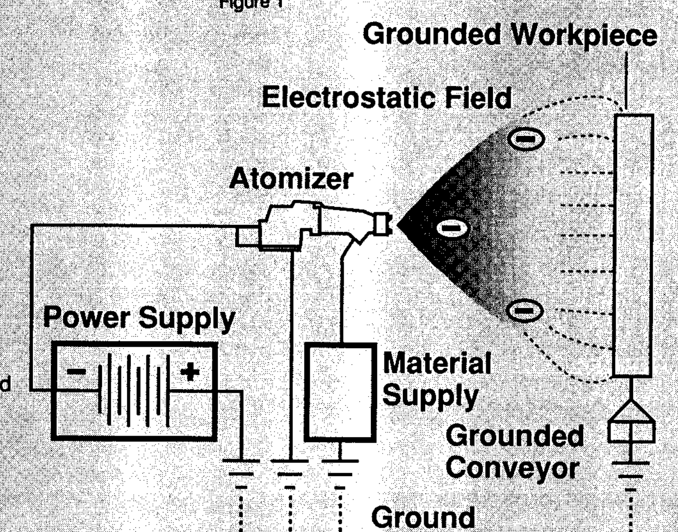
An electrostatic field is created between the charging electrode and the grounded workpiece. The negatively charged paint particles are attracted to the neutral ground. As the particles deposit on the work, the charge dissipates and returns to the power supply through the ground, thus completing the electrical circuit. This process accounts for the high transfer efficiency. Most of the atomized coating can end up on the part.

The degree to which electrostatic force influences the path of paint particles depends on how big they are, how fast they move and other forces within the spray booth, such as gravity and air currents. Large particles sprayed at high speed have great momentum, reducing the influence of the electrostatic force. A particle's directional force inertia can be greater than the electrostatic field. Increased particle momentum can be advantageous when painting a complicated surface, because the momentum can overcome Faraday cage effect (the tendency for charged paint particles to deposit only around the entrance of a cavity) (Figure 2).

On the other hand, small paint particles sprayed at low velocities have low momentum, allowing the electrostatic force to take over and attract the paint onto the work. This condition is acceptable for simple surfaces but is highly susceptible to Faraday cage problems. An electrostatic system should balance paint particle velocity and electrostatic voltage to optimize coating transfer efficiency.

Humidity needs to be controlled on an electrostatic finishing line. High humidity can make an electrical charge leak off into the air, decreasing the charge on paint particles and lowering transfer efficiency.

Figure 1



An electrostatic field influences the path of paint particles. The particles pick up electrons when atomized and become negatively charged.

Advantages

The chief benefit offered by an electrostatic painting system is transfer efficiency. In certain applications electrostatic bells can achieve a high transfer efficiency exceeding 90%. This high efficiency translates into significant cost savings due to reduced overspray. A phenomenon of electrostatic finishing known as "wrap" causes some paint particles that go past the workpiece to be attracted to the back of the piece, further increasing transfer efficiency.

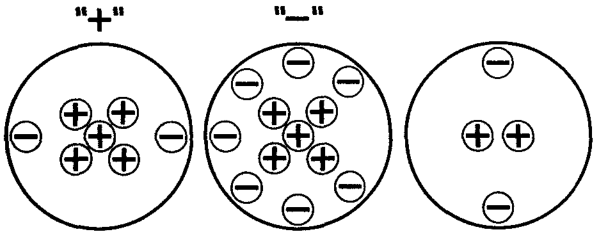
Increased transfer efficiency also reduces VOC emissions and lowers hazardous waste disposal costs. Spray booth cleanup and maintenance are reduced.

Rotary atomizers

The development of low- and high-speed rotary atomizers has been a significant advancement in electrostatic

Electricity and How It Works

The basic building block of electrical energy is the charged particle. All matter is made from electrically charged particles. These particles are either neutral, negative or positive.



Positively Charged Particle **Negatively Charged Particle** **Neutral Particle**

A neutrally charged particle has an equal number of protons (positive charges) and electrons (negative charges). A negatively charged particle has more electrons than protons. A positively charged particle has more protons than electrons.

Particles with equal like charges, such as two with equal positive charges, will repel. Particles with unlike charges or with unequal like charges will attract. This principle is easy to verify with two magnets. Like poles of each magnet repel each other when placed together; the opposite poles are attracted.

Both positively and negatively charged particles are attracted to a neutral "ground," also known as an "earth," because the earth has the capacity to absorb (supply) vast numbers of electrons.

The basic elements of a circuit make electrical energy possible. These elements include a source that can generate electricity, a means of conducting the flow of electrons to the user (in this case, an electrostatic gun) and a means of completing the circuit (the flow of electrons back to the power source).

Electrical conductors are generally made of metals such as aluminum and copper. Water is also a conductor. These materials are comprised of atoms having at least one "free" electron. A free electron is not tightly bound to its atom; it is free to move from atom to atom when affected by a voltage (electromotive force). Electrical current is produced when these free electrons are forced to "flow" through a conductor, very much like water flowing through a pipe.

In some instances, the conductor is protected by an insulator (a material that does not conduct electricity). Insulation is made from a nonconductive material such as ceramic, glass, rubber or plastic. When applied to the conductor, the nonconductor isolates it from materials that conduct electricity. This prevents the circuit from "shorting out."

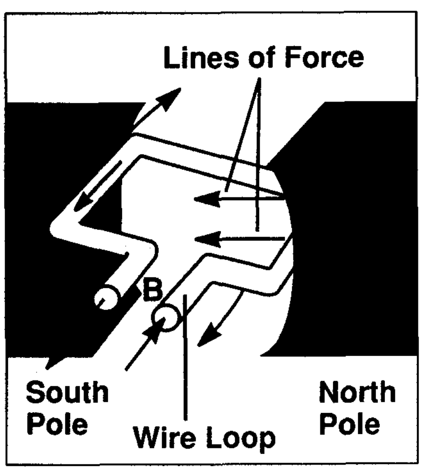
One way to generate electrical energy is by converting mechanical energy into electrical. This principle was discovered by Michael Faraday in 1831. He produced electrical energy by passing a wire coil near a magnet, which he called "electromagnetic induction." A source that produces electricity in this manner is called a generator. Examples include the alternator in a car and the large generators used by utilities to develop electric power. Rotating a wire loop between two magnets generates electrical current, causing free electrons to flow.

Voltage can be likened to pressure in a water system. The greater the pressure, the more force the system has to push water through the pipes. With electrical circuits, the higher the voltage, the more force it has to move electrons through the conductor. With enough voltage, almost any material can become a conductor. Air, for example, is not considered to be a conductor, but during a thunderstorm the extremely high voltages generated by clouds make air a conductor, and lightning is the result. Amperage describes how much electricity is flowing.

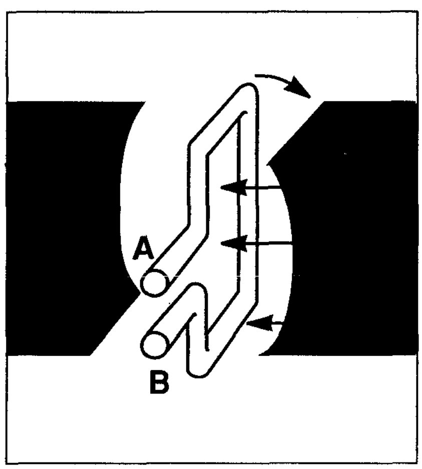
Electricity and electrostatic finishing

An electrostatic painting system operates at from 30,000 to 150,000 volts (30 to 50 kV). Its amperage is very low, usually less than 500 microamps (5/10,000 of an amp). Although the voltage is high, the rate at which it flows is very low.

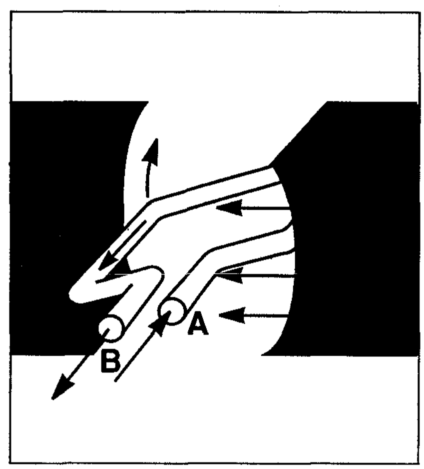
The high-voltage, low-current condition found in electrostatic systems causes a far lower risk of hazardous electrical shock than situations using household current. Normal household current has only 115 volts, but can flow at 15 amps or more, enough to give a serious electric shock if a bare wire is accidentally touched. Electricity generated while walking across a household carpet may produce 8000 to 12,000 volts but will only give a mild shock.



The current flows from point B to point A through the loop when the wire is rotated clockwise, as shown above.



No electricity is generated in the loop in this diagram because the wire does not cut through the lines of force.



The current reverses as the wire makes the second half of the turn. The current flows from point A to point B.

finishing. Some systems use rotating disks; others, bells. The bells incorporate an air turbine that drives the bell.

Low-speed rotary atomizers are very efficient because they rely almost exclusively on electrostatic force to atomize the coatings. The rotating disk or bell distributes a thin, even coating to the atomizer's edge, where electrostatic force tears off tiny paint particles and applies a negative charge. Low-speed disks and bells operate in the 600-rpm range, slow enough for the electrostatic field to attract the particles to the workpiece. This atomization is known as true electrostatic atomization.

Disks on low-speed atomizers can be as large as 25 in. in diam; bells, as large as 12 in. Disks are positioned with their axis vertical so the coating can be applied at right angles to the workpiece; bells are mounted with their axis horizontal so they can apply the coating directly.

Low-speed rotary atomizers have some drawbacks. They require coatings with low viscosities (usually less than 30 sec Zahn No. 2), low surface tension and the right balance of electrical characteristics. They are very susceptible to edge buildup and Faraday cage problems. Fluid flow rates are limited to 100 cc/min/in. of disk circumference, a coating capacity of about 13 oz/min for a 12-in.-diam disk.

High-speed rotary atomizers have overcome many of the limitations of low-speed atomizers. Modern disks and bells are smaller than the low-speed rotary type, only 5 to 8 in. for disks, 1 to 3 in. for bells. The small size allows operation at high rotational speeds: up to 30,000 rpm for disks and 60,000 rpm for bells.

High-speed atomizers operate on the same principle as low-speed, but they rely on centrifugal force to atomize the coatings. At high rotational speeds, the coating is literally spun off the disk or bell to form tiny particles. This provides high particle velocities to overcome most edge and corner problems.

At high speeds atomization is almost completely insensitive to voltage and coating electrical characteristics. This means that high-speed disks and bells can handle coatings with viscosities in excess of 30 sec Zahn No. 3.

The only drawback with high-speed rotaries appears to be the equipment's limited ability to penetrate inside corners and recesses successfully. The workpiece may require more touchup with high-speed rotaries than with some other methods, depending on the shape of the work.

Air/airless spray

Air and airless electrostatic spray guns rely on air or fluid pressure for atomization. The force of this type of atomization increases particle speed and penetration into corners and recesses, the traditional weak spots for electrostatic finishing. A typical high-speed bell may produce a particle forward velocity between 20 and 60 ft/sec as measured 3 in. in front of the bell. An air spray electrostatic gun produces a forward velocity between 100 and 300 ft/sec. The gun also produces a large paint particle, which in combination with increased velocity, improves penetration. Hand-held guns operate at 20,000 to 80,000 volts; automatic systems, 80,000 to 125,000 volts.

The major drawback with air and airless systems is overall transfer efficiency, which is less than high-speed rotaries. This is due to the manner in which coating particles are charged as well as to high momentum forces. Air and airless systems that use conductive coatings apply most of the charge after the coating is atomized, rather than directly as the coating is being atomized. The charging electrode is positioned in front of the atomizing zone and uses high voltage to create a "cloud" of charged air molecules. The coating particles become charged indirectly as they collide with the air molecules. The high particle velocity from a gun tends to increase overspray but can increase transfer efficiency when coating parts with lots of corners and recesses.

Powder guns

Electrostatic guns for applying powder coatings operate under the same principle as conventional electrostatic guns for liquid coatings. The powder particles are propelled by the air pressure, with the negatively charged powders (positive in a tribocharged gun) attracted by the grounded workpiece. After application, the coated part is transferred to an oven where heat fuses the powder to form a smooth finish.

A feeder unit supplies powder to the guns. The feeder uses an air circulation system that keeps the powder in a suspended state, causing the powder to act like a fluid. This circulation system is known as a fluidized bed or powder hopper. Powder overspray is sometimes collected and returned to the feeder for reuse.

External and internal charging guns are available for powder application. External charging guns use an electrode at the tip that creates an electrostatic field in front of the gun. Powder enters the field and receives a negative charge.

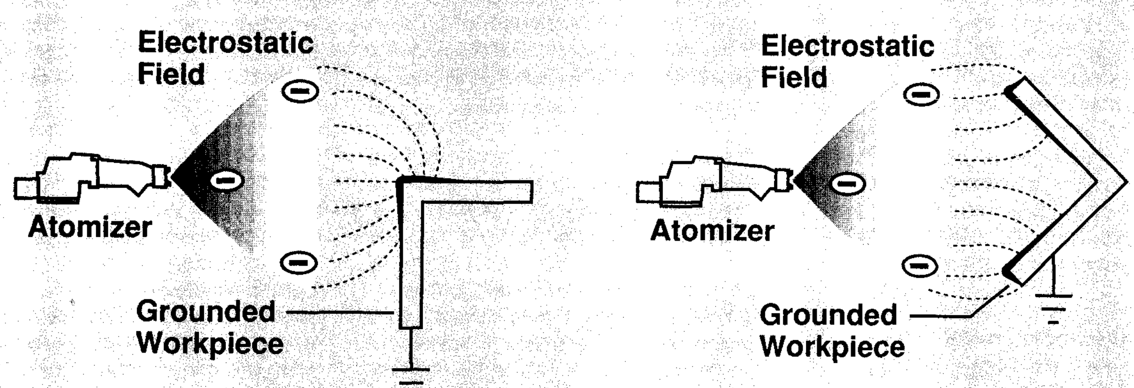
Internal charging guns create the field inside the gun, and particles receive a charge as they pass through. An example of this is the tribo-electric gun. Powder particles receive a charge through friction on an insulator inside the gun.

Applying liquid coatings

Any material that can be atomized can accept an electrostatic charge. Low-, medium- and high-solids solvent-

Figure 2

Faraday Cage Effect



Paint particles are attracted to the edges of a workpiece while avoiding inside corners and recesses.

borne coatings, enamels, lacquers and two-component coatings can be applied electrostatically.

The various types of electrostatic systems can apply coatings regardless of their conductivity. Waterborne and metallic coatings can be highly conductive. Solventborne coatings tend to be nonconductive. Metallic coatings can contain conductive metal particles with rough or sharp edges. These must be kept in circulation to prevent a short circuit in the feed line. As high voltage is introduced into the system, the metal particles can line up to form a conductive path. System modifications may be required because of coating conductivity to prevent the charge from shorting to ground.

Applying powder coatings

Even though liquid and powder coatings can be sprayed electrostatically, there is a major difference in the way they adhere to the surface of a workpiece. As a liquid particle reaches a workpiece, its charge is absorbed by the work as the coating flows over the surface. The workpiece will continue to attract negatively charged paint particles.

As powder reaches a surface, it will retain a charge. If it did not, the powder would fall off the workpiece. The charge will dissipate as the powder fuses into a coating in the curing oven. This characteristic makes it difficult to apply thick films of powder. The negatively charged powder particles will begin to repel incoming particles as they build up on the workpiece surface. One way to avoid this is to preheat the workpiece before coating it. The first particles will fuse and flow as they reach the surface, dissipating their charges and allowing subsequent particles to be attracted to the surface.

Safety

Electrostatic finishing can be safe if equipment is maintained properly and safety procedures are followed. All items in the work area must be grounded, including the spray booth, conveyor, parts hangers, application equipment (unless using conductive/waterborne coatings) and the spray operator.

As electrical charges come in contact with ungrounded components, the charges can be absorbed and stored. This is known as a capacitive charge buildup. Eventually, enough charge is built up so that when the ungrounded item comes within sparking distance of a ground, it can discharge as a spark. Such a spark may have enough energy to ignite the flammable vapors and mists that are present in the spray area.

An ungrounded worker will not know that the capacitive charge has been absorbed until it is too late. Workers should never wear rubber- or cork-soled shoes, which can turn them into ungrounded capacitors. Special shoe-grounding devices are available. If workers are using hand-held guns, they should grasp them with bare hands or with gloves with cut-outs for fingertips and palms that allow adequate skin contact.

Proper grounding of all equipment that is not used for the high-voltage process is essential. Grounding straps should be attached to equipment and connected to a known ground. A quick inspection of all equipment, including conveyors and part hangers, can reveal improper grounding.

Good housekeeping can pay dividends. Removing paint buildup from parts hangers can help ensure that workpieces are grounded. Ungrounded objects such as tools and containers should be removed from the finishing area.

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