AUTOMATIC ELECTROSTATIC PAINT SYSTEM FOR AUTOMOTIVE COMPONENTS

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Introduction

Plastic parts are a growing segment of the automotive components industry. This paper discusses finishing methods and automated systems that can improve finish quality, speed production and reduce paint usage. The precise paint application of today's automated paint systems can minimize paint waste, and reduce the release of VOC emissions.

Pretreatment of Plastics

As with any other substrate to be painted, plastic components require cleaning prior to painting. The typical soils that must be removed are shop and material-handling dirt, machining oils, plastic sanding dust, fingerprints, and mold release.

With today's high production speeds, conveyerized spray washers are the most acceptable method for cleaning. A minimum of three stages are necessary, but five stages are preferred. The cleaner the part is, the better the paint finish will be.

The last stage of cleaning is usually a water rinse with a conditioning chemical to prevent water spotting. The part should be conveyed to a drying oven to ensure that the part is completely dry. This is a critical issue, particularly if you are painting with waterborne coatings.

Some plastics such as RIM (reaction injection molded polyurethane) contain an internal mold release, which may require special processing. These materials can be cleaned in the automated washer, but care must be taken during the oven drying process. The surface temperature of the part in the dry-off oven must be lower than the surface temperature of the post-cure oven. This will prevent the internal mold release from migrating to the surface before painting.

In the past, adhesion of paint to some plastics was a major problem, which required the use of various types of acid treatments prior to painting. However, with today's adhesion promoter coatings and prep coats, this problem has been resolved.

Paint Kitchens

The design of the paint kitchen is an important consideration for the paint system. Ideally, each of the primary, frequently used colors should have a dedicated pumping system. Dedicated fluid tubing should run from the paint kitchen to the spray booth area and back to the paint kitchen for circulation. With this design, color changes do not require flushing of the pump and paint lines.

The paint kitchen requires access with a forklift to move new drums of paint in and empty drums out. If a large volume of one color is used, it may be more efficient to use tote tanks instead of 55-gallon drums. The totes are available in containers that are much larger than drums, which can eliminate daily change-out.

The pumping system should be designed with run-away valves, which turn off the pump when the paint drum empties. Without this safeguard, the pump can be damaged by siphoning air. With run-away valves, the pump is shut off once pressure differential is sensed. The pump will also shut off if there is a break in the paint hose, preventing paint from pumping into the work area.

Check valves should also be installed on the pumps. This will minimize pump "wink," which are momentary drops in pressure caused by the reversing strokes of the pump piston.

All circulating systems should include a proper filtering system to prevent clogging of the spray devices. Heaters should be used to maintain the paint at a constant temperature, winter or summer. This removes one variable parameter that can affect paint system performance.

A major design criteria in paint kitchens is to ensure that pressure drop calculations are run prior to sizing the fluid lines from the kitchen to the spray booths. The size of the fluid lines should be based on the paint volume and minimum pressure required at the last spray device in the paint system. A considerable amount of pressure drop can be caused by elevations, tees, elbows and other spray equipment. If the lines are too small, there may not be enough paint volume or pressure for the last spray device.

Finally, supply and return lines for all paint kitchens installed today should be stainless steel. This will allow for a much faster and less costly conversion to waterborne paints if they are required in the future.

The Automated Finishing Line

Today's automotive component paint finishes are typically applied in the following steps:

1. Primer coat
2. Base or color coat
3. Color match (metallic finishes)
4. Clear coat

Each step has its unique requirements for application equipment, film builds and application techniques. This paper will discuss the spray equipment required for the most efficient paint application. A typical automated paint system is illustrated in figure 1.

Primer Application

Unlike metal, plastic is generally non-conductive. Plastics can be formulated with conductive pigments to allow the parts to be sprayed electrostatically. But in most cases, non-conductive plastic parts are sprayed with conductive prep coat solutions or primers prior to painting.

The primers are also called adhesion promoters, and are usually applied with thin, dry-film builds of 0.4 mil. These primers can be applied automatically using air-electrostatic spray guns or rotary atomizers.

The use of reciprocators with mechanical toeing (figure 2) angles the spray guns toward the part in upward and downward strokes. This allows for improved painting on the tops and bottoms of parts.
Although the part has no conductivity as it enters the prime booth, the wet primer from the first spray gun in the line makes the parts conductive. Coating from subsequent guns on the line will then be electrostatically attracted to the parts.

The choice of air-electrostatic guns or rotary atomizers is dependent upon the product configuration. With the air-electrostatic guns, the high-velocity (approximately 10 meters/second) drive air behind the paint and the smaller fan pattern provide better penetration of paint into part recesses than is achievable with rotary atomizers—particularly with non-conductive parts. However, if deep recesses are not prevalent, rotary atomizers may be the best choice for the primer application. In combination with the toeing feature of the reciprocators, primer can be applied to all areas of the part.

**Base Coat Application**

The base coat is applied with rotary atomizers mounted on oscillators. The atomization of the paint takes place through centrifugal force. The paint is pumped onto the rotary cup which is spinning at speeds of approximately 30,000 RPM. The high-speed cup propels the paint into the air, and breaks the paint into fine particles, or atomized. A small amount of shaping air (approximately 0.7 meters/second) is directed toward the atomized paint to direct the circular spray pattern toward the product.

The particle size of the rotary-atomized paint droplets are much smaller than gun-atomized paint droplets (figure 3). The rotary-atomized paint droplets are also very consistent in size, which results in a smooth, uniform coating.

<table>
<thead>
<tr>
<th>Method</th>
<th>Particle Velocity</th>
<th>Average Particle Size</th>
<th>Particle Size Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airspray</td>
<td>10 meters/second</td>
<td>3.0 mils diameter</td>
<td>0.5–5.0 mils dia.</td>
</tr>
<tr>
<td>Rotary Atomizer</td>
<td>0.7 meters/second</td>
<td>0.8 mils diameter</td>
<td>0.6–1.0 mils dia.</td>
</tr>
</tbody>
</table>

The oscillators move the atomizers in short, vertical strokes to blend the fan patterns. Two coats are usually applied to slowly build the film thickness and achieve the required appearance.

Film builds for base coats will vary depending on the color. For example, a royal blue finish may need a dry film build of only 0.9 to 1.1 mils due to the dark paint's hiding power. However, a white finish could require a dry film build of 1.2–1.4 mils.

Each color booth station is outfitted with rotary atomizer speed controllers, pneumatic controls, trigger solenoids, and color-change manifolds, which house all of the automatic color-change parameters. The color-change manifolds are mounted inside the spray booths as close to the rotary atomizers as possible to minimize color change time and material waste.

All of the application devices such as the guns and rotary atomizers are controlled (triggering, shaping air, fluid flow, rotary speeds, etc.) through programmable controllers, which will be discussed later.

If the base coat is not metallic, the part is conveyed directly to the clear coat application station.
Metallic Coatings

If the base coat is a metallic paint, a non-electrostatic application station is needed prior to application of the clear coat. Without this station, the part will not match the body color of the vehicle.

As illustrated in figure 4, when metallic particles are applied electrostatically, they align themselves vertically to the surface of the part. This gives the color a darker appearance, and reduces the reflectivity of the metallic particles.

To overcome this effect, a non-electrostatic station applies a small amount of paint on the parts. The non-electrostatic application aligns the metallic particles parallel to the surface of the part (figure 5).

The non-electrostatic station consists of conventional air-spray guns mounted on a reciprocator. The station is also equipped with automatic color changers. All of the functions, including automatic color change and gun triggering are operated with the computer controls.

![Figure 4: Metallic Particles with Electrostatics](image)

![Figure 5: Metallic Particles without Electrostatics](image)

Clear Coat Application

As with the base coat, the clear coat finish is applied “wet on wet.” A flash time is needed between stations, but baking the finish between coats is not required. The clear coat is applied in a similar fashion to the base coat. Rotary atomizers are used to apply a smooth finish with minimal overspray. Two spray stations are generally used to build the proper dry film thickness.

Typical dry film builds required for clear coats are approximately 1.5–2.0 mils. The final coat provides a high gloss and protects the color coat finish. These stations are also computer controlled.

Automated Control System

The control system manages nearly all of the fluid dispensing variables involved in the painting process. It can be designed to identify different part sizes and adjust the spray pattern for optimum coverage and paint efficiency. It can automatically perform color changes between parts, and even adjust paint flow rates to accommodate the difference in hiding power between colors.

There are several part identification methods that can be used in an automated control system. The selection should be based on the type of conveyance system, the complexity of the part shapes and the number of painting system variables you would like to have controlled.

For example, detection devices such as light curtains and laser beams can detect the size and shape of parts as they enter the spray booth. The spray devices will trigger on automatically, and only for the duration needed to coat the part. Other parameters, such as flow rates to all of the spray devices, rotary atomizer speeds, shaping air pressures and atomizing air are programmed into the system for optimum paint coverage.

Other part identification methods can provide even more information to the automated control system. Photo cells and bar coding systems can identify specific part profiles and color requirements. Spray parameters for the spray devices and gun movers can automatically adjust, depending on the specific part configuration.

With a recipe-management type of control system the operator enters the product identification numbers for the various products to be run that day. When the computer receives the identification number, it downloads the recipe for that part. This recipe has all the settings required to properly paint that part.

Information from the detection device is relayed to the programmable controller, which precisely activates and de-activates the application equipment based on the preset parameters.

Preceding any group of parts to be painted is a style-change flag (figure 6), which is hung from the conveyor. When a photo cell detects this flag, the programmable controller requests the recipe information from the recipe management computer, and proceeds to set the system parameters according to the recipe.
For example, all of the settings below (figure 7) would be adjusted automatically, without operator intervention.

<table>
<thead>
<tr>
<th>Paint Color</th>
<th>Flow Rate</th>
<th>Turbine Speed</th>
<th>Shaping Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>3.6 oz/minute</td>
<td>22,000 RPM</td>
<td>20 lbs.</td>
</tr>
<tr>
<td>Black</td>
<td>2.9 oz/minute</td>
<td>30,000 RPM</td>
<td>15 lbs.</td>
</tr>
</tbody>
</table>

**Automated System Cost Savings**

Fluid delivery flow computers, which regulate I/P transducers, precisely control the paint delivery rate. By controlling the flow rate, paint can be applied to specified film thicknesses.

Without automatic fluid delivery, the operator regulates the flow by physically turning a regulator. The delivery rate will be inconsistent, and based on either the operator’s visual inspection or a later measurement of dry film builds.

In most cases, the manually adjusted fluid delivery rate will result in more paint on the parts than is needed.

As seen in figure 8, an increased film build of just .2 mil for each application can increase paint costs significantly. These costs are derived from an existing paint shop based on current production and paint costs.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Actual Coverage</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhesion Promoter</td>
<td>0.4 mil</td>
<td>0.6 mil</td>
</tr>
<tr>
<td>Color Coat</td>
<td>1.4 mil</td>
<td>1.6 mil</td>
</tr>
<tr>
<td>Clear Coat</td>
<td>1.6 mil</td>
<td>1.8 mil</td>
</tr>
<tr>
<td>Paint Cost</td>
<td>$2,579,950</td>
<td>$3,444,310</td>
</tr>
</tbody>
</table>

In this example, $864,360 is added to the company’s paint costs each year due to the excess paint coverage.
Paint usage is also reduced due to the automated triggering of the rotary atomizers and spray guns. The spray device triggers on only when there is a part in front of it, and triggers off once the part has passed. Since paint is not sprayed between parts, overspray is reduced substantially.

Automatic color changes are timed to minimize the amount of solvent that is dumped to waste. They can also take place sequentially for the highest productivity. For example, the first booth in a two-booth coating system will change color as the second booth finishes the batch. This reduces the amount of open conveyor space needed for color changes, which increases productivity.

Figure 9 is a comparison of the actual paint costs for a manufacturer of plastic automotive exterior components before and after installation of an automated paint system.

<table>
<thead>
<tr>
<th></th>
<th>Manual System</th>
<th>Automated System</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parts painted per year</td>
<td>8,160,000</td>
<td>8,160,000</td>
<td>0</td>
</tr>
<tr>
<td>Parts painted per gallon</td>
<td>75</td>
<td>340</td>
<td>+265</td>
</tr>
<tr>
<td>Paint cost per gallon</td>
<td>$50</td>
<td>$50</td>
<td>$0</td>
</tr>
<tr>
<td>Paint cost per year</td>
<td>$5,440,000</td>
<td>$1,200,000</td>
<td>$-4,240,000</td>
</tr>
</tbody>
</table>

System Diagnostics
Automated control systems can be programmed to provide a variety of diagnostic functions. The diagnostics can be programmed to simply display the fault on the screen, sound an audible warning, or take specific action such as shutting down all or part of a system.

Examples of these recognitions and diagnostics:
1. Reciprocator/oscillator operation
   Proximity switches in reciprocators and oscillators can alert the PLC when the devices malfunction.

2. Conveyor operation
   Encoders can be read by the conveyor interlock, and send an alarm if there is an unscheduled conveyor stoppage.

3. Booth air monitoring
   A differential pressure switch will monitor air flow. If the booth is not operating, the system will not allow paint to be sprayed. Functions of this type can also satisfy codes set by the National Fire Protection Association.

4. Electrostatic power supply status
   The system indicates which power packs are powered up and whether a fault condition exists.

5. Rotary atomizer status
   The programmable controller sends warnings for bearing air loss, loss of speed signal, and overspeed of turbines.

Process Reporting
Automated finishing systems can include report functions. Information can be processed with conventional personal computer software to enhance statistical process control procedures. Process reporting can also identify areas where system productivity and efficiency can be improved.

Examples of some reports available are:
1. Alarm History
   The contents of the alarm log file are printed and categorized as required. This report helps identify ongoing system faults so corrective action can be taken.

2. Production Report
   Information regarding the number of parts coated per batch, per shift and per day can be captured and analyzed. Related information, such as start and stop times between batches is also retrievable.

3. Paint Usage Report
   The amount of primer, color and clear coat for each batch is captured in the system. The amount of coating per part can be compared with specifications and adjusted for more efficient paint usage.

4. VOC Emissions Report
   Based on the amount of paint used and the paint’s VOC content, the programmable controller can calculate the amount of VOCs released. A report can be generated to help meet EPA requirements.

   The programmable controller can also control and monitor oven temperature, conveyor speeds, pre-treatment washer devices such as level controls, recirculating pumps, heaters, gas safety shut-off valves, combustion air flow switches, and exhaust motors.

   Systems can also include flow metering devices on the touch-up spray guns. Manual spray operators can set the spray guns for the proper flow rates, which prevents the operators from spraying excess paint. The flow rates are monitored on the supervisor’s computer to guard against unauthorized changes. The system can also send an audible alarm or blinking light in the event of flow rate changes outside of optimum settings.

Conclusion
Today’s automated paint systems are bringing finish quality, operating productivity and paint savings to a higher level than ever before. These systems are helping automotive component manufacturers meet growing challenges to increase operating productivity, enhance product quality and meet environmental regulations.

Automatic paint systems can range from a simple single-gun operation to a fully integrated control station. But regardless of the system type, the ultimate goal is to apply paint with uniform film thicknesses, minimal paint overspray, reduced rejects and higher productivity. By selecting the correct system for your operation, you will improve control of your finishing line, and achieve a fast payback on equipment costs.