Electrostatic Spray Coating Equipment

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Conventional air atomizing spray guns have been the primary method of applying paint in industry for over 60 years even though transfer efficiency (TE) averaged only 24%. Choosing new spray equipment to solve today's complex environmental problems is a monumental task. The data needed to support a proper decision is not readily available.

California's South Coast Air Quality Management District (SCAQMD) attempted to pin down one set of variables by establishing the transfer efficiency for various application methods in the wood furniture and cabinet coatings industry under their Rule 1136. The figures they established are given in Table I. The figures they established are given in Table I.

Table I. SCAQMD Established Transfer Efficiency for Various Application Methods

<table>
<thead>
<tr>
<th>Application Method</th>
<th>Transfer Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional air spray</td>
<td>24%</td>
</tr>
<tr>
<td>Airless spray</td>
<td>40%</td>
</tr>
<tr>
<td>Heated airless spray</td>
<td>40%</td>
</tr>
<tr>
<td>Air assisted airless spray</td>
<td>40%</td>
</tr>
<tr>
<td>CFA air spray</td>
<td>65%</td>
</tr>
<tr>
<td>Dipping</td>
<td>90%</td>
</tr>
<tr>
<td>Roller coat, wipe or brush</td>
<td>95%</td>
</tr>
<tr>
<td>Electrostatic disk or bell</td>
<td>85%</td>
</tr>
<tr>
<td>Electrostatic air spray</td>
<td>70%</td>
</tr>
</tbody>
</table>

Rule 1136 calls for a minimum of 40% transfer efficiency. This eliminated conventional air spray but the balance of the application methods were acceptable. The new amendments being proposed will raise the transfer efficiency to 65%. This will probably eliminate all nonelectrostatic guns and some electrostatic guns.

CONVENTIONAL AIR SPRAY, 24% TRANSFER EFFICIENCY

Conventional air spray guns have long established the standard of quality for the spray painting industry. Their only real weakness is transfer efficiency. To achieve top quality of finish, the paint must be atomized into very fine particles. Unfortunately, the small particles are more likely to become airborne and are more likely to get wasted by an increase in overspray. The waste increases substantially for the higher viscosity waterborne and high solids environmental coatings as well since much more atomizing air is needed. Because of their low transfer efficiency, this class of guns is barred for use by South Coast Air Quality Management District code requirements. It is gradually being phased out in all coating operations around the country.

AIRASSISTED AIRLESS SPRAY, 40% TRANSFER EFFICIENCY

This class of guns uses paint under very high pressure directed through a shaped orifice to develop a flat fan-shaped spray pattern and to cause atomization into small particles. The particle size is somewhat larger than produced by an air atomizing gun. While this reduces overspray, it also lowers quality of finish somewhat. This atomizer is extensively used in the wood working industry. It is currently barred under Rule 1107 from the metal working industry by California's South Coast Air Quality Management District. While it is currently acceptable under Rule 1136 in the wood working industry, the new proposed amendment to Rule 1136 will eliminate it in that field as well.

Airless spray is not recommended for the highest quality finishes such as required by the automobile, appliance and architectural coatings industries.

HEATED AIRLESS SPRAY, 40% TRANSFER EFFICIENCY

Use of heat lowers paint viscosity and permits applying a higher solids material. Heated airless spray guns, in an automatic electrostatic version, were the very first to apply high solids coatings on a production line basis. A 100% volume solids plastisol material was sprayed on steel casement window frames for several years starting in about 1966. The coating was applied 6-8 mils thick to serve as an insulation material to prevent the steel frames from "sweating" in cold weather. Since the film thickness was very heavy, the paint flowed out very nicely to produce a smooth finish. The film thickness was much too heavy for a decorative coating and would be far more expensive than a thin film. The operating costs would be much too high for most painting operations.

This class of guns is currently accepted under Rule 1136 by California's South Coast Air Quality Management District for the wood working industry. It is barred by failing to reach 65% transfer efficiency in the metal working industry. New amendments proposed for Rule 1136 will bar it from the wood working industry as well.

CFA AIR SPRAY, 65% TRANSFER EFFICIENCY

CFA stands for conical film atomization. One manufacturer defines it as thin film atomization. Paint in this type
of gun is converted from a round, thick stream to a thin film prior to atomization with compressed air. It holds closer tolerances on spray particle size than other spray guns. A thin film is easier to atomize than a round, thick stream of paint so a much lower atomizing air pressure is needed. This reduces forward velocity and improves transfer efficiency.

The gun is normally adjusted to produce the same large particle size as the conventional air gun. This produces equivalent quality of finish. A high percentage of the smaller particles that cause paint waste are eliminated and this improves transfer efficiency without hurting quality. When many of the smaller particles are eliminated, this is frequently interpreted as poorer atomization but the net results are a high percentage of the smaller particles that will produce a paint savings of 65%. This is true only if you disregard film thickness specifications. The efficiency of dipping is overrated and the quality of finish is low. It does have an important advantage over conventional spray at 24% TE, if you can live with the lower quality.

The SCAQMD rates dipping at 90% and this is true only if you disregard film thickness specifications. The efficiency of dipping is overrated and the quality of finish is low. It does have an important advantage over conventional spray at 24% TE, if you can live with the lower quality.

### ROLLER COAT, WIPE OR BRUSH, 95% TRANSFER EFFICIENCY

Roller coating is heavily used in industry. Transfer efficiency is excellent. The quality of finish is somewhat less than with a spraying operation. If the product is sheared and formed after coating, the sheared edges are uncoated and some damage to the paint film can be expected in the forming operation. On heavier gauge metal, the hills and valleys in the sheet can receive different film thickness. On products where roller coating is feasible, it provides a very low cost operation.

### ELECTROSTATIC DISK, 85% TRANSFER EFFICIENCY

Electrostatic disk and bell systems fall into the highest transfer efficiency category shown by the South Coast Air Quality Management District. The CFA air spray electrostatic system also belongs in this category, but it has not been tested by the SCAQMD. It will be discussed as a separate category, however, since it competes more closely with disk and bell systems rather than with conventional air gun electrostatic systems.

A disk applies a flat fan-shaped spray pattern that is directed at the grounded ware from a full 360° circumference around the disk. The spray pattern is similar to many air spray guns, only much longer. It cannot be triggered off for open spaces between pieces, empty hangers or for conveyor openings in a silo type spray booth. It must spray well ahead of the first piece on a production run and long after the last piece. The extra spray directed ahead or after a production run can cause "wrap-sag" on the end pieces. This is frequently overcome by placing a dummy part at the beginning and end of each run. Production runs have occurred with file cabinets, for example, where the dummy cabinets represented 25% of the total production. Every time the cabinet size or color was changed, it was a new production run.

A disk will paint only one vertical height at a time in a given production run. Parts cannot be mixed together by color unless they are the same size.

In the architectural field, with aluminum extrusions hanging vertically, it becomes impossible to touch-up recessed areas because of the excessive long vertical dimension, so a lower quality of finish must normally be accepted. A possible alternative is to run parts around the line twice. Since the baked paint film tends to insulate the easily coated areas, more of the paint reaches recessed areas on the second pass. This, of course, cuts production in half and increases operating costs very substantially.

A reciprocating disk system provides the best overall transfer efficiency under certain specific operating conditions. The product must be relatively small to permit it to pass around a tight conveyor loop in a silo type spray booth. The depth dimension of the product must fall within a narrow range since the conveyor loop cannot be expanded or contracted to provide optimum clearance between the disk and the product being painted. The product must not have recessed areas, since they are poorly painted because of the serious Faraday cage effect of disk systems. This greatly increases costly manual touch-up and lowers the overall performance of the system. Only one
size of product can be run at a given time. Production runs must be very long with a minimum of color changes to be practical. Disks also function much better with solvent base paint and lose some atomizing ability with conductive water borne coatings. Air dry paints may dry on exposed metal disk surfaces and interfere with operation. Metallic paints can interfere with atomization as well.

**ELECTROSTATIC BELL, 85% TRANSFER EFFICIENCY**

Spinning bells provide a totally different production method that really falls into a different category than disk systems. They are mounted in a stationary position or are stacked in a vertical line, one above the other on an oscillating machine. The bell puts out a round doughnut shape spray pattern that provides a nonuniform paint application as shown in Fig. 1.

The figure shows a 2:1 variation in applied film thickness. This is very difficult to correct. It causes a lower quality of finish, poor color matching, excessive manual touch-up and at least 25% more paint consumption than a disk system. The building of excessive film thickness in spots represents paint waste even when the paint is on the product. Reaching 85% of the measured, it is overly optimistic.

A bell system can be triggered off between parts on the line and for empty hangers. It can also be triggered to suit different part heights by selecting the proper number of bells for a given part. Because of the very large vertical spray increments with oscillating bells stacked vertically, it is rare that the spray height is equal to the height of the ware. Overspray at the top, bottom and sides of the ware results in excessive paint waste. If the paint that misses the target is not wasted by discharging it into the spray booth, there can be a major problem of "wrap-sag" at the edges of the ware. It is usually more acceptable to waste paint than to cause rejects due to "wrap-sag". This is particularly true since the edge build-up is not available to coat additional pieces per gallon anyway. It represents another form of paint waste.

Many problems that apply to reciprocating disk systems will also apply to high speed bell systems. In addition, the need for "shaping air" causes additional problems. The atomized paint particles are directed off the edge of the bell in a direction parallel to the work surface and toward the floor, ceiling and side walls of the spray booth. The shaping air is added to redirect the paint toward the product. The shaping air causes a loss in transfer efficiency since a high volume of air is required. Where it can be used, the disk is a much better system.

**CFA AIR ELECTROSTATIC, 85% TRANSFER EFFICIENCY**

By contrast, the flat fan shaped spray pattern generated by most air spray guns provides much better control over applied film thickness. Figure 2 shows this type of spray pattern. The biggest difference is that the CFA air electrostatic gun is more efficient and operates in the 85% transfer efficiency range indicated for disk and bell systems. The gun triggers with precision and is easily computer controlled. The guns are normally mounted on a full stroke vertical reciprocating machine with the reversal points of gun travel well above and below the longest part to be sprayed. The spray guns turn off above and below the ware so that no painting is done at the stall point during reciprocator reversal. This prevents uncontrolled build-up of film thickness at the stall point.
Vertical and horizontal trigger points can be held within 1/2". Vertical spray height is determined by electric eyes scanning the conveyed parts prior to their entering the automatic painting system. The horizontal spray dimension is determined by the length of time the electric eyes are broken. The system programs itself automatically to suit conveyor loading. Parts with up to 16 different vertical dimensions and an infinite number of horizontal dimensions can be mixed together on the line and still be painted accurately and efficiently.

Perhaps the biggest improvement is a substantial reduction in the Faraday cage effect. The result is a higher quality finish that will require far less manual touch-up. It is not unusual to see some electrostatic systems followed by several touch-up people. If the electrostatic system does only half of the job at 85% transfer efficiency and manual touch-up does the other half at 24% with conventional air guns, the result is an overall transfer efficiency of only 37%. This falls way short of environmental requirements. A large improvement occurs in overall transfer efficiency when manual touch-up is reduced or eliminated.

Perhaps the biggest problem with the CFA air automatic electrostatic system is its forgiving nature. It tends to turn out a high quality finish at the desired production speed even when it is operated carelessly. The net result can be excessive paint waste.

**ELECTROSTATIC PAINTING OF FLAT PANELS**

There is a vast difference in end results with different types of electrostatic painting systems. The two flat panels in Fig. 3 show one of the major differences. Both panels were sprayed to the same average film thickness. Panel A on the left is typical of coverage achieved with a CFA air electrostatic automatic system. It will provide a higher quality of finish, superior corrosion resistance and much better color matching than panel B. This is due to a greater minimum film thickness and closer tolerances on applied film thickness. Panel B is more typical of results achieved with a disk or bell system.

If the two panels were sprayed to produce the same minimum film thickness, the corrosion resistance of Panel A and Panel B would be approximately equal. This means that the air spray electrostatic system could apply 30% less paint on Panel A and still hold the same minimum film and be equivalent to Panel B. Obviously, transfer efficiency must be redefined to reflect this added variable.

**ELECTROSTATIC PAINTING OF RECESSED AREAS**

The Faraday cage effect and mechanical limitations also affect transfer efficiency. This is shown in Fig. 4. Part A represents the coverage that can be expected with a disk or bell system. The system has poor throwing power into recesses and there is a build-up of film thickness around openings. The system requires a substantial amount of manual touch-up.

Part B has a similar limitation but this is a mechanical limitation that occurs with a CFA air atomizing electrostatic system. In the sample shown, the area of the opening is only one-third as large as the recessed surface area.
being coated. This means that the film thickness on the recessed surface is only one-third as much. This is a mechanical limitation and should not be confused with the Faraday cage effect which is an electrical limitation. Manual touch-up may or may not be needed depending on acceptability of the coating in the recess. If more film is needed, more paint must be sprayed. This makes parts with recessed areas more costly to paint since more film is added all over.

When adding manual touch-up to Part A, it is necessary to spray as much paint as is used on Part B. This requires spraying twice as much paint as is needed to achieve the coverage in the recesses for Part B alone. The end result is shown on Part C of Fig. 5. The recessed area was finally covered but the overall quality of finish is poor, film thickness is excessive and paint consumption is also excessive. The extra film thickness represents 50% waste.

### ELECTROSTATIC AIR SPRAY, 70% TRANSFER EFFICIENCY

Setting conventional electrostatic air spray at 70% transfer efficiency does not tell the full story. The actual transfer efficiency can vary from 0 to 70%. It can fall well short of code requirements in poorly engineered painting systems or by careless operation. Of course, this comment applies to all systems.

When an electrostatic spray gun is turned on without a “target” in front of it, the gun operates at 0% transfer efficiency. All of the paint is wasted. This is true of all spray guns and should be avoided at all costs.

Another variable that affects transfer efficiency is operating voltage. Tests were conducted by spraying 2 ft x 4 ft shelving panels under different output voltages with automatic electrostatic equipment while holding paint flow rate, atomizing air pressure and all other variables constant. The results are shown in Table II. The differences in applied film thicknesses indicate the differences in transfer efficiency at the different voltages.

Electrostatic hand guns operate at an electrode voltage of 50,000 or less regardless of transformer voltage because of very large resistance in the high voltage output circuit. Using this large resistance in automatic electrostatic guns drops operating electrode voltage to the same lower level and causes excessive paint waste. The extra waste at 50 KV compared to 100 KV based on the differences in dry film thickness applied at 50 and 100 KV is 26.9%.

The film thickness in the above test was measured on the surface facing the guns. Electrostatic wraparound was disregarded although this factor starts to improve beginning at the lower electrostatic threshold of 50,000 V. The test was also conducted with air atomizing guns using the patented concept of “conical film atomization” that provides improved transfer efficiency at all levels of operating voltage including zero voltage. Conventional air atomizing electrostatic guns would not do as well in the same test.

The highest level of operating voltage is achieved when not using the built-in resistance required for electrostatic hand guns. These higher voltages are used for disk, bell and CFA air spray automatic electrostatic systems. With their higher operating voltage and improved transfer efficiency, automatic electrostatic systems are preferred over manual operation. A CFA automatic system is even preferred over a single hand sprayer when expensive fluoropolymers ($60 to $200 per gallon) are involved. A single hand sprayer can spray several hundred dollars’ worth of fluoropolymer coatings per hour so that the cost of paint rather than the cost of labor becomes the deciding factor. The higher efficiency of good automatic electrostatic equipment pays off quickly.

### Table II. Effect of Operating Voltage

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Electrode Voltage</th>
<th>Dry Film Thickness, mils</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0.70</td>
</tr>
<tr>
<td>2</td>
<td>30,000</td>
<td>0.80</td>
</tr>
<tr>
<td>3</td>
<td>50,000</td>
<td>0.95</td>
</tr>
<tr>
<td>4</td>
<td>90,000</td>
<td>1.20</td>
</tr>
<tr>
<td>5</td>
<td>100,000</td>
<td>1.30</td>
</tr>
</tbody>
</table>

A conventional air atomization elec-
Electrostatic hand spray gun can boost the transfer efficiency from 24% at zero voltage to 65% at normal operating voltage but, unfortunately, this applies to low viscosity, conventional solvent base paint only. Much higher atomizing air pressure is needed to atomize the higher viscosity waterborne and high base paints and fail to meet compliance standards. This increases the spray velocity and greatly lowers transfer efficiency. As a result, most electrostatic hand guns in use in the Los Angeles area are not in compliance with the rules calling for 65% transfer efficiency with environmental paints containing only 2.3 lbs/gal of VOCs. Automatic guns with built-in resistance encounter the same problem and fail to meet compliance standards.

The CFA air electrostatic gun starts out at a much higher level of transfer efficiency nonelectrostatically (65%) and provides a large improvement when a high voltage electrostatic field is added. It reaches the rating of 85% transfer efficiency spelled out for disk and bell systems. This type of atomizer is not sensitive to broad changes in paint viscosity since it is atomizing a thin film of paint. It will atomize the higher viscosity environmental coatings with very little increase in atomizing air pressure and maintains high transfer efficiency with these coatings as well.

ELECTROSTATIC POWDER COATING, 95% TRANSFER EFFICIENCY

Electrostatic powder coating systems are available with both manual and automatic guns. The transfer efficiency on the initial pass falls well below the 95% indicated transfer efficiency and may be as low as 30 to 40%. The high efficiency is achieved by reclaiming and reusing the powder overspray several times.

Dry powder does not contain any solvent and provides an excellent solution for air pollution problems. The discharge of volatile organic compounds (VOCs) into the atmosphere is cut to a minimum.

Another savings is achieved by re-cycling the exhaust air back into the booth after it is fully filtered.

The limitations to powder coating include the following:

1. Color changes are slow, time consuming and costly.

2. Applied film thickness is frequently twice as heavy as necessary and doubles the cost as well.

3. Reclaim is normally mixed with virgin material for reuse. Reclaim material available frequently exceeds the optimum 30% of the mix.

4. Quality of finish may deteriorate after two reclaims, yet 5-6 reclaims may be needed to reach the 95% transfer efficiency mentioned above.

5. Many people are not aware of the direct competition to powder that occurs with reclaiming and reusing liquid high solids overspray. Operating costs can be cut up to 50% compared to powder.

6. As much as 80-90% of the spray booth exhaust air can be recycled with some liquid electrostatic systems as well.

CONCLUSIONS

A high quality finish, low labor costs and maximum production rate must be combined with high transfer efficiency, low VOC emissions and low operating costs. Anything short of this on a new capital expenditure can do serious harm to the buyer. The new equipment may fail to pay for itself in a reasonable length of time. Even worse, it may have to be replaced if it falls short on environmental requirements. It is essential to know and understand fully the limitations of all equipment before a new system is purchased.

The more stringent environmental requirements appear to be the most troublesome problems to solve. The best way to meet these requirements are as follows:

1. Improve transfer efficiency.

2. Stretch each gallon of coating to a maximum by holding uniform film thickness.

3. Avoid applying excessive film thickness. This can double coating consumption and double costs even when applied at high transfer efficiency.

4. Increase the volume solids content of the coating to cut VOC emissions. Don’t assume that all equipment on the market can handle these coatings efficiently.

5. Cut manual touch-up to a minimum. This will reduce both paint and labor costs. It can also reduce rejects since manual spray cannot be controlled with precision.

6. Switching to chlorinated solvents will increase the choice of coating tools since the applied viscosity is much lower. The long range wisdom of discharging one form of solvent vapor into the atmosphere as compared to another is questionable. Solvent vapor of any kind is not a normal ingredient of the atmosphere.

7. Do not operate your equipment carelessly. Remember spraying at nothing provides 0% transfer efficiency. Electrostatic spray does not offer any magical solutions but it does respond to common sense.

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The Phoenix from the Ashes

Compliance with environmental regulations is the theme associated with this issue. In its original context the term compliance coating referred to a material which contained less than a specified amount of volatile solvent which would be released into the atmosphere during application and subsequent curing. The objective of regulating these volatile organic compounds (VOCs) was to prevent formation of smog. Ozone was selected as the substance to be measured to evaluate progress in achieving the goal of reduced pollution.

The results are fairly well known. Paints have been reformulated and technologies such as powder coating and electrocoating, addressed in articles within this issue, have found wide application; however, the ozone levels continue to rise.

Regulators are now seeking further reductions by specifying the method of application of spray finishes to increase efficiency and thereby reduce paint usage and the emission of solvent. This brings in the complicated subject of transfer efficiency for spray equipment, a subject also discussed within this issue. Finally, in related developments, there is an update on proposed land disposal restrictions for sludges.

It is this latter subject which recalls the conversion just 50 years ago this month of an ash dump into the magical domes and towers that became the New York World's Fair. Fluorescent lights, nylon stockings, automated milking machines, and electric dishwashers were among the products for the future.

Twenty five years later the same site saw another fair and introduced the push button telephone. The underground house was proposed to protect its owner from pollution, pollen, noise and radioactive fallout. It featured the ultimate in privacy with dial-a-view murals to replace the outmoded concept of the window. After all, who wants to look at all that smog?