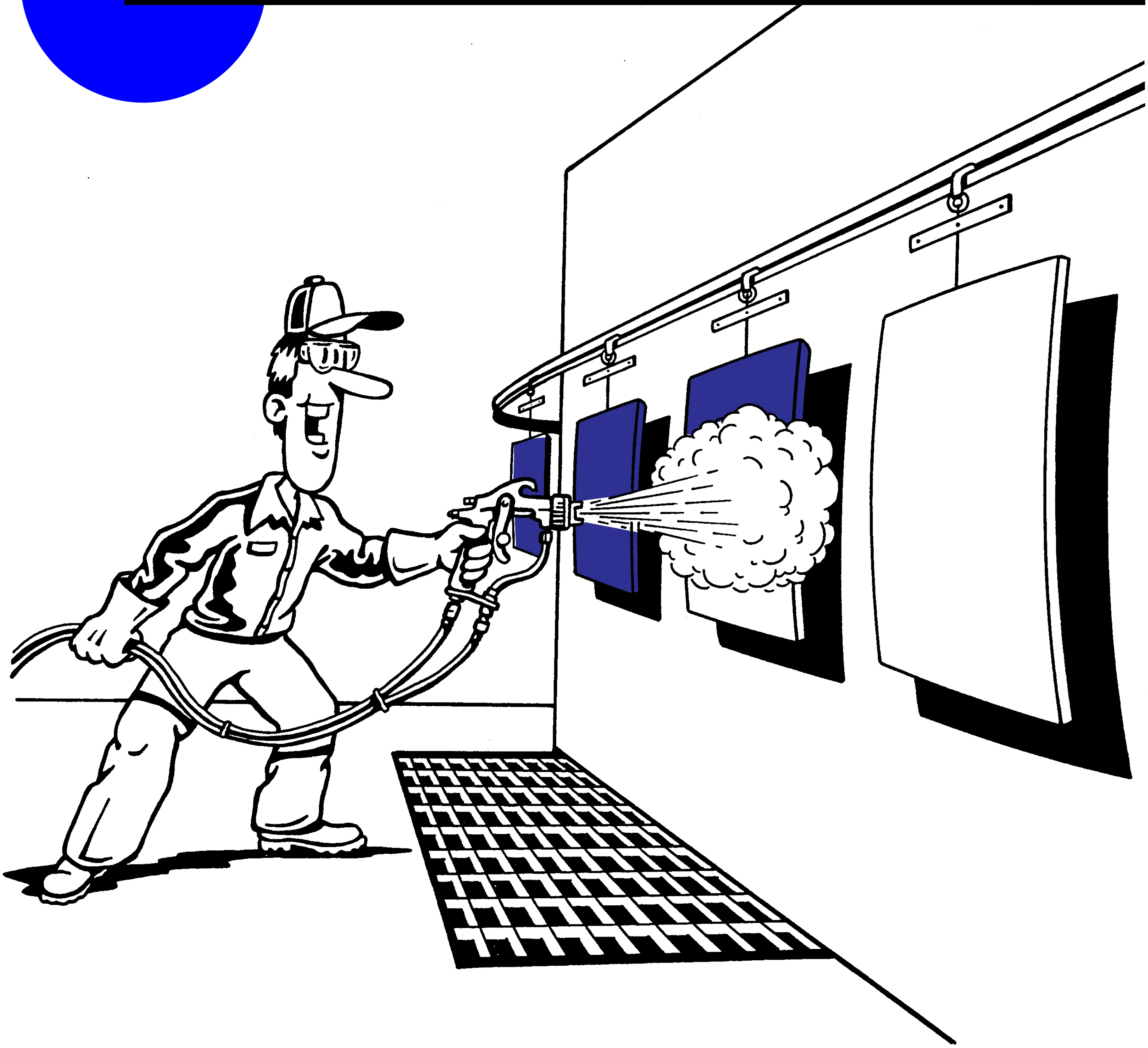
Environmentally Conscious Painting



Kansas Small Business Environmental Assistance Program

Acknowledgements

This manual has been prepared by the Kansas Small Business Environmental Assistance Program (SBEAP), a consortium of the Center for Environmental Education and Training at The University of Kansas, the Pollution Prevention Institute at Kansas State University, and the Center for Technology Application at Wichita State University, under contract from the Kansas Department of Health and Environment. All SBEAP services are free and confidential.

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Published June 1996

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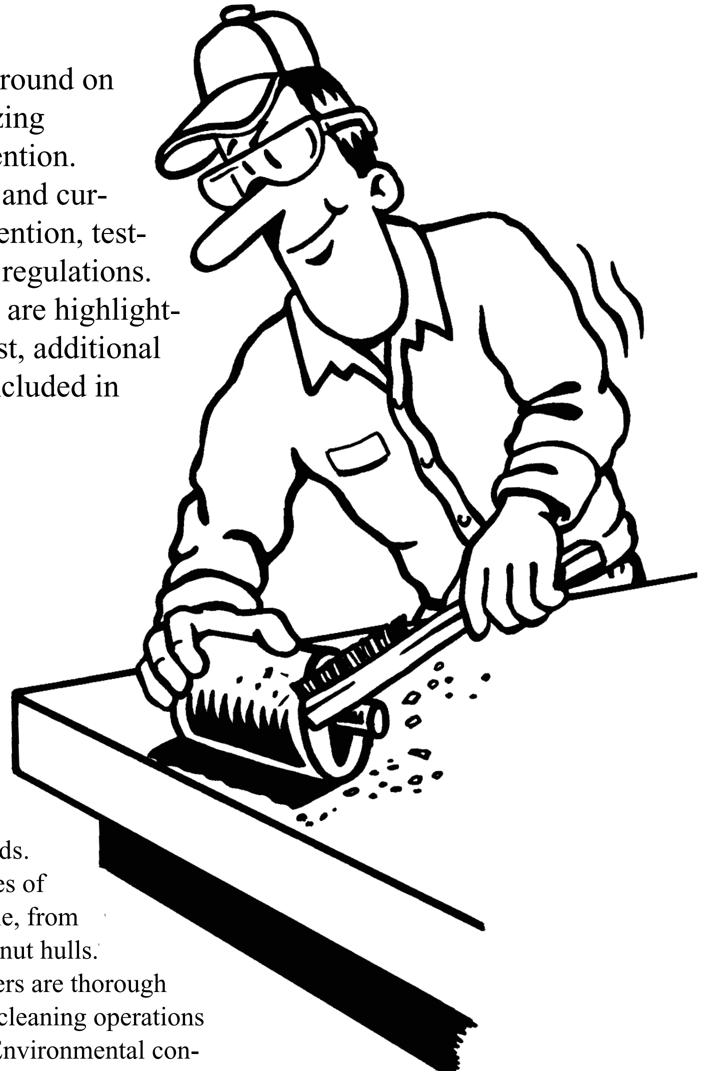
Environmentally Conscious Painting Manual

A guide for Kansas painters

Introduction

The purpose of this manual is to provide general background on painting technology with specific emphasis on minimizing adverse environmental impacts through pollution prevention. The manual reviews surface preparation, coating types and curing characteristics, coating applications, pollution prevention, testing, personal protective equipment, and environmental regulations. Advantages and disadvantages of specific technologies are highlighted. A pollution prevention checklist, coatings vendor list, additional resources, regulatory information, and a glossary are included in the appendix.



1 Surface preparation

A substrate must be clean before applying coatings. Cleaning is critical to the quality of the finished product. Any dirt, grease, lint or other foreign material will block the bonding surface and create an imperfection on the finished part. Minimize the amount of cleaning needed by keeping the substrate from getting dirty during storage or processing. For example, proper storage of materials and just-in-time delivery of parts can keep contaminants from becoming a problem.

Mechanical cleaning

The first cleaning step is mechanically removing any debris from the substrate. Wiping loose dust and dirt off the part with a rag is an example of mechanical cleaning. Typically more vigorous mechanical action is needed to remove rust or contamination more firmly attached to the substrate.

For wood surfaces, sanding followed by wiping with a lint-free cloth is appropriate. Water is avoided because it raises the grain of the wood, which then requires additional sanding.

For metal substrates, rust and metal scale can be removed via sanding, brushing with a wire brush, a sand or grit blaster, or plastic wool pads. There are many types of grit blasters available, from plastic media to walnut hulls. Some of these blasters are thorough enough that further cleaning operations can be eliminated. Environmental concerns and rising prices dictate accomplishing the major portion of cleaning via mechanical methods.

Chemical-assisted cleaning

Aqueous

Aqueous cleaning uses water and detergent, and acidic or alkaline chemicals. It is generally more environmentally friendly than traditional solvent cleaning and adapts to a wide variety of cleaning needs. Following mechanical cleaning, spray, dip cleaning, or a combination of both is typically used, depending upon the part shape and material to be cleaned. Elevated temperature solutions are more effective

P2 tips for cleaning

- Start with a clean substrate:
  - buy clean raw materials
  - store raw materials properly to avoid unnecessary contamination
  - avoid dirty manufacturing processes (oily cutting fluids, poor housekeeping, etc.)
- Maximize mechanical cleaning step
- Maximize cleaning capacity of aqueous or solvent cleaners:
  - use countercurrent cleaning (begin with dirty cleaner, followed by clean cleaner)
  - add an additional rinse
  - recycle cleaning solvent
  - for aqueous cleaners, control water temperature and pressure

for removing greases and oils, which have increased mobility at higher temperatures.

Acidic solutions effectively and rapidly remove rust, scale, and oxides from metal surfaces. The solutions actually etch the surface of the metal and can improve coating adhesion. Inhibitors are used to control the etching rate. In addition to being an environmental concern (because they are classified as hazardous waste and have special disposal, storage, and transportation requirements), acidic solutions can cause hydrogen embrittlement as hydrogen gas formed during surface etching penetrates the metal and reduces its strength.

Mild alkaline detergent solutions are used to clean many substrates because no hydrogen embrittlement results from alkaline cleaning. Alkaline cleaners remove rust, scale, and oxides from metal surfaces. In general, the stronger the solution, the faster it cleans. Relatively mild solutions are often used, however, to easily accomplish thorough rinsing.

Solvents

Traditionally, solvents have been used to remove oily type contamination. Various processes are used to contact solvent with the substrate, including wiping, spraying, dipping, or vapor degreasing.

There are problems associated with these cleaning methods. Dip tanks get dirty as they are used. Spraying can be wasteful, if too much solvent is used. Wiping is labor-intensive. Vapor degreasers are regulated under environmental laws and pose a potential health hazard.

Often a combination of techniques can be employed to reduce solvent usage and still obtain clean substrates. For example, use a dip tank followed by wiping, or confined spray. Vapor degreasers can be very effective if dragout is minimized. However, the key to solvent cleaning is to have the parts as clean as possible before they enter the solvent cleaning cycle.

Conversion coatings

A conversion coating may be applied to metal prior to painting to improve adhesion, corrosion resistance, and thermal compatibility. Conversion coatings chemically react with the metal surface and provide a more efficient physical surface for bonding of the coating. Additionally, conversion coatings act as a buffer between the coating and the substrate, reducing the effects of sudden temperature changes.

Phosphate and aluminum conversion coatings are usually confined to large operations with elaborate waste treatment facilities, because of extensive regulations controlling disposal of rinse waters and sludges containing heavy metals.

Phosphate coatings for steel

Iron or zinc phosphate coatings are usually used for steel. A thoroughly clean surface is critical. In the phosphating process, acid attacks the metal surface, forming an iron or zinc phosphate salt. Accelerators and oxidizers are added to the phosphating solution to improve its effectiveness. Molybdic acid, added for corrosion inhibition, gives a purple cast to iron phosphate coatings.

Process time, temperature, and chemical concentration affect the acid s chemical reaction with steel.

Process time is usually fixed because the line must run at a certain speed. It is best for the temperature preceding the phosphating process to be higher than required for phosphating. Iron phosphating solution temperatures typically operate between 120¡F and 140¡F, but can be operated at room temperature. Using the phosphating solution for heating the parts as well as coating them reduces deposition efficiency, may require additional chemicals, and may generate excess sludge. It is possible to combine cleaning and phosphating in a single solution; however, this is usually only successful for lightly soiled parts. If parts are heavily soiled, they will not get clean in a combination solution.

Zinc phosphate forms finer, denser crystals than iron phosphate and has better corrosion resistance and paint adhesion. Typical zinc phosphate solution temperatures are around 140¡F. It is not possible to achieve cleaning and zinc phosphating with a single solution.

Phosphate coatings for aluminum

Iron, zinc, and chromium phosphate coatings are all used for aluminum. Choice of solution largely depends on the volume of aluminum in the process. When a small amount of aluminum is processed, the same phosphating solution is typically used for aluminum as for the other metals as a matter of convenience.

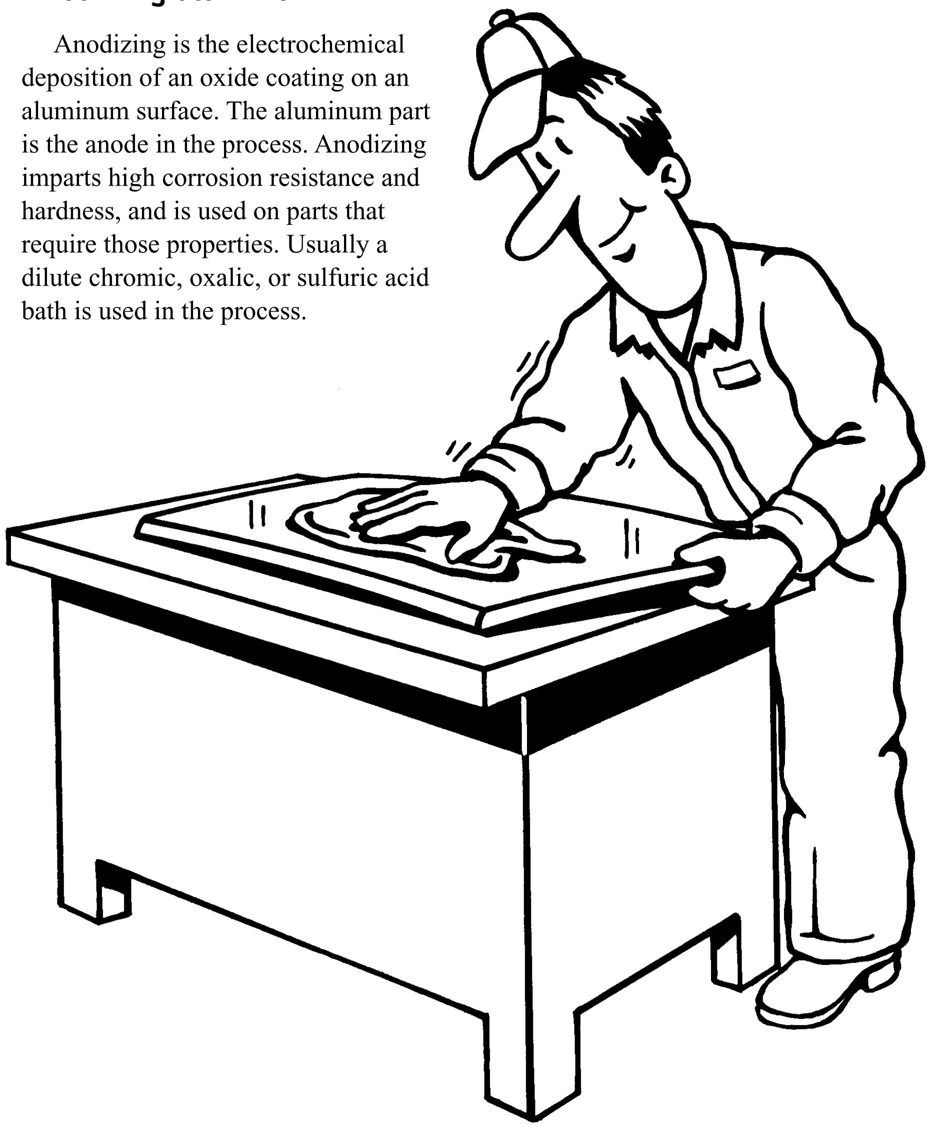
When steel and a small volume of aluminum are processed, iron phosphating is often used. Iron phosphating solutions can effectively clean the surface of the aluminum and improve paint adhesion. However, they leave little or no coating on the substrate.

Zinc phosphating may be used for coating steel or zinc surfaces. In order to etch the aluminum, a fluoroborate or fluoride additive is required.

Chromium phosphate coating is often used for small volumes of aluminum. No-rinse chromium phosphate solutions, which have the advantage of not being classified as toxic waste, are available. They typically provide less corrosion resistance, however, due to incomplete coverage. Chromic acid sealers can be used but they contain hexavalent chromium, a regulated carcinogen. Chromium phosphate solutions containing no hexavalent chrome are approved for use inside food cans.

Anodizing aluminum

Anodizing is the electrochemical deposition of an oxide coating on an aluminum surface. The aluminum part is the anode in the process. Anodizing imparts high corrosion resistance and hardness, and is used on parts that require those properties. Usually a dilute chromic, oxalic, or sulfuric acid bath is used in the process.



P2 tips for conversion coatings

- Avoid soiling the substrate prior to beginning the cleaning process.
- Analyze water for hardness and dissolved solids. Use alkaline cleaners or phosphate compounds with hard water stabilizers where necessary.
- Use low temperature, energy conserving, alkaline cleaners or phosphate compounds.

2 Coating types and curing characteris-

Traditionally, paint has been considered a liquid made up of several components that when applied and cured imparts a thin plastic film. Paints have traditionally contained petroleum based solvents to aid in application. Solid paints, such as powder coatings and paints containing no solvents that are electrodeposited, are now available. These materials have given rise to the term coatings instead of paints.

Coating components

Coatings are made of resins, pigments, solvents, and additives. The amount of each of these constituents varies with the particular paint, but solvents traditionally make up about 60% of the paint. (See Paint Composition figure, page 5.)

Resins

Resins (or binders) hold all paint constituents together and enable it to cure into a thin plastic film. Resins are made up of polymers, which are long organic molecules of several repeating units (chemical groups). Polymers are chosen based on the physical and chemical properties desired of the finished film, and on the paint application method.

Curing by solvent evaporation is characteristic of lacquer paints. Enamels are a general category used to describe any coating that cures by crosslinking (chemical reaction of the polymers).

Acrylics

Acrylics contain suspended polymer particles. When the solvent and water evaporate, the polymer particles remain and form a film. Acrylics produce a shiny, hard finish with good chemical and weather resistance.

Alkyds

Alkyds are made from chemically modified vegetable oils, and are relatively low in cost. They can be easily modified, changing the paint properties. They can react with oxygen in air (in ambient conditions) to form a crosslinked film, thus are very functional for a wide variety of applications. They can also react with other chemicals in the paint and be heat-cured. Because of their versatility and moderate cost, they are considered a general purpose paint.

Epoxies

Epoxies provide excellent water resistance and superior chemical resistance. Their adhesive properties make them especially good primers. They can be formulated in a variety of ways, from one-component formulations that require elevated temperature curing to two-component systems that cure at or below ambient conditions. Epoxies lose their gloss from ultraviolet light exposure, but the damage is rarely structural.

Urethanes

Urethanes combine high gloss and flexibility with chemical and stain resistance. They require little or no heat to cure and demonstrate excellent water and weather resistance. They are two to five times more expensive than other paints, so they are used in applications where high performance justifies the cost.

Urethanes result from a reaction between an isocyanate and alcohol. The two components can be mixed together in a pot prior to application or can be mixed in the atomizing portion of the spray gun. Once mixed, the material has a limited potlife, which is the amount of time the components can be mixed before crosslinking begins. The potlife can be adjusted to fit the process requirements. Typical ranges commercially available are from a few minutes to 16 hours.

Others

Polyesters are similar to alkyds in chemical structure, but must be heat cured. They are used extensively as powder coatings. Isocyanate and TGIC (triglycidyl isocyanurate) crosslinked polyesters are two popular powder coatings.

Silicones have high heat-resistance and superior resistance to weather and water. They are used alone or blended with acrylics or alkyds.

Vinyls can have a wide range of flexibility. They are used extensively in marine applications, as interior metal can liners (polyvinylchloride), and for structural wood finishes (polyvinylacetate).

Pigments

Pigments are tiny particles which are insoluble in paint. They are incorporated to enhance physical appearance or improve physical properties. Many pigments still contain lead, chromium, cadmium, or other heavy metals. These paints cannot be thrown away because heavy metals leach out of landfills and contaminate groundwater. Their production is being phased out because of their toxicity. Inorganic pigments have high thermal stability and ultraviolet light stability. Organic pigments are brighter and clearer than inorganic pigments.

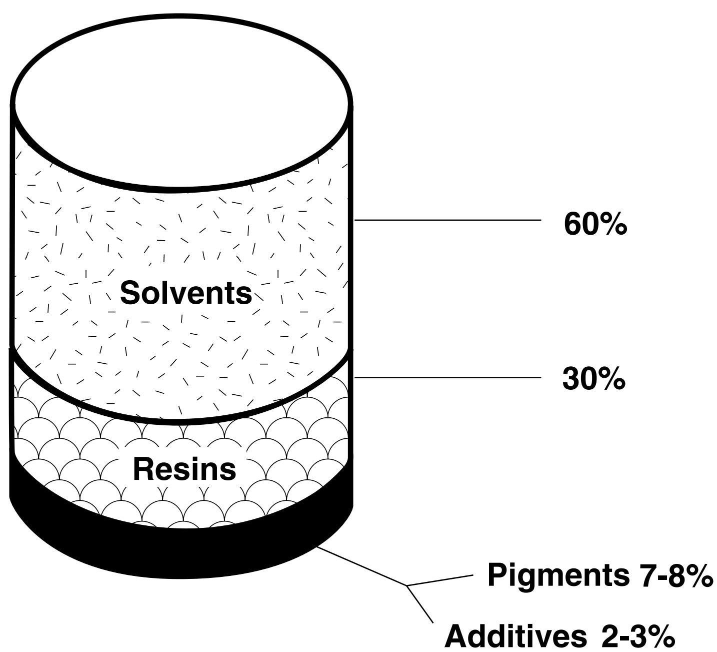
Solvents

Solvents are added to paint to aid in its application. Solvent dissolves the binder and evaporates at a specific rate, depending upon the particular characteristics of the coating. Solvents are primarily present to reduce viscosity so the coating may be easily applied to the substrate by whatever application method is desired. The evaporation rate is critical to ensure that the paint film forms properly.

Solvents are a major source of environmental concern because they evaporate, releasing volatile organic compounds (VOC) and hazardous air pollutants (HAP) during the paint curing process. VOC react in the presence of sunlight with nitrogen oxides and sulfur oxides to form smog. In addition, solvents cannot be dumped on the ground because they seep into groundwater and contaminate it.

Additives

Additives are chemicals used in coating formulations to impart specific physical or chemical properties to the coating. Paint performance may be improved by adding curing agents, defoamers, flow control agents, gloss modifiers, softeners, stabilizers, thixotropes, antifreeze, or other agents. The vendor can choose from hundreds of chemicals to achieve improved performance. A coating s processing characteristics can change significantly depending on the specific additives used.



Paint Composition by Volume

courtesy **Industrial Painting** by Norman Roobol

High solids coatings advantages

- Reduced VOC and HAP emissions
- Reduced solvent usage
- Reduced inventory
- Reduced fire hazards
- Reduced number of spray applications to achieve a given film thickness
- Improved abrasion and mar resistance
- Reduced environmental, odor, and safety problems associated with solvents
- Compatible with existing technologies, such as conventional air spray equipment and electrostatic equipment
- Energy savings associated with curing ovens, since less solvent must be evaporated

High solids coatings disadvantages

- Generally requires high cure temperatures
- Sensitive to inadequate substrate cleaning
- Extremely sensitive to temperature and humidity
- Difficult to control film thickness
- Tacky overspray difficult to clean
- May require paint heater in system
- Difficult to control sagging
- Narrow time-temperature-cure window
- Cannot use dip or flow coating
- Difficult to repair
- Solvent use not completely eliminated
- Shorter pot life than conventional coatings

High solids coatings

High solids coatings are an evolutionary change from traditional coating formulations. The coating liquid formulation is very similar, but the resin systems are modified to produce a coating with a higher solids concentration and lower VOC concentration. Solids content ranges from 50 to 70 percent, although some formulations are higher. High solids coatings use technology similar to conventional solvent-based coatings. Many users find the transition to high solids coatings is met with less resistance because conventional equipment can still be used.

Although high solids coatings offer a real reduction in VOC emissions, potential reductions are not as great as with powder coatings or 100 percent reactive liquid coatings.

A conventional plant painting 12,000,000 ft^2/yr with a 1.2-mil-thick coat will release about 127 tons/yr of VOCs. A plant using high solids paint, applying a similar amount of coating, will emit about 31 tons/yr of VOCs.

Waterborne coatings

Traditional coatings use an organic, petroleum-based solvent to disperse resin molecules. Waterborne coatings mainly use water to disperse the resin, although they usually also contain some solvent. Many resins are incompatible with water and must be chemically modified for use in waterborne coatings.

Waterborne coatings may be classified based on how the resin is fluidized. Solutions, emulsions, and dispersions are the three different categories. Within each category, physical properties and performance depend on which specific resins are used. (See figures on page 8.)

Solutions

Solutions are materials that are completely dissolved in one another. Salt dissolved in water is an example of a solution. Resins can be modified to dissolve in water but in order for the coating to cure, both water and the modifying agent must evaporate. If the modifying agent evaporates prematurely, the pH of the solution will change and the resin may come out of solution (called resin kickout).

Emulsions

An emulsion is a dispersion of two immiscible liquids: minute globules and an emulsifier, which keeps them in suspension. Mayonnaise is an example of an emulsion. Oil and water do not mix, but the oil exists in small globules surrounded by an emulsifying protein (e.g., egg, which has an affinity for water so it can hold the oil particles in suspension). The term latex is used by scientists for any emulsion of an organic material in water. Latex paints contain no natural or synthetic rubber or rubber-like resins. They are waterborne emulsion coatings.

The viscosity behavior of emulsions is not consistent with solution coatings. Waterborne emulsion coatings can contain high concentrations of solids without adversely increasing viscosity. Water and solvent determine the viscosity of the coating; the resin exists as small globules.

During the curing process, first solvent then water evaporates, leaving the resin to coalesce. If the waterborne emulsion is an enamel, crosslinking occurs after the resin molecules coalesce.

Dispersions

Dispersions are small clusters of resin molecules suspended in a liquid. Dispersions differ from emulsions in that the clusters are smaller and no emulsifier is used. Mechanical agitation is sufficient to suspend the clusters. Waterborne dispersion coatings contain organic solvents as well as water.

Dispersion coatings can be formulated for higher solids content for a given viscosity. Viscosity is initially linearly proportional to solid content, but does not change between about 21% and 35% solids. It then increases

Waterborne coatings advantages

- Reduced VOC and HAP emissions
- Conventional application processes can be used
- Reduced toxicity and odor, resulting in improved worker safety
- Good storage life
- Easy cleanup with water
- Reduced fire hazard
- Disposal of hazardous waste minimized or potentially eliminated

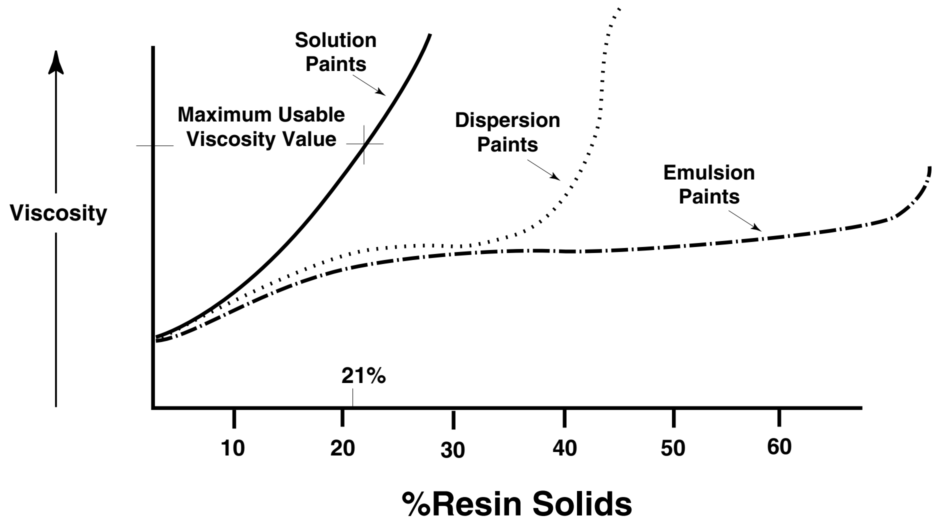
Waterborne coatings disadvantages

- May cause grain raising in wood
- Surface must be free of oil and dust
- Longer drying times or increased oven temperatures required
- Difficult to obtain high gloss finish
- Cleanup after cure is difficult
- May cost more per gallon on an equivalent solids basis
- Not many resins available for waterborne formulations
- Converting solvent-borne coating line may be complex, e.g., stainless steel or plastic lines, valves, etc., are needed
- Problems with atomization, reduced paint transfer efficiencies
- Increased runs and sags
- Temperature/humidity control are required
- Refinishing is difficult

rapidly with additional solids, due to intertwining of the resin clusters. Emulsion coatings can achieve the highest solids content for a given viscosity. (See Viscosity figure at right.)

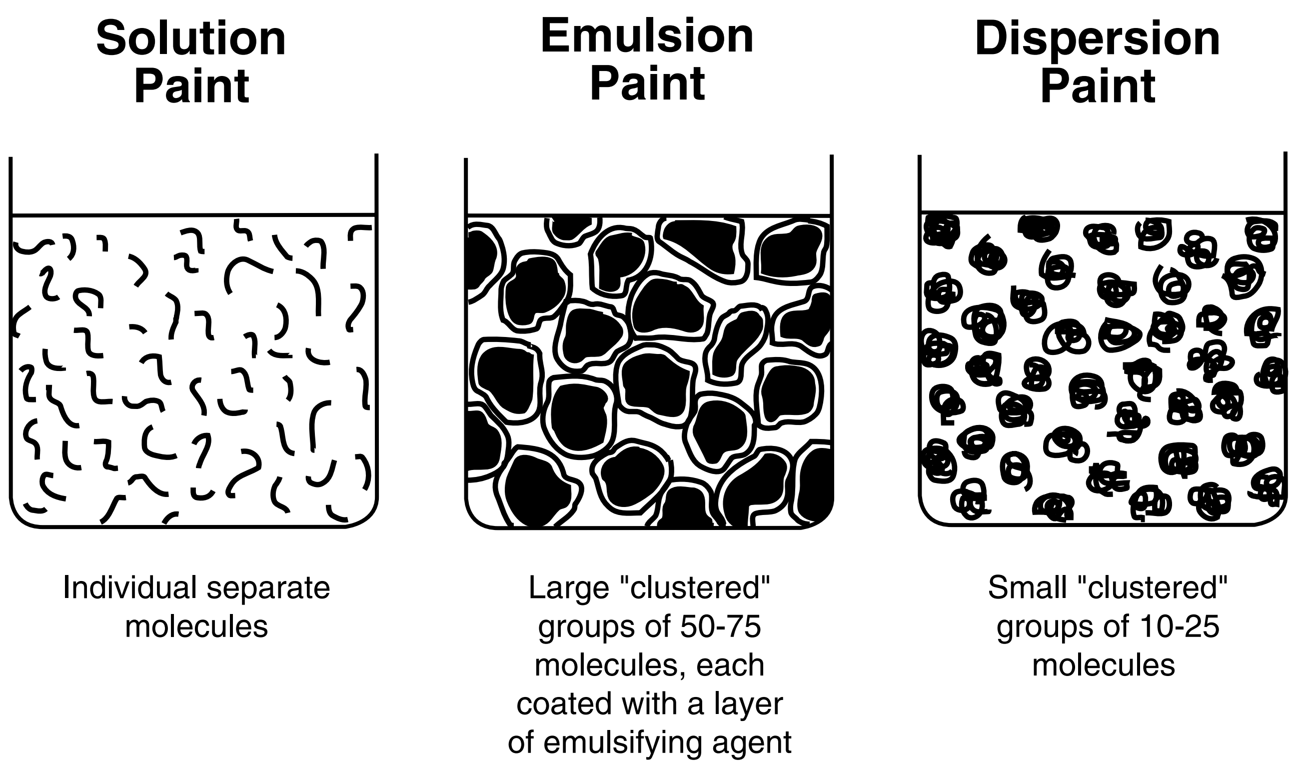
Advantages/disadvantages

Environmental regulations restricting VOC emissions are driving the waterborne coatings industry. There is less solvent vapor in the operating areas and less bulk solvent storage. Reduced solvent use reduces health and safety problems such as worker exposure to solvent fumes or liquids and potential fire or explosion hazard. There are some disadvantages to using waterborne coatings that must be overcome in order for them to be received as acceptable alternatives to solvent-borne coatings.



Viscosity Vs. Percent Resin Solids

courtesy **Industrial Painting** by Norman Roobol



Major Resin Fluidation Methods

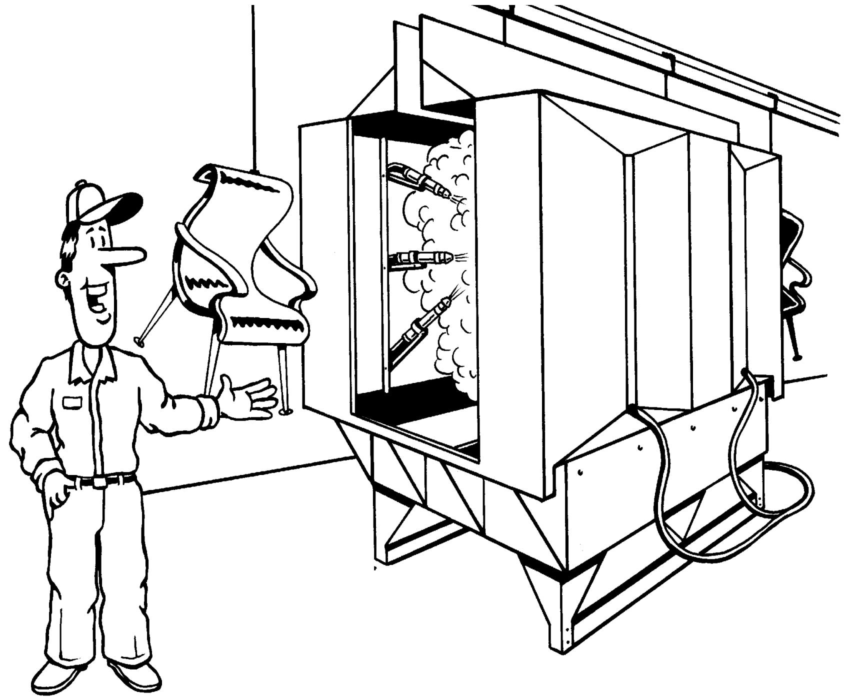
courtesy **Industrial Painting** by Norman Roobol

Powder coatings

Powder coating technologies have been available since the 1950 s. Powder coatings were initially used to coat pipes to prevent corrosion, and for insulating electric motor parts. Powder constituents are very similar to wet paint with resins, pigments, and additives, but lack a solvent carrier. Initially, powder was applied using a fluidized bed process in which heated parts were dipped in a vat with the suspended coating powders. As these particles came in contact with heated parts they softened and began to flow into other particles to create a coating. The coatings were thick, usually vinyl or epoxy, and focused on functionality rather than decorative qualities.

Powder coatings became a major factor in the metal finishing industry when the electrostatic spray process was introduced in the early l960 s. Electrostatic spraying made it possible to apply thin layers of coatings for higher quality decorative finishes, and allowed powders to be used on parts not suitable for dipping in a fluidized bed. As the powder coating technology developed, advances were made in powder formulations to offer a limitless range of colors, glosses, and textures. Cost savings and environmental benefits associated with solvent-free powder coatings frequently overshadow the superior finish they also provide. Thus, powder coatings have become a viable alternative for decorative as well as functional coatings, although it remains predominately a metal finishing process given the high temperatures needed for curing.

Equipment manufacturers have made significant design improvements in spray booths that allow color changes to be made with minimal downtime and allow recovery of a high percentage of the overspray. As with spray guns, there are many spray booth powder recovery designs from which to choose, depending on the requirements of a given finishing system.



Powder coating advantages

- Cost savings due to:
  - low reject rates (eliminates sags, drips, or runs)
  - no coatings mix room needed
  - minimal oven length required
  - reduced energy needed for heating & circulating of makeup air
  - little or no waste disposal
  - low maintenance
  - VOC and HAP compliance, i.e., no solvents
- Durable finish
- Good corrosion resistance
- Can apply thick coatings in one pass, even over sharp edges
- Can use basic resins not easily soluble in organic solvents
- Coating utilization efficiencies can reach 95 to 99 percent
- Little operator expertise required
- No solvent needed for cleanup
- Virtually eliminates worker exposure to solvent vapors
- No hazardous overspray, waste sludge, or contaminated water
- Lowest annual operating costs compared to conventional solvent, water borne, or high solids painting operations

Thermoplastic powders

Thermoplastic powder coatings melt and flow when heat is applied, but retain the same chemical composition when cool and solidified. Thermoplastic powder coatings include thermoplastic polyester powders, polyethylene powders, nylon powders, polyvinyl chloride powders, and polypropylene powders. They provide excellent chemical resistance and outstanding electrical insulation properties. Thermoplastic powders provide a thick coat especially well suited for extreme performance requirements. Given the inherent thickness of these coatings, they do not generally compete with liquid paints.

Powder coating disadvantages

- Generally higher initial equipment investment (capital costs)
- Enhanced Faraday cage effect
- Difficult to achieve thin films below 1.0 to 1.5 mils
- Difficult to change colors
- Difficult to match coatings for repair with liquid paint
- Hard to strip
- Cleanliness of substrate is critical
- Texture control is limited by particle size and distribution
- Metallic powder finishes not as attractive as wet metallic finishes
- Need gentle air stream to apply powder
- Need cool, dry powder storage area
- Parts must be subjected to elevated temperature cure
- For electrostatic application, part must be electrically conductive or covered with electrically conductive primer

Thermosetting powders

Most powder coating resins are thermosetting resins based on epoxy, polyester, polyurethane, and acrylic resin systems. The cured (crosslinked) coating has a new chemical structure and will not return to the liquid phase if heated. Coatings created by thermosetting resins have outstanding physical properties and corrosion resistance.

Different types of thermosetting resins are available to achieve desired physical, electrical, chemical, and decorative properties. Current resin technology provides coatings with abrasion resistance, scuff resistance, impact resistance, heat resistance, and outdoor weatherability. Thermosetting powder coatings are available in a variety of decorative finishes including textures, low gloss, high gloss, wrinkle, smooth, clear, pigmented, and metallic.

Epoxy, polyester, and acrylic resins have been used to make thermosetting powders, with epoxy resins used most often. Major functional uses for epoxy powder coatings include electrical insulation coatings, pipe coatings, and coatings for reinforcing steel bars (rebars) used to support concrete bridges and decks. These applications make the most of epoxy s outstanding electrical and corrosion resistant properties.

Hybrids of epoxy and polyester resin blends offer slightly better UV resistance while maintaining the good mechanical strength and corrosion resistance characteristic of epoxies.

Polyester-TGIC coatings are made of polyester resin crosslinked with triglycidyl isocyanurate (TGIC) as a curing agent. This coating offers very good mechanical properties, impact strength, corrosion protection, edge coverage, low temperature cure, and weather resistance.

Acrylic urethane and polyester urethane coatings consist of acrylic resins crosslinked with isocyanates. They have excellent appearance and good flexibility.

UV-cured coatings

Ultraviolet (UV) cured coatings require electromagnetic radiation to initiate crosslinking of the resin. UV-cured coatings can be 100 percent reactive liquids, eliminating solvent use and achieving nearly 100 percent transfer efficiency, reducing paint waste. UV coating techniques are typically used to coat flat sheet stock and to apply wet look finishes to assembled furniture. They can be used on a variety of materials, including wood, plastic, paper, and metal. They can be applied using traditional spray methods, but roll-coating is often used since the parts typically are flat stock.

UV-cured coatings can only be about 1 mil thick if pigmented because the pigment molecules block the light. All coated surfaces must be visible to the UV light so the reaction can occur.

UV coating advantages

- Coatings typically contain lower amounts of VOC and HAP than conventional coatings
- Increased production rates because of rapid curing
- Low energy costs
- Low-temperature processing
- Consistent performance
- High transfer efficiency
- Equipment requires less space than curing ovens
- Low air movement reduces dust and dirt contamination
- Equipment easily installed or retrofitted
- Reduced fire and explosion hazard

UV coating disadvantages

- Interference of photocure by pigments
- Higher capital investment than conventional ovens
- Higher material costs
- Shrinkage and adhesion problems with acrylate
- Not applicable to all finish types because it produces a specific look
- Curing is sensitive to shape of part

Comparison of Coating Technologies

Benefits	High Solids Coatings	Water Based Coatings	Powder Coatings	Ultraviolet (UV) Radiation-Cured Coatings
Pollution Prevention Benefits	• reduces solvent in coating • less overspray compared to conventional coatings	• eliminates or reduces solvent in coating • water used for cleanup	• eliminates solvent in coating • reduces solvent for cleaning • reduces need for solid paint waste disposal	• eliminates solvent in coating • 100% reactive liquid
Operational Benefits	• can apply thick or thin coat • easy color blending or changing • compatible with conventional and electrostatic application equipment	• can apply thick or thin coat • easy color blending or changing • compatible with conventional and electrostatic application equipment	• can apply thick coat in one application • no mixing or stirring • efficient material use (nearly 100% transfer efficiency)	• can apply thin coat • easy color blending or changing • efficient material use (nearly 100% transfer efficiency)
Energy Savings	• reduced air flow in work spaces and curing ovens (low VOC) • reduced energy needed for heating makeup air	• reduced air flow in work spaces (little or no VOC) • reduced energy needed for heating makeup air	• little air flow needed for worker protection (no VOC) • little energy needed for heating makeup air	• little air flow in work spaces (no VOC), cure with UV instead of oven • little energy needed for heating makeup air
Applications	• zinc-coated steel doors • miscellaneous metal parts • same as conventional coatings	• wide range • architectural trade finishes • wood furniture • damp concrete	• steel • aluminum • zinc and brass castings	• some metal applications • filler for chipboard • wood • wet look finishes
Hazards and Limitations	• solvent use not completely eliminated • shorter pot life than conventional coatings	• coating flow properties and drying rates can change with humidity, affecting coating application • sensitive to humidity, workplace humidity control required • may have poor flow characteristics due to high surface tension of water • special equipment needed for electrostatic application • water in paint can cause corrosion of storage tanks and transfer piping, and flash rusting of metal substrates	• requires handling of heated parts • electrostatic application systems—part must be electrically conductive; complex shapes difficult to coat • difficult to apply thin coatings • need special equipment or extra effort to make color changes • difficult to incorporate metal flake pigments	• styrene volatility • typically best applied to flat materials • limited to thin coatings • high capital cost of equipment • yellow color

3 Application of coatings

HVLP

HVLP stands for high volume low pressure. This principle has been applied to conventional type atomizing spray guns to apply paint with a high volume of dispersing gas (air) at very low pressures less than 10 pounds per square inch (psi). HVLP guns have nozzles with larger diameter openings for atomizing air, can be bleeder or non-bleeder types, and require air volumes of 10—30 cubic feet per minute. Air can be supplied to the sprayer by turbine driven blowers, or by conventional shop compressors. Air and fluid delivery to the spray gun affect the efficiency, ease of use, cost, and versatility of HVLP sprayers. Each model has advantages and disadvantages.

In a ***siphon fed*** system, air pressure to the sprayer is used to pull paint from the cup located below the gun, producing a fully atomized pattern for even surface coverage. The simple design of these guns have made it possible to buy conversion kits for conventional siphon sprayers, making HVLP technology very affordable for small shop owners. Siphon-fed fluid delivery produces a typical HVLP soft spray pattern with only 5 psi of supplied air, and produces acceptable quality for auto refinishing. Its operational performance is comparable to conventional air guns, but with greater transfer efficiency.

Gravity fed systems are well adapted to higher viscosity paints, such as clears, water based paints, high-solid paints, and epoxy primers, given the paint cup location. The cup, located on top of the gun, allows paint to completely drain, minimizing paint waste.

The ***pressure assist cup*** uses a pressure cup mounted beneath the gun with a separately regulated air line to feed paint to the gun. This design increases transfer efficiency and makes it possi-

HVLP advantages

- Increased transfer efficiencies—from 50 to 90 percent reported efficiencies depending on air delivery system used
- Reduced amount of overspray
- Reduced paint booth filter use and consequent cleanup costs
- Reduced VOC and HAP emissions
- Good coverage on intricate parts
- Reduced worker exposure due to high pressure blowback from the spray
- Finish quality comparable to conventional air sprayers
- Comparable transfer efficiency to air-assisted airless sprayers at low fluid delivery rates with low to medium viscosity fluids
- More efficient air atomization
- Air spray coating adaptable to any size coating operation and application rate
- Equipment technology easily adaptable to mechanized automatic applications, decreasing employee exposures and further improving operating efficiency
- Equipment fittings allow for fast color changes, and application of very different fluid viscosities

HVLP disadvantages

- Fine finishing necessary for topcoat blending may be very difficult due to thick coatings needed and inability to feather the spray for gradual tapering
- Delivery rates are much lower than conventional sprayers
- Atomization might not be sufficient for fine finishes
- Higher fluid delivery rates with high viscosity materials may not be possible
- Non-turbine models clog more easily, requiring stricter gun cleaning practices and paint filtration

ble for the operator to spray evenly while the gun is inverted offering maximum flexibility in application techniques.

HVLP spray guns contain many of the conventional spray gun components that allow the operator to control fluid delivery and pattern shape. There also is a high level of gun control, as with conventional sprayers. HVLP guns allow operators to finish intricate parts with comparable quality to conventional sprayers. This makes them a good choice for small shops that finish smaller, more intricate parts which demand a higher level of gun control.

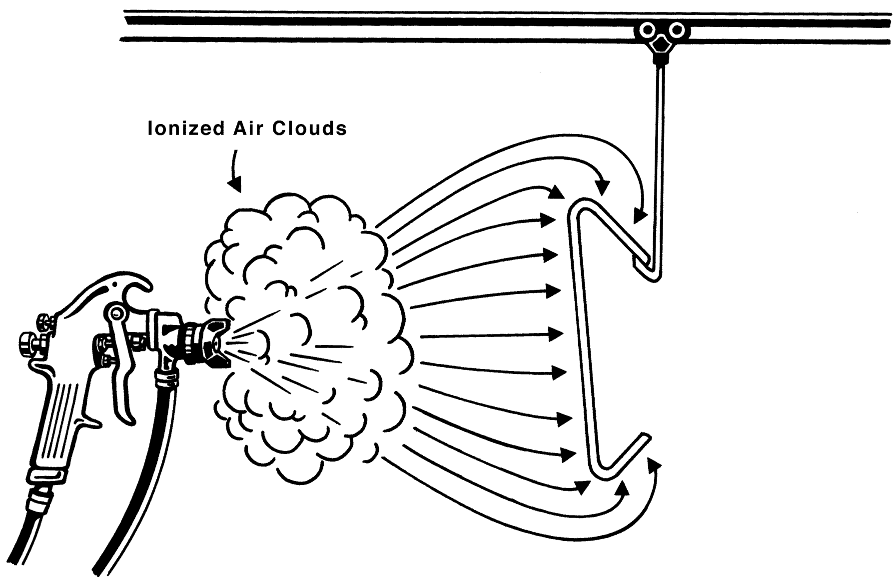
HVLP guns are beneficial for shops that need to maintain high levels of efficiency while minimizing emissions. HVLP guns have limited adjustment to higher flow rates or pressures. This results in reduced waste from overspray. Some recent environmental regulations mandate use of HVLP spray guns to comply with air emission regulations.

Powder coating

Powder is supplied to the spray gun by the ***powder delivery system***. This system consists of a powder storage container, or feed hopper, and a pumping device that transports a stream of powder into hoses or feed tubes. Compressed air is often used as a pump because it aids in separating the powder into individual particles for easier transport. The powder delivery system is usually capable of supplying powder to one or several guns. Delivery systems are available in many different sizes depending on the application, number of guns to be supplied, and volume of powder to be sprayed in a given time period. Recent improvements in powder delivery systems, coupled with better powder chemistries that reduce clumping, have made delivery of a consistent flow of particles to the spray gun possible. Agitating or fluidizing the powder in the feed hopper also helps prevent clogging or clumping before it enters the transport lines.

Electrostatic powder spray guns impart electrostatic charge to the powder being sprayed via a charging electrode located at the front of the spray gun. This technique is called corona charging and these guns generate a high-voltage, low-amperage electrostatic field between the electrode and the product being coated. The charge on the electrode can be controlled by the operator. Powder particles become charged as they pass through the ionized electrostatic field at the tip of the electrode. They are thus directed by the electrostatic field, which controls the deposition rate and powder s location on the part. The field can be adjusted to direct the powder s flow and control pattern size, shape, and powder density as it is released from the gun.

All spray guns can be classified as either manual (hand-held) or automatic (mounted on a mechanical control arm). Although basic operating principles of most guns are the same, an almost limitless variety in style, size, and shape of spray guns exists. The type of gun chosen for a given coating line can be matched to the performance characteristics needed for the products being coated.



Electrostatic

Electrostatic paint systems deliver paint that has been atomized by various methods, such as air-atomizing, airless or rotary. The atomized fluid droplets are given a negative charge as they leave the spray gun. This charge acts as an additional driving force for the fluid to the part. The part to be painted is electrically grounded, giving it a neutral charge. The charge difference causes the paint particles to be attracted to the part. If the charge difference is strong enough, fluid particles can actually reverse direction as they fly past the part, coating the edges and back of the part. This effect is called wrap-around and increases transfer efficiency. (See figure at right.) Electrostatic systems must be grounded properly at all stages of paint delivery to reduce injuries and fire hazards that may result from shorting or sparking. The electron pathway must be complete or paint will not be attracted to the part. The pathway involved in electrostatic applications is as follows:

Power supply is grounded, electrons flow to the gun tip

↓

to the paint

↓

to the part (when surface contact is made)

↓

through the part supports or hangers

↓

through the grounding device

↓

into the ground

Electrostatic spray system advantages

- High transfer efficiency
- Edge coverage
- Wrap-around abilities
- Uniform coating thickness

Electrostatic spray system disadvantages

- Complicated spray guns tend to be bulky and delicate
- Extra cleanliness required to maintain grounding pathways with hooks and hangers for parts
- Limited coverage with complicated parts due to Faraday cage effect
- Fire and safety hazard
- Parts must be conductive
- High equipment cost and maintenance requirements
- Limited usefulness for metallic coatings
- Solvent selection critical
- Can be adversely affected by humidity

Conductive paints such as water-borne and metallic paints can conduct electrons through the paint lines back to the paint supply tank which creates a serious potential for shorting-out. For solvent-borne paints, use non-polar solvents that are not conductive.

Metallic coatings are especially conductive; metal flakes stand on edge to help the particles release their negative charge. This orientation reduces the amount of surface area that reflects light, producing a darker finish than metallics applied with nonelectrostatic guns where the flakes lay flat providing maximum surface area for reflecting light. Metallic effects can be produced with electrostatic guns by replacing the metal flakes with mica, a nonconductive sodium aluminum silicate which is not affected by electrostatic application.

Electrostatic systems are affected by compounds or components that conduct electricity because they will easily divert or absorb electrons from the paint circuit. These compounds decrease efficiency of the system or in some cases, will alter how the paint adheres to the part. Humidity affects electrostatic attractions between the paint and the part. Water droplets in the air will absorb or drain the electrostatic charge from the ionized air cloud at the gun tip, ultimately reducing the paint s attraction to the part, decreasing transfer efficiency.

Airless

Another method of atomizing paint is to increase the spray gun s fluid pressure to 500—6500 psi and redesign the fluid nozzle so paint is atomized without pressurized air flow. This is called an airless spray gun. Airless guns are effective for applying high viscosity coatings (e.g., high solids, low VOC coatings) with relative ease since there is only one hose attached to the gun.

The airless gun has the same components as an air-atomized gun except the fluid nozzle is beveled outward, elliptical in shape, and designed for high pressure operation. Because of the extremely high operating pressure, a serious risk of injury exists from paint being injected under the skin. Operator protection is provided by a duckbill safety device that prevents the operator from touching the paint stream as it exits the nozzle.

Pressure is generally supplied to the gun by an air-driven reciprocating fluid pump. As the paint exits the nozzle, it expands slightly, is finely atomized, and propelled toward the part. The airless system provides high delivery rates, with the size of the nozzle orifice determining quantity and thickness of the paint applied to the part.

Airless spray system advantages

- High flow rates of paint
- Relatively high transfer efficiency
- Gun handling ease
- Ability to handle high viscosity fluids

Airless spray system disadvantages

- Relatively poor atomization
- Expensive nozzles
- Reduced fan pattern control
- Coating type limited
- Tendency for tip plugging
- Skin injection danger
- Increased operator training and skill
- Increased maintenance requirements

Air-assisted airless

Air-assisted airless sprayers look very much like air atomizing guns. Paint is delivered to the gun at pressures of 150 to 800 psi with air pressure of only 5 to 30 psi. Air is used to shape the pattern of the fluid spray when leaving the gun nozzle.

The major difference between the airless and the air-assisted spray gun is in the atomizing tip. The air-assisted tip has a fluid nozzle with an orifice in the center of the tip and an air nozzle that allows jets of atomizing air to exit from ports in small projections on each side of the tip. The jets of air impact the paint stream, breaking up the large droplets of paint and atomizing it to a finer degree.

Other technologies

Rotary atomizers

Rotary atomizers feed paint to the center of a spinning disk or bell and use centrifugal force to break the paint into droplets. Rotary devices always use electrostatic charge to guide the paint to the part being coated. No directional air is used with disk applicators, but it is used with bell applicators to reduce the circular size of the paint cloud. Electrostatic charging plays a key role in atomizing the paint at low speed rotations. Particle size is very dependent on rotational speed, with atomization efficiency best at rotations above 15,000 rpm and higher. At these speeds, atomization is achieved mostly by centrifugal force.

Air-assisted airless spray system advantages

- Good atomization superior to airless but less than air-atomized
- Variable fluid delivery 5 to 50 oz. per minute
- Low bounceback that allows spray into corners and hard-to-reach areas
- Reduced danger of paint injections
- High transfer efficiency, usually higher than airless systems
- Capable of high production rates
- Performs well on complex shapes
- Can handle wide range of fluid viscosities
- Low equipment maintenance due to lower operating pressures

Air-assisted airless spray system disadvantages

- Danger of skin injection to operators
- Increased operator training requirements
- High initial capital costs

Rotary atomizers advantages

- Well suited for covering large broad surfaces
- Excellent atomization
- High solids, waterborne versatility
- Viscosity flexibility on low VOC coatings
- High transfer efficiency
- Portable capabilities

Rotary atomizers disadvantages

- Extra cleanliness essential for proper grounding
- Limited use on complicated surfaces due to the Faraday cage effect
- Safety and fire hazards
- Parts must be conductive
- Increased equipment maintenance needs

Low-volume high-pressure spray (LVHP)

LVHP is considered the conventional method of applying coatings. It depends on air atomizing the paint at pressures of 40—70 psi. Air is supplied from an air compressor or air turbine. Paint can be supplied to the system by gravity feed, siphon system, or by a pressurized system.

LVHP advantages

- Excellent atomization creates high quality finishes
- High production rates possible
- Viscosity versatility

LVHP disadvantages

- Extensive overspray
- Increased booth cleanup cost
- Increased filter use, cost, and disposal requirements

Dip coating

In dip coating, parts are coated by being dipped into vats of paint. Dip coating requires paint viscosity to remain constant to assure acceptable film quality. Paint thickness is controlled by the paint viscosity and the rate at which parts are pulled from the dip tank. This process is well suited for parts that are always the same color and have minimum decorative finish requirements, such as agricultural equipment.

Flow coating

Flow coat systems use 10—80 separate streams of paint that coat all the part s surfaces. Paint viscosity controls the coating thickness. Paint is applied liberally to the part and the excess flows into a collection vat where it is filtered and recirculated to the bulk paint supply. An area must be provided for the part to hang while dripping excess paint. This process is suited for standardized color needs with low decorative finish requirements.

Dip coating advantages

- High production rates
- Low labor requirements
- High transfer efficiency

Dip coating disadvantages

- Extremely dependent on viscosity of the paint
- Not suitable for items with hollows or cavities
- Color changes are slow
- Fire hazards associated with open vats
- Poor to fair appearance

Flow coating advantages

- High transfer efficiency
- Low installation cost
- Requires little maintenance
- High production rates
- Low labor requirements

Flow coating disadvantages

- Poor to fair appearance
- Film thickness entirely dependent on viscosity of paint

Autodeposition advantages

- Excellent anticorrosion properties; no phosphate pretreatment coating required
- 100 percent surface coverage
- Uses waterborne materials and no organic solvents
- Requires no electricity to drive the reaction
- Produces no VOC emissions

Autodeposition disadvantages

- Dull or low gloss finish
- Limited color choice

Electrodeposition advantages

- Coating thickness is uniform
- Capable of high production rates
- Primer/one coat options
- Low VOC emissions

Electrodeposition disadvantages

- Coating contains some solvent, has VOC emissions
- Substrate limited to metal or conductive materials
- Separate tanks and rinse lines needed for each color
- High initial investment cost
- Intensive maintenance requirements
- Air entrapment in or on part prevents coating
- Requires de-ionized water
- Rework difficult
- Restricted to large production finishing requirements
- Coating thickness is limited
- High level of training is needed
- Large quantities of small parts difficult to coat

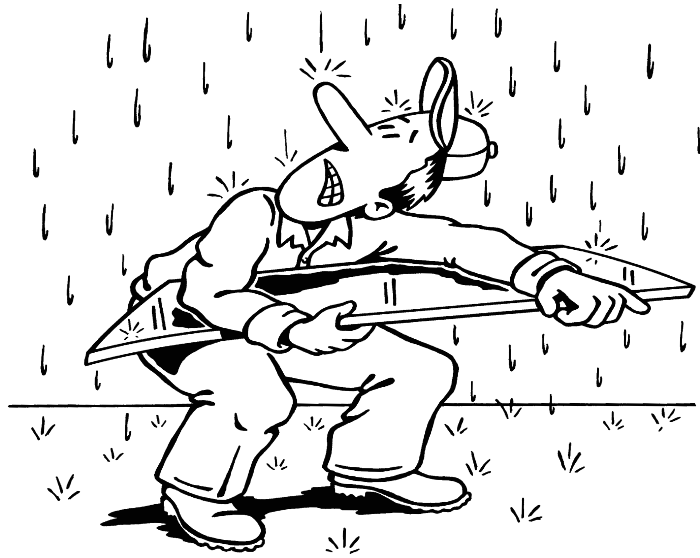
Autodeposition

Autodeposition relies on a chemical reaction called oxidation-reduction (redox) to deposit an organic coating onto iron, steel, zinc, and zinc alloy-plated materials. The part is immersed into a solution containing paint compounds, usually a vinyl emulsion, hydrofluoric acid, and hydrogen peroxide. When the part is submersed the paint compound precipitates out of the solution and coats the part. The part is then removed from the tank, rinsed, and cured. This process does not use organic solvents so no VOC are emitted.

Electrodeposition

Electrodeposition also requires the part to be immersed in a waterborne coating. The cosolvent is typically an organic solvent. The process is very much like electroplating in that the reaction is driven by electricity. Direct current is passed through the solution and causes an electrochemical reaction with the paint resin. The paint resin becomes insoluble, precipitates out of the solution, and deposits on the part. Pigments are entrapped with the resins providing uniform color results.

4 P2 and waste minimization in painting processes



Paint application wastes include leftover paints, dirty thinner from cleaning spray guns and paint cups, air emissions of volatile organic compounds (VOC) and hazardous air pollutants (HAP), dirty spray booth filters, dirty rags, area wash downs, and disposal of out-dated supplies. Ways to reduce these wastes include rigid inventory control, better housekeeping practices, mixing paint according to need, better operator training, proper cleaning methods, using alternative coatings, using styrofoam filters, recycling solvents on- and off-site, and using waste exchanges.

Better operating practices, or good housekeeping, applies to all waste streams and requires minimal capital outlays, yet can be very effective in reducing the amount of wastes generated. Good housekeeping includes management initiatives to increase employee awareness of the need for and benefits of pollution prevention, and preventive maintenance to reduce the number of leaks and spills.

Waste	Pollution prevention option
■ Paint waste	• Rigid inventory control to reduce thinner use • Instill better housekeeping to reduce leaks and spills • Mix paint according to need, document usage • Provide operator training • Schedule jobs to maximize color runs
■ Solvent waste	• Control inventory to reduce solvent use • Substitute coating material for one with low or no solvents • Substitute cleaning solution for one with low or no solvents • Practice proper equipment cleaning methods • Recycle solvent on-site • Recycle solvent off-site by means of thinner leasing agreements • Contact waste exchanges
■ VOC emissions	• Use high transfer efficiency equipment • Use enclosed cleaning devices • Use low- or no-VOC coatings and cleaners
■ Booth filters	• Use high transfer efficiency equipment • Use styrofoam filters
■ General	• Improve material handling and storage to avoid spills • Segregate waste streams • Perform preventive maintenance • Practice emergency preparedness • Charge departments generating waste for costs associated with its management and disposal

Rigid inventory control

Rigid inventory control is an effective and efficient way of reducing indiscriminate use of raw materials. The owner may monitor employee operations and make verbal or written comments on product usage. Limit employee access to storage areas containing raw materials. This inaccessibility can force the employee to stretch the use of raw materials.

In one shop, records are kept on the amount of paint each worker uses. These records can be checked against the number of parts the worker repairs or produces, and wasteful use of materials can be spotted quickly. This information is very useful in determining trouble spots or problem areas that need careful attention. Comparing usage rates among workers and facilities allows a manager to determine if the problem is worker-related (correct procedures improperly performed) or facility-related (improper procedures specified and implemented).

Better housekeeping practices

Basic housekeeping techniques can be very effective in reducing pollution. Many methods are available to control and minimize material losses which can be implemented easily and at little or no cost to the operator. Specific approaches to bulk material drum location, material transfer methods, evaporation, and drum transport can effectively limit material loss.

- Control inventory by storing drums together in an area of limited accessibility.
- Reduce leaks and spills by placing drums at points of highest use.
- Use spigots or pumps when transferring materials from storage containers to smaller containers.
- Control evaporation by using tight-fitting lids and spigots.
- Use drip pans.
- Use secondary containment in bulk storage area.
- Move drums correctly to prevent damage or punctures which could lead to leaks or ruptures during future use.

Paint mixing

In automotive refinishing, many operators prepare a set amount of paint for each job (e.g., one pint or quart). For small jobs, the amount of paint prepared will often exceed the amount of paint actually applied. Have various sizes of paint mixing and sprayer cups available to limit overmixing of paint for a specific project, and to reduce the amount of solvent needed for equipment cleanup. Consider any paint not used for the job as hazardous waste and dispose of it as such. Note that as the amount of paint mixed decreases, weighing accuracy becomes more critical.

Better operator training

Operators may be very skilled at producing high quality finishes but poorly trained in minimizing paint usage. Key points for operators include:

- Do not arc the spray gun and blow paint into the air.
- Maintain a fixed distance from the painted surface while triggering the gun.
- Air pressure (often set too high) should be kept low; this can increase transfer efficiency by 30 to 60 percent.
- Keep the gun perpendicular to the surface being painted.

High transfer efficiency equipment

Less overspray means less air emissions. Transfer efficiency is a measure of how much paint goes on the part, compared to how much is sprayed. Typical transfer efficiency from conventional air guns ranges from 20 to 40 percent, thus 60 to 80 percent of the paint is overspray. Overspray is a function of the design and operation of the system used. The efficiency of several systems is listed at right.

Alternative coatings

VOC emissions are related to the type of coating used and the number of coats necessary for a high quality finish. Acrylic lacquers are typically thinned with solvent by 125 to 150 percent. At least four or five double coats are applied to achieve enough buildup for sanding and buffing.

With synthetic enamels, solvent thinning amounts to 15 to 33 percent. Since enamel dries to a gloss and is not sanded, only two or three medium coats are required. Base coat/top coat systems usually require two or three coats of each.

Minimize or eliminate VOC emissions by substituting solvent-based paint with waterborne paint, high solids paint, or with medium- or low-solvent paint.

Proper cleaning methods

Reduce solvent use in equipment cleaning. Scrape paint cups or tanks before rinsing with solvent. Make use of Teflon-lined metal paint containers which are easier to clean. Use an enclosed gun cleaning station. Spray solvent through the gun into the cleaning station, where it is condensed for recovery and reuse.

Schedule jobs so that large batches of similar items are painted, instead of small batches of custom items, to reduce the amount of dirty cleaning solvent and waste paint generated.

System	Transfer Efficiency
Conventional air-atomized spray	30-60%
Conventional pressure-atomized spray	65-70%
Electrostatic air-atomized spray	65-85%
Electrostatic centrifugal-atomized spray	85-95%
Roller/flow coating machines	90-98%
Electrocoating systems	90-99%

Styrofoam filters

Thinner suppliers or recyclers may replace and dispose of dirty spray booth filters. Consider filters hazardous waste if they contain wet paint (e.g., solvents), due to their flammability. Filters also may be hazardous due to their potential toxicity.

Use a cleanable styrofoam filter to reduce filter waste. When dirty, clean the filter by blowing with compressed air and reusing it (removed paint would require collection and may still be classified as hazardous). When the filter is no longer reusable, dissolve it in waste solvent. Before using this filter, check with your solvent recycler to determine if dissolved styrofoam will interfere with their thinner recycling operation.

On-site solvent recycling

Several alternatives are available for recycling solvent on-site. Gravity separation is inexpensive and relatively easy to implement by allowing the solvent/sludge mixture to separate under quiescent conditions. The clear solvent can then be decanted with a drum pump and used for equipment cleaning, reducing the amount of wash solvent purchased. Reclaimed solvent can be used for formulating primers and base coats, but might create problems if not sufficiently pure.

For those facilities that generate larger quantities of waste solvent, on-site distillation may provide a more cost-effective alternative. Batch distillation of all high grade solvent wastes can virtually eliminate the need for purchasing lower quality solvents for use in preliminary painting operations and cleanup. An operator may reclaim 4-1/2 gallons of thinner, with 1/2 gallon left as sludge from 5 gallons of paint and thinner wastes. This ratio varies depending on the operations.

Advantages of on-site solvent recycling

- less waste leaves the shop
- owner s control of reclaimed solvent s purity
- reduces future liability from improper disposal
- reduces cost of transporting waste off-site
- reduces reporting (manifesting) costs
- possibly lowers unit cost of reclaimed solvent

Disadvantages of on-site solvent recycling

- capital cost of recycling equipment
- possible need for operator training
- additional operating and maintenance costs

Off-site solvent recycling

Low volume solvent users or those who find it uneconomical to recycle contaminated solvents on-site, usually send their wastes to commercial recyclers for recovery. Commercial recyclers have versatile distillation processes and can handle large volumes and varieties of solvents. Generally, solvent recyclers recover 70 to 80 percent of the incoming spent solvents into reusable products. Recyclers often sell reclaimed solvents back to the user.

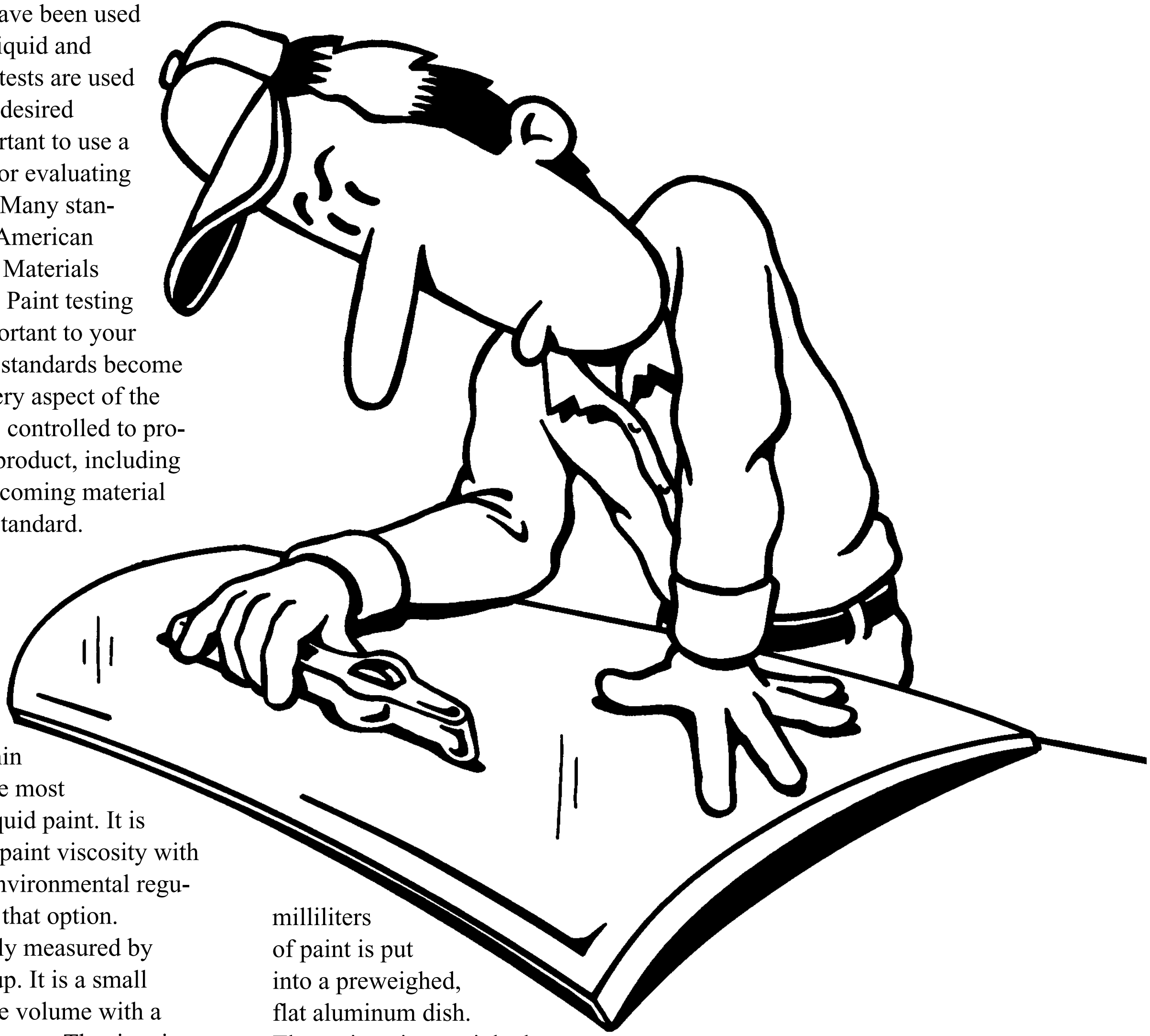
In general, suppliers who offer recycling services include the cost of waste collection and recycling in the price of their solvent. This increases the thinner cost, but effectively eliminates separate hauling and disposal or recycling costs. It also reduces the administrative burden on the owner or manager.

Waste exchanges

Waste exchanges provide another alternative for removing waste. Waste exchanges are organizations that manage or arrange the transfer of wastes between industries, where one producer s waste becomes another industry s feed stock. Most exchanges exist as information clearinghouses, which provide information on available waste. Opportunities exist for these exchanges to oversee direct transfer (without processing) of waste solvents from industries requiring ultra-high-purity solvents (e.g., the electronics industry) to industries that do not have such stringent purity requirements (e.g., the machinery and painting industries).

5 Testing

Different tests have been used over the years for liquid and cured paints. Most tests are used to verify a specific desired property. It is important to use a consistent system for evaluating coating properties. Many standards are found in American Society for Testing Materials (ASTM) standards. Paint testing becomes more important to your business as quality standards become more stringent. Every aspect of the process needs to be controlled to produce a top-quality product, including ensuring that the incoming material meets a particular standard.



Liquid paint

Viscosity can be characterized as the ability of the paint to flow, i.e., how thick or thin it is. Viscosity is the most common test for liquid paint. It is common to reduce paint viscosity with thinner, although environmental regulations are limiting that option. Viscosity is typically measured by using a viscosity cup. It is a small metal cup of precise volume with a small hole in the bottom. The time it takes for the paint to drain through the hole corresponds to the viscosity. Viscosity is temperature sensitive, so the test must be performed at a specific temperature. When applying paint, heaters are sometimes used to lower the viscosity in lieu of adding solvents.

Another test is weight percent solids, or weight percent VOC. Environmental regulations in some areas specify VOC content of paints. (See Appendix IV A.) The VOC content is determined using the following test. For solvent-borne paints, paint is drawn into a small syringe and the entire syringe is weighed. Four milliliters of paint is put into a preweighed, flat aluminum dish. The syringe is reweighed, and the difference is the weight of wet paint in the dish. The paint is then baked in an oven one hour at 235¡F, cooled and reweighed. Percent solids and percent VOC can be found using the following equations:

$$\textit{Percent Solids} = \frac{\textit{weight of dry paint}}{\textit{weight of wet paint}} \times 100$$

$$\textit{Percent VOC} = 100 - \textit{percent solids}$$

The procedure for waterborne paints is more complicated. It requires chemical testing to determine water content. The details can be found in ASTM D-2697.

Other tests that may be done on bulk paint include pot life and fineness of grind.

Application equipment

Transfer efficiency (TE) is a measure (by weight) of the amount of paint on the part compared to the amount of paint used. It is somewhat difficult to accurately quantify, and varies with the operator. To determine TE, measure the amount of paint used by weighing the container before and after painting. Measure the amount of paint on the part by weighing the parts before painting and after the paint is cured. Percent solids is defined in the previous section. Remember to measure percent solids as applied, which includes any additional thinner added by the operators. The transfer efficiency is found using the following equation:

$$TE\% = \frac{\text{paint on the part} \times 100}{(\text{percent solids}) \times (\text{paint used})} \times 100$$

Other application equipment tests include measuring electrostatic voltage, checking for electrical ground, booth airflow, gun airflow, and gun air pressure.

Cured paint

A variety of tests are used on cured paints. Thickness, adhesion, various forms of chemical resistance, color match, and extent of cure are typically tested. Choose tests based on customer requirements. For example, applications that involve high exposure to water or weather require certain performance from the coating. Whether the coating supplier provides this information or the manufacturer does the tests at their facility, it must be assured that the coating can perform according to specifications.

Thickness measurements can be performed on substrates containing iron by using a magnetic pull-off type gauge. Magnetic attraction decreases in proportion to the coating thickness. Pencil and banana gauges are two types of pull-off gauges. For other substrates, micrometers can be used to measure coating thickness. Destructive thickness methods include placing a piece of tape on the substrate prior to painting, removing it, and measuring the difference between the tape thickness before and after painting.

Flexibility (bend or impact) is usually measured by bending a painted panel in a prescribed way or by dropping objects on the panel. Brittle paints will not retain adhesion under these stresses.

Adhesion (tape) can be measured by removing a piece of tape applied prior to painting. The method is deceptively simple. ASTM D-3359 gives details about the test, including a rating scale for evaluating results. It is critical to perform this test consistently. The actual method may vary but the procedure must be performed identically every time.

A simple hardness test is the pencil hardness test (ASTM D-3363), where pencil lead with specified hardness (within the range of 6B-B, HB, F, H-6H) is pushed against the paint. The hardest pencil that does not mar the paint is considered the paint hardness. As with other subjective tests, specific procedures must be followed consistently so test results are meaningful.

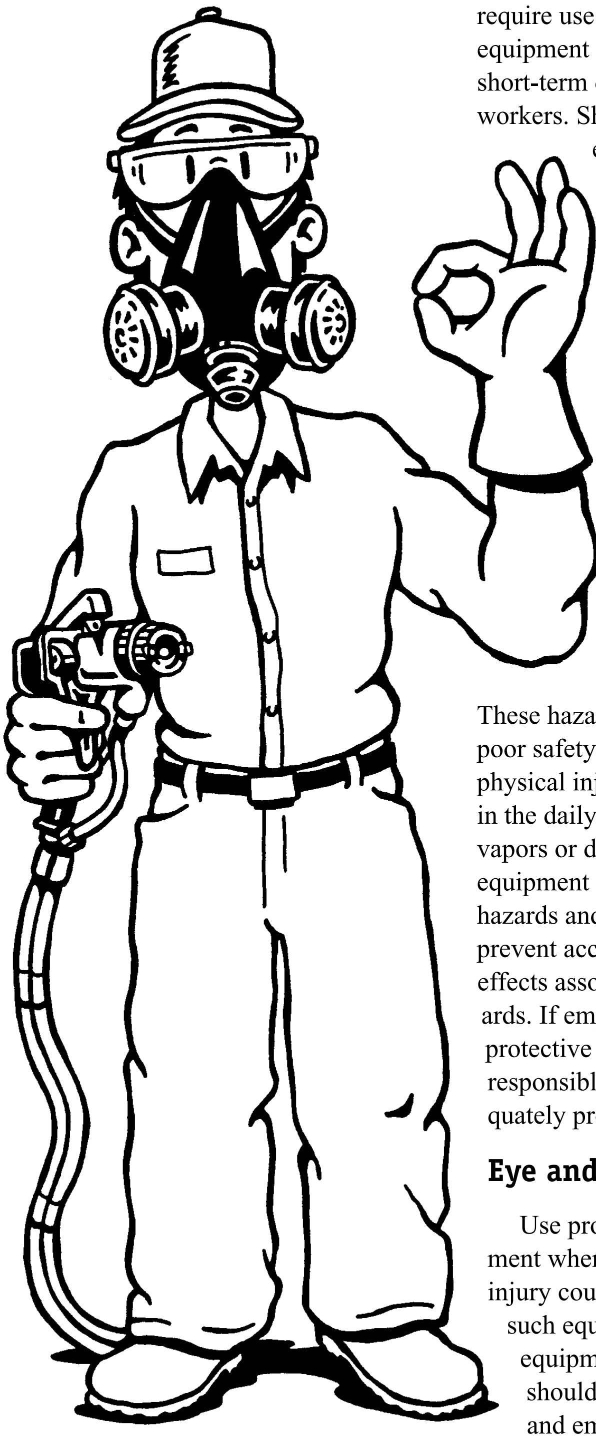
Extent of cure can be determined via hardness testing or a solvent rub test. The solvent rub involves rubbing the cured coating a prescribed number of times with a paper towel or cloth saturated with a specific solvent. If no color appears on the towel, the paint is considered cured.

Water and weather resistance can be measured in a variety of ways. Immersion, humidity resistance, and accelerated weathering are all typical methods. Accelerated weathering can combine UV light exposure with elevated temperatures and humidity or salt sprays. In addition to predicting field performance, a primary benefit of accelerated weathering is to differentiate different coatings performance. It can be used as an effective screening tool for choosing alternate formulations.

Color matching is challenging because many variables contribute to the test s outcome. Reflected light is the basis for interpreting color. Light sources (sunlight or specific artificial sources) vary, thus reflected light from the paint can vary. Conduct color matching, whether visual or instrumental, under several light sources. The Munsell system and the CIE system are commonly used and employ three different light sources to determine color.

Attribute measure	Test
thickness	pencil or banana gauge micrometer tape thickness
flexibility	bend or impact
paint adhesion	tape adhesion
hardness	pencil hardness
extent of cure	solvent rub
water or weather resistance	immersion humidity resistance accelerated weathering
color matching	Munsell or CIE

6 Personal protective equipment



Painting and related processes require use of personal protective equipment to reduce long-term and short-term detrimental health effects to workers. Short-term effects, or acute effects, are associated with events that lead to an immediately recognized health consequence. Concentrated solvent fumes may cause oxygen deficiency. Long-term health hazards, or chronic effects, are created by exposures to repeated events or conditions over a long period of time where effects are not immediately evident. The painting industry poses both acute and chronic health hazards. These hazards may be associated with poor safety practices, which cause physical injury, or with materials used in the daily process such as solvent vapors or dusts. Personal protective equipment is designed to minimize hazards and should always be used to prevent accidents or serious health effects associated with work place hazards. If employees provide their own protective equipment, the employer is responsible for assuring that it adequately protects the employee.

Eye and face protection

Use protective eye and face equipment where there is a chance that injury could be prevented by using such equipment. In these cases, equipment suitable for the work should be conveniently available, and employees trained on how to use the equipment. People with glasses who also need eye protection should wear goggles or glasses with safety prescription lenses.

Hazards requiring eye protection

- Flying objects
- Glare
- Liquids
- Harmful radiation
- Combination of these

Respiratory protection

Air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors must be controlled. The best option is to use engineering control measures to reduce air contaminants, such as enclosing or confining the operation, ventilating the work area, and substituting less toxic materials. When controls are not feasible, or while controls are being instituted, use appropriate respirators.

There are air purifying or air supplied respirators. Air purifying respirators do not have their own oxygen supply, so use them only where there is sufficient oxygen. Match the filtering canister to the contaminant present. Wear supplied air respirators when there is not sufficient oxygen or the contaminant present could be immediately dangerous to life and health.

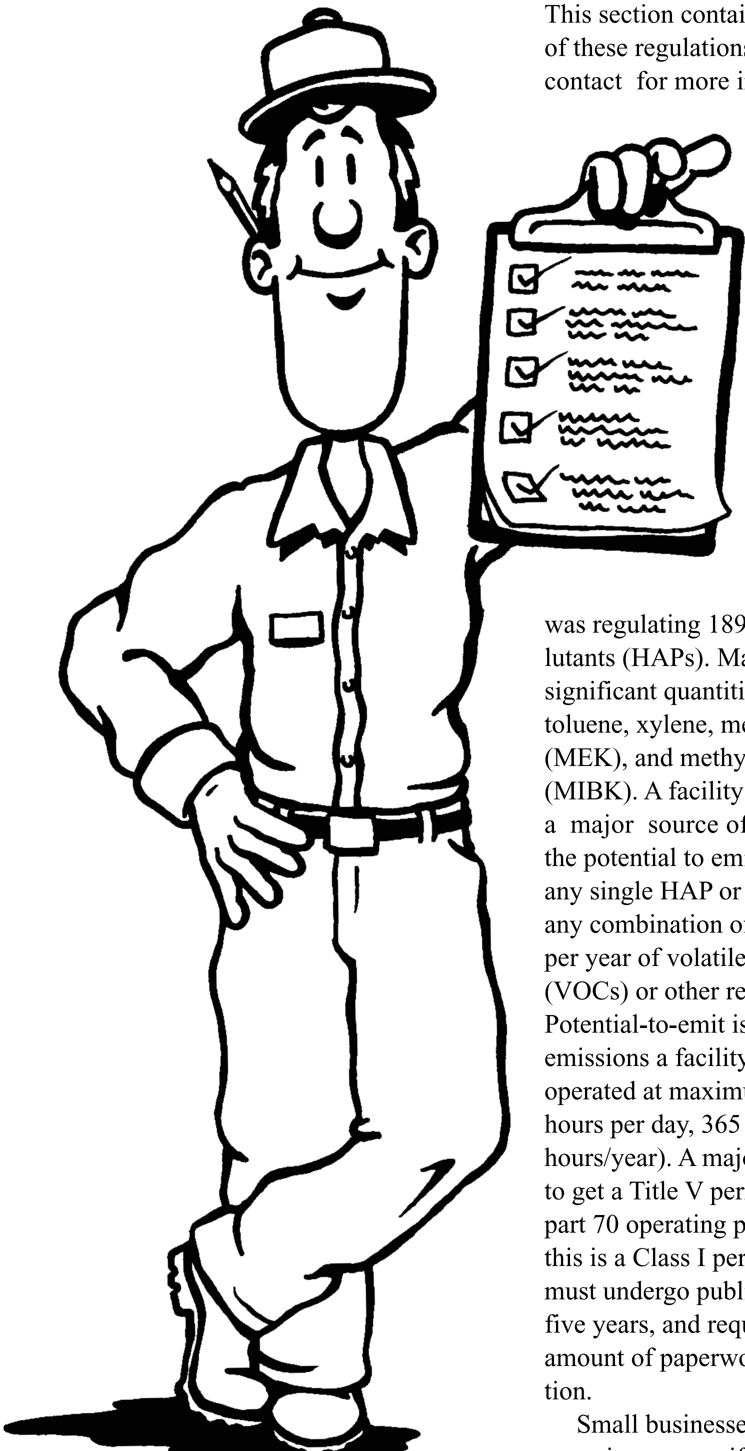
Respiratory problems can result from breathing unreacted isocyanate vapors over a period of time. Since isocyanates have no recognizable odor, the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) have recommended respiratory equipment with separate air supply. Isocyanate-free urethanes are on the market. Their performance is nearly identical to traditional urethanes and they pose less application risk.

Proper instruction in respirator selection, use, and maintenance is essential and mandated by OSHA for both supervisors and workers. Provide employees an opportunity to handle the respirator. Have it fit tested properly: Test its face piece seal, wear it in normal air for a period of time, and wear it in a test atmosphere to ensure that the seal is gas-tight. Do not wear respirators unless they have a good face seal. Make sure the face piece and corrective lenses, if required, are fitted by qualified individuals. Regularly inspect, clean, and repair equipment. Store respirators properly. Do not store them in lockers or tool boxes unless they are in carrying cases or cartons.

Skin protection

Protect skin from harmful materials that can be absorbed. Use gloves, lab coats, face shields, and other appropriate clothing. Gloves may also be required to protect against electric shock. Clothing should be chosen by a qualified person aware of all electrical hazards, chemicals, and their uses.

7 Environmental regulations



Three major categories of regulations affect painting operations: air, hazardous waste, and workplace safety. This section contains brief summaries of these regulations. A list of who to contact for more information, a summary of air regulations, and other pertinent regulatory information can be found in Appendices III and IV.

Air

The Clean Air Act Amendments of 1990 reorganized the way air emissions are regulated. One change was regulating 189 hazardous air pollutants (HAPs). Many paints contain significant quantities of HAPs, such as toluene, xylene, methyl ethyl ketone (MEK), and methyl isobutyl ketone (MIBK). A facility can be classified as a major source of emissions if it has the potential to emit 10 tons per year of any single HAP or 25 tons per year of any combination of HAPs, or 100 tons per year of volatile organic compounds (VOCs) or other regulated pollutant. Potential-to-emit is the amount of emissions a facility could release if it operated at maximum capacity 24 hours per day, 365 days per year (8760 hours/year). A major source is required to get a Title V permit (also known as a part 70 operating permit). In Kansas, this is a Class I permit. This permit must undergo public review, lasts for five years, and requires a significant amount of paperwork and documentation.

Small businesses can be classified as major sources if their potential-to-emit is at the major source level, even if actual emissions are well below those levels. Many small businesses are potentially major sources because of the relatively low threshold for HAP emissions. In Kansas, less rigorous permits, called Class II permits, are available to help small businesses avoid Title V permitting. These permits are simple to complete and they limit a facility s potential-to-emit. By limiting potential-to-emit, a facility with lower actual emissions is not classified as a major source. In order to avoid getting a Class I permit, the facility must apply for the Class II permit six months before it would need a Class I (major source) permit.

A facility should conduct an emissions inventory to know what kind of permit is needed. Information on calculating potential solvent emissions, including solvent emissions from painting and cleaning, is included in Appendix IV B.2.

Certain counties have additional restrictions. In Kansas, facilities in Johnson and Wyandotte Counties are restricted to using coatings with low VOC content. The current regulations (K.A.R. 28-19-73) mainly affect surface coating of miscellaneous metal parts and products and metal furniture, at facilities which have potential VOC emissions greater than three tons per year. For example, the regulations limit the VOC content to 3.5 pounds per gallon for a coating that is air dried or warm air-dried. Automobile refinishers and customized top coaters of automobiles and trucks that process less than 35 vehicles per day are exempt from this regulation.

Hazardous waste

Solvents in paints (and corresponding thinners and clean-up solvents) and metals in paints may be sources of hazardous waste. Empty paint cans and used filters may be classified as hazardous waste if the paint is hazardous waste. Wet materials may be classified as hazardous waste because of their solvent content. Reduce the amount of hazardous waste generated by switching to coatings that do not contain hazardous chemicals. In addition to potential future liability associated with hazardous waste disposal, the regulatory burden associated with hazardous material management is significant. There are limits on the amount of hazardous waste that may be stored on-site as well as the length of time these wastes may be stored. Labeling requirements must be met and recordkeeping must also be maintained.

Wastes can be characterized as hazardous as a result of any of several attributes, including flammability or toxicity. A test to determine whether or not constituents in waste will leach from the landfill into the groundwater is the Toxicity Characteristic Leaching Procedure (TCLP). Have a certified laboratory perform this test on a representative sample of waste destined for landfill disposal.

In Kansas, there are three classifications for facilities that generate hazardous waste. A small quantity generator can generate a maximum amount of 55 lbs (25 kg) of hazardous waste per month and accumulate no more than 2,200 lbs of hazardous waste without being required to meet extensive regulation. The facility must properly dispose of any hazardous waste generated.

A Kansas generator can generate up to 2,200 lbs per month of hazardous waste and store up to 2,200 lbs of hazardous waste. An EPA generator exceeds these thresholds. Both of these generators must obtain EPA identification numbers, maintain records, meet labeling requirements, follow prescribed guidelines for storing and maintaining containers, follow emergency preparedness requirements, and properly dispose of their hazardous waste.

Health and safety

The Occupational Safety and Health Administration (OSHA) regulates all aspects of workplace safety, including personal protective equipment, paint booth design, fire and explosion precautions, emergency response, and worker protection. Although this manual contains a section on personal protective equipment, thorough review of OSHA regulations is not included. Further information on OSHA regulations may be obtained from one of the contacts listed in Appendix III.