OVERVIEW OF POLLUTION PREVENTION COATING APLLICATION PROCESSES

Significant amounts of pollutants are generated from paint and coatings processes. The exact amount for the nation is difficult to calculate, because use is spread across numerous industry groups and companies do not report emissions by manufacturing process to EPA. Wastes from paint application include leftover paints, dirty thinner from the cleaning of spray guns and paint cups, air emissions of VOCs and HAPs, dirty spray booth filters, dirty rags, debris from area wash downs, and outdated supplies. Simple and cost-effective ways to reduce these wastes include rigid inventory control, good housekeeping practices, proper paint mixing, increased operator training, proper cleaning methods, recycling solvents, reusable paint booth filters, and the use of waste exchanges

Rigid Inventory Control

Rigid inventory control is an efficient and effective way of reducing indiscriminate use of raw materials. The facility should monitor employee operations and make verbal or written comments on product use. Another option is to limit employee access to storage areas containing raw materials. This inaccessibility can force employees to stretch the use of raw materials. Rigid control can reduce solvent use by as much as 50%.

Good Housekeeping

Improvements in better operating practices, or "good housekeeping" methods apply to all emissions and waste streams, require minimal capital outlays, and can be very effective in reducing wastes and pollutants. Good housekeeping includes the development of management initiatives to increase employee awareness of the need for, and benefits of: pollution prevention; preventative maintenance to reduce the number of leaks and spills; and efficient use of raw materials.

Many methods are available to control and minimize material losses. The following approaches to bulk material drum consolidation, 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 to transfer materials from storage containers to "working" containers
- Control evaporation by using tight-fitting lids and spigots
- Use drip pans
- Use secondary containment in bulk storage areas
- Move drums correctly to prevent damage or punctures that could lead to leaks or ruptures during future use.

Paint Mixing

In many cases, facilities will mix a fixed amount of paint for each job (e.g., one pint or one quart). For small jobs especially, the amount of paint prepared often exceeds the amount of paint actually applied. Facilities can encourage the use of the correct amount of paint by having various sizes of paint-mixing and sprayer cups available to limit overmixing. Any paint not used for a job is usually considered a hazardous waste and should be disposed of as such. A disadvantage to this technique is that if too little paint is mixed for the job and more needs to be made, color matching can be difficult.

Operator Training

Untrained and hurried workers using poorly maintained equipment could contribute to the need to rework products and to clean up and dispose of wasted coatings, thereby increasing costs. A well-trained operator is far more important than the type of gun used. By training operators on proper equipment setup, application techniques and maintenance, companies can reduce the use of materials by 20 to 40%. These savings will depend on the parts coated, material sprayed, and operator technique and experience level. The fundamentals of effective spray technique that operators can follow are:

- Proper gun setup. Use the paint gun manufacturer's suggested air cap and fluid tip combination for the viscosity of the product being sprayed. Check the spray gun to see that it produces a proper spray pattern, and keep the air and fluid pressures at the lowest possible settings.
- Spray distance and angle. Keep the distance between the gun and the part being sprayed as close as possible to the manufacturer's recommendations at all times (e.g., 6 to 8 inches for conventional spraying, 12 to 15 inches for airless spraying, and 10 to 12 inches for electrostatic spraying). Move the spray gun parallel to the work, keeping the gun at a right angle.
- Triggering and overlap. Overlap each successive stroke (e.g., 50% for conventional spraying or 25% for airless spraying), using a crosshatch overlap when required. Trigger the spray gun at the beginning and end of each stroke, making sure that the gun is in motion before triggering. In so doing, operators can minimize the lead (i.e., the distance between where the gun is triggered and the point where the gun pattern hits the part) and the lag (i.e., the distance between the point where the pattern leaves the part and the point where the gun is untriggered), thereby reducing overspray.

Whenever helping companies adjust the spray technique of operators, technical assistance providers should keep in mind that, over a period of time, the firm may have selected a coating and application equipment to conform to an incorrect technique. Equipment settings and materials might need to be changed to conform to an improved technique.

The Spray Technique Analysis and Research (STAR®) Program is a revolutionary and unique approach to improving the efficiency of manual spray coating operations. The STAR® program teaches spray technicians how to optimize the efficiency of an entire spray system and was developed at the Iowa Waste Reduction Center.

The key to the STAR® is the development of a laser touch targeting device that can be attached to most commonly used spray guns. Powered by only two AA batteries, the device emits two laser beams that are positioned to converge at a specified distance. When the painter holds the gun at the right distance from the work piece, the beams converge and the painter sees but a single laser dot. The Laser Touch permits setting the convergence point anywhere from one inch to 20 feet to accommodate a wide variety of finishing operations. The device also helps the operator maintain proper spraying angle. Use of the Laser Touch yielded the following results:

- A 30 percent reduction in material consumption,
- A 31 percent reduction in hazardous air emissions,
- A 13 percent increase in transfer efficiency.

Proper Cleaning Methods
When a painting process is completed, a color change is needed, or maintenance is required, the metal coater must clean the equipment. There are numerous P2 opportunities for reducing waste and air emissions in equipment cleaning operations.

Pollution Problem
External equipment surfaces generally are cleaned by soaking, wiping or flushing with solvent. If equipment cleaning is done in an open container, a significant quantity of solvent is lost to evaporation. Internal parts and passageways as well as paint guns are commonly cleaned by flushing solvent through the gun and orifice. This practice also results in significant evaporation and loss of usable product.

P2 Options
A cost-effective method for reducing wastes is to eliminate unnecessary cleaning. For equipment that requires cleaning, making improvements in operating practices that minimize solvent use and reduce evaporation should be implemented wherever practical. Using a gun washer to clean spray guns is one example. Various solvent recovery and reuse technologies are also available. In addition, alternative cleaning solutions can be used. Each of these options is discussed below.

P2 Tips for Equipment Cleaning

- Eliminate unnecessary cleaning
- Improve current operating practices
- Use a gun washer
- Recover and reuse spent solvents
- Use alternative nontoxic cleaning solutions

Scheduling Improvements
Implementing better operating practices and scheduling can significantly reduce waste generated from cleaning operations. The amount of waste generated is directly related to the number of times paint color or paint types are made. For this reason, scheduling improvements have perhaps the largest effect on the volume of waste produced from cleaning equipment. Making large batches of similarly produced items instead of small batches of custom items, increases the time between cleaning. Additionally, scheduling paint jobs so that they move from the lightest color to the darkest can also reduce the need to clean.

Eliminate Unnecessary Cleaning

When assessing the cleaning process, all the typical cleaning tasks should be reviewed to learn whether cleaning is necessary. While most coaters assume that spray guns, tips and lines must be cleaned for reuse, cleaning some low-cost items might not be advisable. Costs from cleaning solvent purchases, solvent waste disposal and solvent emissions could be higher than simply replacing the item being cleaned. However, the costs of proper disposal must be factored into any decision.

Improve Current Operating Practices

A technical assistance provider should also help a client company review the ways in which cleaning solvents are handled. All solvents should be stored in covered containers when not in use. Leaving solvents in the open air creates unnecessary solvent waste and VOC emissions. In addition, the company should set a standard for the minimum strength necessary for cleaning in order to ensure that used solvent is disposed of or recycled only when it loses its cleaning effectiveness, not just because it looks dirty.

Use a Gun Washer

The use of a gun washer can also help to reduce wastes generated during equipment cleaning. An automatic gun washer operates like a dishwasher. The paint gun is partially disassembled and placed in the unit. Cleaning is accomplished by recirculating solvent sprays. These units reportedly reduce solvent waste by 50 to 75%. VOC emissions can be reduced by up to 20%, and a 60% labor time savings can be achieved.

Units range in cost from $600 for small units to approximately $1,500 for industrial type units (i.e., gun and paint hose wash). Similar units may also be leased through various chemical suppliers and waste management companies at a cost of $165 to $195 per 5-gallon waste solvent change out interval.

Pressure Pot Liners

For maintenance of pressure pots, many companies use a polyethylene inner liner with the pressure pot. The main advantage of this practice is that only a small amount of paint comes into contact with the steel or stainless steel body, and cleaning the liner requires only a small amount of solvent. After pouring solvent into the liner, the operator should swirl it around for a few seconds. The operator can then discard the spent solvent into a hazardous waste drum and the liner is ready to be reused.

Some operators choose to allow the paint that sticks to the side of the liner to dry out, which causes it to flake off with ease. If the solid paint is shown to be hazardous per RCRA guidelines the facility must manage it as a hazardous waste. If it is not hazardous, it can be discarded with the rest of the solid waste. The liner should then be reused.

Use Alternative Cleaning Solutions

Because of the increased need to reduce VOC emissions, alternative cleaning solutions are available. They include dibasic esters (DBE), N-methyl-2-pyrolidone (NMP), and a variety of other alkaline-, citric-, and water-based solvents such as d-limonene, naphtha, and terpenes. These chemicals have reduced VOC emissions due to their lower evaporation rate. Although toxicology information specific to these chemicals is relatively limited at this time, many researchers believe that the relative safety of similar chemicals indicate that they are a feasible alternative to organic solvents in certain applications.

Recover and Reuse Spent Solvents

Onsite recycling of used solvent is another way to reduce waste and save money. Savings come from reducing the amount of solvent purchased and the volume of spent solvent that must be sent offsite for costly disposal. Two common methods of solvent recycling are settling and distilling.

Settling involves putting used solvent in a container and letting the particulate matter settle out. The container should be designed to allow for removal of solvent without shaking up the sludge that has settled out. Solvents can be used for gun cleaning and then can be placed back into the storage container for subsequent settling and reuse. Eventually, sludge will make up the majority of the container and offsite hazardous waste disposal will be necessary. At this point, the processes can be repeated using a different container. Solvent waste reduction of up to 33% can be accomplished with this simple method. Filtering equipment, which removes the particulate matter from solvents, also is available.

Waste solvent also can be collected and processed through distillation equipment. Approximately 80% of the used solvent is recovered with basically the same cleaning properties as a new product. The remaining 20% sludge (still bottoms) must be collected for offsite hazardous waste disposal. To help maintain the cleaning properties of the recycled thinner, certain paint and solvent wastes should be segregated. Waste gun wash solvent and any waste lacquer paint and thinner mixtures can be included for recycling. All waste urethanes, enamels and enamel reducers should be placed in a separate container; enamel and urethane products will not clean as well as pure lacquer thinner. By segregating the two, the reclaimed solvent will possess cleaning properties like a virgin thinner. This waste management technique has the advantage of reducing the volume of virgin thinner purchased as well as the amount of waste thinner generated.

Onsite distillation equipment comes in a wide range of capacities, from 5 gallons per 8-hour shift batch operations to more than 100 gallons per hour flow-through units. Costs for 5-gallon batch units start at approximately $1,500 with an average cost of $3,000.

Waste exchanges provide another alternative for reducing waste disposal costs. Waste exchanges are organizations that manage or arrange for the transfer of wastes between companies, where one producer's waste becomes another producer's feedstock. Most exchanges exist as information clearinghouses that provide information on available wastes. Opportunities exist for these exchanges to oversee direct transfer (without processing) of waste solvents from one company to another.

Filters

Reducing the amount of filters used in painting can reduce hazardous waste generation. Facilities should handle filters as a hazardous waste if they contain wet paint (e.g., solvents), due to their flammability and the existence of toxics in the paint. One method for reducing filter waste is to use a cleanable polystyrene filter or a reusable metal filter. When the filter is too clogged for use, it can be cleaned by blowing compressed air over the filter until it is clean enough for reuse (paint removed in this process would require collection and may still be classified as a hazardous waste).

GENERAL DESCRIPTION OF SPRAY SYSTEMS

Paints and coatings can be applied to surfaces in a number of ways. Industrial coatings often are applied on a production line using spray application techniques. Curing is done usually by an accelerated curing operation involving heat, surface catalysts or radiation.

In general, spray methods use specially designed guns to atomize paint into a fine spray. For industrial applications, the paint is typically contained in a pressure vessel and fed to the spray gun using compressed air. Traditionally, hand-held or automated guns (mounted on a mechanical control arm) have been used to apply liquid paints to metal substrates.

Although spray systems are easy to operate and have low equipment costs, they have a certain amount of overspray and rebound from the sprayed surface and, therefore, are unable to transfer a substantial portion of the paint to the part. Spray booths with an open front and exhaust at the rear are generally used to remove the overspray as it is generated.

1. Conventional Spray - This technology, in use for over 40 years, uses air at high pressure (40 – 70 psi) to atomize a liquefied stream of paint. The high-energy air stream that is mixed with the paint causes atomization that is generally very fine and easily applied. This yields very good finishes with high-quality visual characteristics.

A disadvantage is that along with a high degree of atomization comes a spray that is very fine and highly susceptible to overspray, resulting in more paint waste and less transfer efficiency. The solvent in the paint is also highly atomized along with the paint solids, meaning that volatile organic compound (VOC) emissions from the solvent in paint are increased.

Advantages and Disadvantages

The main advantages of conventional air spray systems are the high level of control that the operator has of the gun and the versatility of the systems. Disadvantages of this system include high air emissions, low transfer efficiencies and high compressed air use. However, using proper training and setting the gun at low pressure (20 psi), transfer rates similar to HVLP can be achieved.

Costs

The capital investment for a new conventional air spray system that includes spray gun, two-gallon pressure pot, hoses and fittings can range from $500 to $1,500.

Safety

Painters are required to wear respirators to prevent inhalation of overspray, hazardous vapors and toxic fumes. Depending on the noise level in the spray booth, ear protection may also be required.

2. High-Volume/Low-Pressure (HVLP) - As the name suggests, a high volume of air at low pressure is used to atomize paint. The defined air-pressure limit for HVLP is 10 psi at the center of the air cap on the spray gun. It is this reduced gun spray energy level that reduces overspray and improves transfer efficiency. Generally, fluid delivery rates up to 10 ounces per minute with low viscosity paint will work best with the HVLP gun. However, continued development is underway to accomplish faster delivery rates to accommodate higher production. At higher fluid-delivery rates and with heavier materials, HVLP may not atomize well enough to achieve an acceptable finish.

Advantages and Disadvantages

An HVLP gun is portable and easy to clean, and has a lower risk of blowback to the worker. In many cases, HVLP guns are mandated to comply with state air regulations. However, the atomization of HVLP guns might not be good enough for fine finishes, and production rates might not be as high as with conventional LVHP spray. Generally, fluid delivery rates of up to 10 ounces per minute with low viscosity paints work best with HVLP guns. For more information on other advantages and disadvantages of HVLP, see **Table 1**.

Table 1. Advantages and Disadvantages of HVLP Spray Guns

Advantages	Disadvantages
Reduces overspray	Has atomization that may not be sufficient for fine finishes
Increases transfer efficiency	May not be able to operate with high production rates
Reduces paint waste	
Lowers booth cleanup costs	
Reduces filter replacement costs	
Decreases waterwash reservoir treatment costs	
Reduces VOC and HAP emissions	
Is portable and easy to clean	
Sprays well into recesses and cavities	
Reduces worker exposure to blowback	

Types of HVLP Systems
Several different configurations of HVLP systems are available. The specific air supply (i.e., turbine or compressor) and fluid delivery system (described below) will affect the efficiency, ease of use, cost and versatility of the particular system.

Siphon-fed System - Air pressure to the sprayer is used to pull paint from a cup located below the gun, producing a fully atomized pattern for even surface coverage. The simple design of siphon-fed guns has made it possible to buy conversion kits for conventional siphon sprayers, making HVLP technology very affordable for small shop owners.

Gravity-fed Systems – These systems are well adapted to high viscosity paints such as clears, water-based paints, high-solids paints and epoxy primers because of the design of the system. The cup, located on top of the gun, allows paint to completely drain, minimizing paint waste.

Pressure Assist Cup – This system uses a cup that is mounted beneath the gun with a separately regulated airline to feed paint to the gun. This design increases transfer efficiency and makes it possible for the operator to spray evenly while the gun is inverted, offering maximum flexibility in application techniques.

Cost and Implementation Issues
HVLP paint spray systems can be used in a variety of painting applications. The finer atomization of HVLP systems produce smoother finishes. There are many paint gun models with a variety of tip sizes to accommodate most coatings including solvent-based paints, water-based coatings, fine finish metallic, high-solids polyurethane, contact adhesives, varnish, top coats, lacquer, enamel primer, latex primer, epoxy and vinyl fluids. The efficiency of these systems is greatly reduced if the painting is done in an exposed area.

Costs can vary depending on specific applications, painting/coating type, paint volume, workpiece specifications and technique. Generally, costs for HVLP paint-spray system equipment range from $500 to $1,500 for a gun, hose and paint pot.

Safety
Painters are required to wear respirators to prevent inhalation of overspray, hazardous vapors and toxic fumes when using HVLP equipment. Depending on the noise level in the spray booth, ear protection may also be required.

3. Airless - This is a method of atomizing paint without the use of compressed air. The paint is pumped at high pressure through a small opening at the spray tip to achieve atomization. Adjustments in airless spraying are made by adjusting the viscosity or the system pressure. This method has higher transfer efficiencies than conventional spray. Many high-viscosity coatings can be applied without costly solvent thinning. Also, this method allows for rapid application of a heavy paint coat, which is useful for keeping up with a fast-moving painting line.

Advantages and Disadvantages

Airless spraying has several distinct advantages over air spray methods. This method is more efficient than the air spray because the airless spray is softer and less turbulent, thus less paint is lost in bounce back. The droplets formed are generally larger than conventional spray guns and produce a heavier paint coat in a single pass. This system is also more portable. Production rates are nearly double, and transfer efficiencies are usually greater (65 to 70%). Other advantages include the ability to utilize high-viscosity coatings (without thinning with solvents) and its ability to have good penetration in recessed areas of a workpiece.

The major disadvantage of the airless spray is that the quality of the applied coating is not as good as conventional coatings, unless a thicker coating is required. Airless spray is limited to painting large areas and requires a different nozzle on the spray gun to change spray patterns. In addition, the nozzle tends to clog and can be dangerous to use or clean because of the high pressures involved. For more information on other advantages and disadvantages of airless spray, see **Table 2**.

Table 2. Advantages and Disadvantages of Airless Spray Systems

Advantages	Disadvantages
Has high rates of paint flow	Has relatively poor atomization
Has relatively high transfer efficiency	Has an expensive nozzle
Has versatile gun handling (no air hose)	Reduces fan pattern control
Has ability to apply highly viscous fluids	Has coatings limitations
	Has a tendency for tip plugging
	Has a skin injection danger
	Requires increased operator training
	Requires increased maintenance

Application Considerations

Small fluid nozzle orifices limit the coating materials that can be sprayed with airless systems to those that are finely ground. This rules out fiber-filled and heavily pigmented materials. In addition, airless spraying lacks the feather capability that air guns have. This can result in flooding of the surface and sags or runs if gun movement is too slow. The high pressures used with airless spray deliver a high rate of paint flow through the nozzle, tending to enlarge the orifice, increase flow rates and change spray pattern characteristics. This is especially true at very high pressures and with paints containing high amounts of pigments or abrasive pigments. Strict maintenance is required for this system. Foreign objects in the fluid that are larger than the nozzle tips can block or shut off the system. Equipment maintenance on pumps is high because of the high pressures used.

Economics
The capital investment required for a new airless spray system consisting of an airless spray gun, carted mount pump, hoses, and fittings, could range from $3,500 to $7,500.

Safety
The high velocity of the fluid stream and spray pattern as it exits the gun and hose is a potential hazard. Operators should never allow any part of their body to come into contact with this high-pressure material. Failure to keep several inches away from the coating as it exits the gun will result in serious injury. As with other spray systems, respirators are required, and hearing protection may be required as well.

4. Air-Assisted - Air-assisted airless systems are a variation of airless spraying. These systems use supplemental air jets to guide the paint spray and to boost the level of atomization. Approximately 150 to 800 psi of fluid pressure and 5 to 30 psi of air pressure are used. Air-assisted airless spray systems atomize paint well, although not as well as air spray methods. The use of air-assisted airless systems improves the quality of the finish, presumably because finer paint particles are formed.

The transfer efficiency of the airless, air-assisted spray gun is greater in comparison to airless, and with proper operator training, the manufacturer can obtain finishes comparable to conventional guns. This system has the same dangers as airless spraying, but it also requires more maintenance and operator training and has a higher capital cost.

The major difference in gun construction between an air-assisted airless gun and an air-atomized gun is found in the atomizing tip. The air-atomized tip incorporates a fluid nozzle and an air nozzle. The fluid orifice in the center of the tip is surrounded by a concentric atomizing ring of air. The air-assisted tip delivers a flat fan spray of partially atomized paint. Jets of atomizing air, exiting from ports in small projections on each side of the tip impacts at a 90-degree angle into the spray. The air jets break up the large droplets and complete the atomization, assisting the airless spray process.

Advantages

- Low equipment maintenance. The reduced fluid pressures in comparison with airless spray cut down on pump and fluid nozzle wear.
- Good atomization. The atomization quality of an air-assisted airless gun is rated as superior compared to an airless gun but it is not nearly as good as with an air-atomized gun.
- Low bounceback. The extremely low atomizing air pressure allows air-assisted airless guns to spray into corners and hard-to-reach areas better than with air-atomized spray.
- Varied fluid delivery. The paint flow rates can vary considerably from about 5 to 50 ounces per minute.
- With a low-end delivery rate of 5 ounces per minute versus 25 ounces for airless, air-assisted transfer efficiency is even higher than airless.

Economics

The capital investment required for a new air-assisted airless spray system, including an air-assisted airless spray gun, 10:1 ratio carted mount pump, hoses and fittings, can range from $2,500 to $5,000.

5. Electrostatic - This spray method is based on the principle that negatively charged objects are attracted to positively charged objects. Atomized paint droplets are charged at the tip of the spray gun by a charged electrode; the electrode runs 30 to 140 kV through the paint at 0 to 225 microamperes. Paint can be atomized using conventional air, airless, or rotary systems. The electrical force needed to guide paint particles to the workpiece is 8,000 to 10,000 volts per inch of air between the gun and its workpiece. The part to be painted, which is attached to a grounded conveyor, is electrically neutral, and the charged paint droplets are attracted to that part. If the charge difference is strong enough, the paint particles normally fly past the part and reverse direction, coating the edges and back of the part. This effect is called "wraparound" and increases transfer efficiency.

Advantages and Disadvantages

The major advantage of using electrostatic spraying is that it saves in material costs and labor. The labor savings is often associated with a changeover to automated lines, although labor savings for cleanup is significantly reduced in either automated or manual lines. Another benefit of electrostatic is its ability to completely cover an object with a uniform thickness, including areas that are normally inaccessible.

The initial capital investment for electrostatic systems is high. In addition, electrostatic systems must be properly grounded at all stages of paint delivery in order to reduce injuries and fire hazards that can result from shorting or sparking. Another problem with electrostatic spray is that the paint is attracted to all grounded objects, including the conveyor and conveyor protection systems in assembly line painting, the paint booth ceiling, the spray gun and the spray gun handler. Work has been done on developing an electrically charged paint-repelling panel to protect against stray paint. Such repelling panels are not 100% effective, but they can cut down on problems from stray paint. For more information on other advantages/disadvantages of electrostatic spray, see **Table 3**.

Table 3. Advantages and Disadvantages of Electrostatic Spray Guns

Advantages	Disadvantages
Has high transfer efficiency	Has guns that tend to be bulky and delicate
Has good edge cover	Requires extra cleanliness
Has good wraparound	Creates Faraday cage effect
Has uniform film thickness	Can be safety/fire hazard
	Requires all parts to be conductive (however, special conductive precoatings on nonconductive workpieces can be used to permit electrostatic spray)
	Has high equipment and maintenance cost

Implementation Issues

Part and gun cleanliness are essential for efficient electrostatic operation. Dirt or oversprayed paint can form on a conductive track on the plastic gun tip and short out the system. For top efficiency, the part to be coated should be the closest grounded object to the charging needle on the spray gun. The charged paint particles are attracted to the nearest electrically grounded item; the larger the item, the greater the attraction.

Ungrounded objects in the vicinity of the charged gun electrode can pick up a considerable electrical charge. The charge buildup can arc over or spark if a grounded object is brought near. The intense heat of the arc may be sufficient to ignite the solvent-laden atmosphere typically found in a paint booth.

Paint buildup on hooks or hangers can act as an insulator and block the flow of electric current in the electrostatic circuit. Hangers and hooks should be regularly stripped or otherwise cleaned of paint buildup to maintain good grounding contact between the parts and the conveyor.
Because of high transfer efficiencies, air velocity in spray booths may be reduced from 100 to 60 feet/minute. This results in a 40% reduction in make-up air costs and reduces emissions.

Safety

In 1995, the National Fire Protection Association (NFPA) rewrote the NFPA 33 Standard to require fast-acting flame detectors for all automatic electrostatic liquid painting applications. These are also required for automatic electrostatic powder coating applications. All electrically conductive materials near the spray area such as material supply, containers and spray equipment should be grounded as well.

Cost

The capital investment for a new liquid electrostatic spray system consisting of an electrostatic spray gun, 2-gallon pressure pot, and hoses and fittings can range from $4,900 to $7,500. The capital investment required for a new electrostatic powder coating spray system, including powder application equipment, powder booth, cleaning system and bake oven, may range from $75,000 to $1,000,000.

Cost and Implementation Issues

This system requires investment in new equipment for paint mixing, handling and spraying. In 1991, five coating formulators were licensed to develop, manufacture and market UNICARB systems, including Akzo (automotive components, furniture), BASF (automotive), Guardsman (furniture), Lilly (furniture, plastics, heavy equipment) and PPG Industries (automotive, heavy equipment).

Summaries of the different types of spray processes are provided in **Table 4** and 5.

Table 4. Transfer Efficiencies of Various Application Technologies

Technology	Transfer Efficiency	Operating Cost	Finish Quality	Recess Coverage
Conventional Air Spray	30 to 60%	Low	High	Good
HVLP Spray	50 to 90%	Low	High	Good
Airless Spray	65 to 70%	Medium/high	Low	Good
Electrostatic Spray	65 to 95%	Medium/high	Low	Poor

Table 5. Overview of Application Technologies

Technology	Pollution Prevention Benefits	Reported Application	Operational Benefits	Limitations
HVLP Spray	Reduces overspray, increasing transfer efficiency	Can be used on many surfaces	Is portable and easy to clean	Has production rates that are not as high as conventional air spray
	Reduces VOC and HAP emissions		Allows operator to vary the air pressure, air volume, paint pressure and spray pattern	
	Lowers risk of blowback to the worker			
Airless Spray	Has a transfer efficiency of 65 to 70%	Hydraulic atomization used most widely by painting contractors and	Is twice as fast as air spray and produces a higher film build; is more portable	Is limited to painting large areas, requires a different nozzle to change spray

		maintenance painters	than air spray	patterns; nozzle tends to clog and can be dangerous to use or clean because of the high pressures involved
	Cuts overspray by more than half, and is cleaner and more economical	Heated atomization used by furniture manufacturers and industrial finishers		
Air-Assisted Airless Spray	Has higher transfer efficiency and lower chance of blowback	Used by furniture and industrial finishers	Has material savings that are 50% better than air spray	Has same dangers as airless, but requires more maintenance and operator training, and has a higher initial capital cost
			Has higher film build per pass than air spray	
Electrostatic Spray	Has high transfer efficiency	Is good for painting oddly shaped objects	Produces a uniform coat because the paint itself acts as an insulator	Has limited coverage with complicated parts because of Faraday cage effects
	Produces little overspray and uses relatively little paint	Is used by most appliance manufacturers		Can paint only conductive parts
				Presents a possible shock hazard
				Is limited to only one coat
				Is more

				expensive, slower and has higher maintenance costs than air spray
				Is limited to chargeable paints
				Surface of the object must be extremely clean

COATING TYPES

The major components of solvent-borne paints and coatings are solvents, binders, pigments, and additives. In paint, the combination of the binder and solvent is referred to as the paint "vehicle." Pigment and additives are dispersed within the vehicle. The amount of each constituent varies with the particular paint, but solvents traditionally make up about 60% of the total formulation. Typical solvents include toluene, xylene, MEK, and MIBK. Binders account for 30%, pigments for 7 to 8%, and additives for 2 to 3%. Environmental issues surrounding paints usually center around solvents and heavy metals used in the pigments. Binders and other additives can also affect the toxicity of the paint depending on the specific characteristics of the paint. A general description of the more common types of coatings is provided below.

1. Organic Solvent-Based - This is the traditional type of painting material, typically containing about 40 percent solids with a relatively high organic-solvent content. While this coating material is one of the most versatile, its low solid content and high percentage of solvent carrier can cause it to have low overall (solids) transfer efficiency. To get the required coverage, more material must be sprayed compared to materials with higher solids content and lower VOC emissions.

2. High-Solids - This paint type has a higher percentage of paint solids and a lower percentage of solvent carriers. Overall transfer efficiency tends to be better than traditional solvent-based paint. The increased solids content means that fewer applications are needed to get the required film thickness. Air emissions from the solvent are generally lower due to reduced organic solvent content. However, a paint heater may be required to reduce viscosity and the film thickness is more difficult to control.

3. Water-Based - These paint types typically have a high solids content, utilize water as the solvent, and have very low or no organic-solvent content. Advantages of these paint types include reduced VOC emissions, reduced fire hazard, minimized or eliminated hazardous waste disposal, and easy cleanup. However, using a water-based coating may require stainless steel components in the preparation and delivery areas, a cleaner surface, longer drying times, increased oven temperatures, and a temperature-controlled paint storage area. The switch to water-based materials must be done carefully. Water-based coating technology is the fastest changing in the market today.

4. Catalyzed or Two-Component - These coatings are created by mixing two low-viscosity liquids just before entering the application system. One liquid contains reactive resins, and the other contains a catalyst that promotes polymerization of the resins. These coatings eliminate or reduce solvents and cure at low temperatures.

However, it is important to remember that catalysts and paint components may be hazardous themselves and create a different set of emission and exposure problems than those of organic solvents. Catalyzed painting also means that more material may be used if strict attention is not paid to the pot life.

5. Powder Coating - These coatings use 100 percent resin in dry, powdered form which must cure in an oven. Powder-coating materials can provide a high-quality, durable, corrosion-resistant coating. There are little to no VOC emissions, hazardous overspray wastes, or waste-water sludges. With powder coating it is also possible to collect the dry coating material that does not stick to the part and reuse it. Reuse allows powder coaters to achieve very high transfer efficiencies.

Powder coating requires specialized application equipment using electrostatic charges to apply the material. Its use also means that the substrate must be able to tolerate the curing temperature of the oven (typically 300 - 450° F). However, advancements in powder coating formulations are occurring at a rapid pace, and new coating powders are increasingly becoming available to meet special manufacturing needs.

6. Radiation Cured - Ultraviolet (UV), Electron Beam (EB), and Infrared (IR) coatings use electromagnetic radiation to cure. These coatings typically have lower VOC content than conventional coatings, require smaller ovens, and allow for increased production rates due to shorter curing period. The shape of the part will effect the curing; flat surfaces are easiest to cure. Capital investments are usually higher than conventional ovens and the cost of the raw material coating is higher.

PAINT BOOTHS

A paint booth is an enclosure that directs overspray and solvent emissions from painting operations away from the painter and toward an entrainment device. Spray booths are designed to capture particulate matter that is released into the air during coating operations. They are not abatement devices for VOCs. A spray booth's primary function is to protect the painter and other employees from exposure to potentially toxic vapors and particulates. Another function of the booth is to prevent fires within a facility by venting high concentrations of flammable solvent vapors out of the building.

Pollution Problems
Discharges from paint booths consist of particulate matter and organic solvent vapors. Particulates result from solids in the paint that are not transferred to the part. Organic solvent vapors are from the solvent, diluent or thinner that is used with the coating to reduce the viscosity of the paint. Much of the particulate matter is captured by a dry, water-wash or baffle filter (these are discussed later). Solvent vapors are controlled or recovered by the application of control technologies such as condensation, compression, absorption, adsorption or combustion. Solvent vapors can be minimized by using more efficient equipment, and low or no VOC materials. Increasing the transfer efficiency of the painting operation can result in both reduced particulate and solvent emissions.

Types of Paint Booths
There are two basic types of enclosures that are used in most painting applications: dry booths and wet booths. The key difference between the two is that a dry booth depends on a filter of paper, fiberglass or polystyrene to collect overspray, while the wet booth uses water with chemical additives to collect overspray. The type of booth selected can affect the volume and type of paint waste. Another type of booth is used exclusively in powder coating operations. Although a spray booth is generally thought of as an enclosed painting area, this is not always the case. For instance, facilities that paint very large pieces may have a booth that only has one side, consisting of an exhaust plenum that draws solvent and particulates away from the operator. It is also not uncommon to see two spray booths opposite one another. This set-up allows for very large workpieces to be transported in between the booths either by a conveyor or a forklift truck that runs between the booths. Often neither booth has a ceiling, and they draw air from the surrounding factory.

Generally, small-volume painting operations will find the lower purchase cost of a dry filter booth will meet their requirements. One disadvantage in the use of a dry-filter booth is in the disposal of the waste. Typically the majority of this waste is the filter media itself which has been contaminated by a relatively small amount of paint. Reusable filters may decrease waste volume and reduce disposal cost. In some applications, overspray can be collected for reuse. If overall painting volume can justify the investment, a wet booth may work to your advantage. This type of booth eliminates disposal of filter media and allows waste to be reduced in weight and volume. This is achieved by separating the paint from the water through settling, drying, or using a centrifuge or cyclone.

Regardless of the size or design of the booth, they consist of one of three basic designs for directing airflow.

- Cross-draft. In a cross-draft booth, air moves from behind the operator toward the dry filter or water curtain (parallel to the floor). This type of booth is ideal for systems where the parts are moved through the facility in a rack or conveyor system, and the painter applies the coating from only one direction. However, these types of systems can be used if the paint must be applied in more than one direction. This type of ventilation system is usually the least expensive.

- Down-draft. Down-draft booths move air from the ceiling of the booth vertically downward toward an exhaust plenum in the floor. This type of booth is preferred when the paint operator must be able to walk around the part, particularly in the case of painting large machines. These booths usually cost more than cross-draft booths because they require building a pit beneath the booth. The operating expenses with a down-draft are also usually higher because these systems draw more air.
- Semidown-draft. This type of booth moves the air down and then to the side where the exhaust is located. Semidown-draft booths offer a compromise between the cross-draft and down-draft configurations.

Decisions about equipment should be made based on the type and volume of painting done and the volume of waste generated.

Choosing between a dry filter, water-wash or baffle spray booth encompasses many different issues. The following section provides information on these systems. Analysts estimate that 80% or more of the spray booths in use today are of the dry filter type. In recent years, however, many facilities have switched to water-wash booths because of their lower maintenance and hazardous waste costs. However, there are other concerns with these booths. The following section provides more detail on dry filter, water-wash, baffle and powder coating booths.

1. Dry Filter Booths
There are many types of dry filter systems, however, they all operate on the same principle: particulate-laden air flowing toward the filter medium is forced to change directions rapidly. The particulate, having more inertia than the surrounding air, impacts the filter medium and is removed from the air flow. The scrubbed air is then vented to the atmosphere.
There are four general types of filters currently used: fiberglass cartridges, multilayer honeycombed paper rolls or pads, accordion-pleated paper sheets, and cloth rolls or pads. Each type of filter has different characteristics for particulate capacity, removal efficiency, cost and replacement time. Filter performance is characterized by three basic parameters: particulate capacity, resistance to airflow and particulate removal efficiency. Filter replacement is required when the filter becomes heavily laden with captured particles, resulting in a reduction in removal efficiency and an increase in the pressure differential across the filter face. The primary waste stream generated by dry booths is spent filters. When using lead or zinc chromate paints, the dry filter will eliminate 50 to 90% of the hazardous waste generated by water-curtain paint booths.

Dry filters effectively remove up to 95 to 99% of particulates. These systems are also versatile. They can be used in booths of all designs (small, large, cross-draft, down-draft and semidown-draft). These booths can also be operated for a variety of coating technologies, including polyurethanes, epoxies and alkyds. However, they cannot be used for nitrocellulose paints and some waterborne coatings (proper filter selection is critical in these cases). They are inexpensive to purchase, and depending on the nature of the paint (i.e., pass or fail TCLP test), they are also inexpensive to operate.

A disadvantage of dry filter booths is that they are generally not appropriate for facilities with high coating use (i.e., greater than 5 gallons per square foot of filter areas per day). They also have problems with VOC emissions, since they do not remove VOCs.

Regarding safety, dry filters are a potential fire hazard, especially if dry overspray is allowed to build up. Typically, the majority of this waste is the filter media, which can be contaminated by a relatively small amount of paint. Reusable filters may decrease waste volume and reduce disposal cost. In some applications, such as powder coatings, overspray can be reused. Choosing the proper type of dry filter is important for a facility's operations. Dry filter characteristics that should be considered include:

- Efficiency - its ability to remove particulates before they enter the stack
- Resistance - this is the pressure differential that ensues when the high velocity of air passes across the filter bank
- Holding capacity - the amount of overspray that a filter can hold or retain during its service life
- Incineration profile - can spent filters be burned?
- Biodegradability - does the product degrade naturally?
- Landfill option profile - does it meet landfill standards?
- Flammability - does it meet the National Fire Protection Bulletin number 33 requirement and Underwriter's Laboratories Approved Class 2 list?
- Suitability for various coatings - some waterborne coatings may complicate filter choice; facilities should check to make sure filter is compatible with all coatings that will be used

Filters made from expanded polystyrene are also available. Facilities can reuse these types of filters after carefully brushing the overspray off the surface with a bristle brush. Hence, the same filters can be used several times until they break or become unusable. Manufacturers have promoted the practice of dissolving the filter in a drum of solvent and paint waste when a facility is ready to scrap the filter. The solvents dissolve the filter into the waste, which must then be treated as a hazardous waste. Some facilities have argued that this is counterproductive due to disposal costs of liquids versus solids. Others argue that this qualifies as treatment of a hazardous waste and therefore is a violation of

Table 6. Advantages and Disadvantages of Dry Filter Booths

Advantages	Disadvantages
Decreases operating costs when compared to water curtain spray booths due to reduced chemical, electrical, sewer and water costs	Is not compatible with powder paint applications
Reduces waste generation of wastewater and sludge	Has filter selection that depends on paint type and application
Eliminates need for daily skimming and removal of sludge from the booth	Requires frequent downtimes if improper filter is used
Increases efficiency of particulate removal	

2. Water-Wash Booths
Water-wash booths capture overspray paint by using positive air pressure to force the particles into a cascading curtain of water. As a result of being captured in the water curtain, uncured particles of paint accumulate in a wash-water pit, located either beneath a grating that the painters stand on or above ground behind the booth itself.

When overspray enters the water, it remains sticky and can plug up holes, nozzles, pipes and pumps. In addition, it can form a deposit on the water curtain, slowly building up a layer that eventually impedes the smooth water flow down the water curtain's face. With time, the water becomes contaminated with bacteria and requires disposal. To prevent this from occurring, the water needs to be treated with chemicals designed to de-tack overspray particles.

If overall painting volume can justify the investment, a water-wash booth has substantial advantages. This type of booth eliminates disposal of filter media and allows waste to be reduced in weight and volume. This is achieved by separating the paint from the water through settling, drying, or using a centrifuge or cyclone. However, the primary disadvantage of this technology is the resulting generation of large quantities of wastewater and paint sludge. Typically, spent wastewater and sludge requires offsite treatment, and the paint sludge is disposed of as a hazardous waste. Depending on the amount of coating used, this option could use more energy, require more maintenance time, add to chemical use for water treatment, and/or result in additional cost to dispose of "wet," low BTU value, heavy paint sludges than a dry filter booth.

These units are also more expensive to install and to operate than dry filter booths.
The water-wash booth design faces substantial challenges and more restrictive landfill regulations than they have in the past. Prior to 1993, some liquid nonhazardous special wastes could be disposed of in a landfill with little or no treatment. EPA's decision to redefine liquid wastes and ban certain materials from landfill disposal pertains to sludge generated from water-wash booths. This material still can be disposed of, however, the material must be processed prior to disposal, resulting in a significant increase in waste treatment costs.

3. Baffle Booths
A baffle spray booth is an uncommon alternative to both dry filter and water-wash booths. In a baffle spray booth, the face of the booth has steel baffles that run the height of the booth and are several inches wide. The baffles usually overlap each other, forcing the air that passes through the booth to change direction in order to reach the back of the booth. When the air does reach the entrainment section in the back, the paint particulates that the air is carrying fall into the trough for reuse. These booths are used less frequently because unless the facility is reclaiming paint, this type of booth offers no advantages.

4. Powder Coating Booths
In most powder coating operations, the coating is reclaimed and reused in the process, optimizing material use. Powder coating booths have smooth sides with steep, hopper-like sloping bottoms that empty into collectors and an exhaust system that removes powder suspended in the air. The powder is drawn into a cylindrical chamber that has a centrifugal

blower to force the powder to the outside walls where the powder collects and then falls through an opening in the cone-shaped bottom. The air flows through a filter at the top to remove any fine suspended powder particles. The reclaimed powder can then be blended with fresh material.

BEST MANAGEMENT PRACTICES

There are a number of steps that a company can take to minimize the defects that result in rejected work. Most of the defects require painters to perform rework or, in some cases, completely reject a part. Higher reject rates result in increased waste generation and reduced profits. The most common coating defects that relate to paint booths include:

- Poor wrap when using electrostatic paints. Poor wrap can happen for a variety of reasons. However as they relate to paint booths, assistance providers should ensure that the spray booth has a proper ground. Wrap may also occur as a result of turbulent airflow.
- Dust and dirt in the finish. This is probably the most common cause for reworks and rejects. Facilities can take several steps to avoid this including: avoid having sanding or other dirty operations take place immediately outside the booth; make sure that air filters at air intakes of the booth are not dirty, or have too large of a mesh size; make sure that the booth is operating under negative pressure; make sure that the air make-up system draws fresh air into the booth and that the intake stack is not too close to the exhaust ducts from sanding or other dirty operations; keep booth walls, floor and ceiling free of loose, dry, overspray or the booth blowers may pry particles loose, allowing them to fall onto freshly painted surfaces; and make sure that proper booth size is selected.
- Water spots in the finish. When using a water-wash booth, operators must properly clean the nozzles above the water curtain. Omitting this step creates the opportunity for water droplets to settle on the painted finish.
- Haziness (blushing) that reduces gloss. This problem occurs when humidity is high and moisture condenses on freshly painted surfaces. This is more likely to occur in a water-wash booth than a dry-filter booth. To avoid this, parts should be moved out of the booth shortly after painting is completed.
- Dry overspray on the finish. The most common reason for this dry overspray is that the solvent is too fast. As the solvent flashes off during application, the overspray loses its wetness. This problem is usually not a result of the booth but a result of high air velocity. Proper monitoring and control of booth airflow should assist in reducing this problem. Dry overspray on the finish also arises when more than one dry filter spray booth is being operated at the same time. If the airflow within the larger spray room is not uniform, overspray from one booth can settle on the freshly painted surfaces in another booth. Maintaining proper airflow between the two booths or providing each booth with its own air make-up system can solve this problem.
- Nonuniform coating finish with gloss, patches, orange peel and voids. Numerous causes exist for this defect, however, causes solely associated with spray booths are often related to poor lighting. Investment in adequate lighting and regular cleaning of the cover plates can have quick payback in the form of better looking finishes and fewer touchups.