Ohio EPA

Office of Pollution Prevention

Woodworking and Refinishing Pollution Prevention Opportunities

Contents

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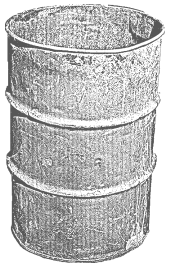
If your business makes new furniture, repairs old furniture or does other types of woodworking or refinishing, you must comply with environmental regulations. This fact sheet outlines opportunities to help your woodworking and refinishing business comply with environmental regulations, reduce operating costs, improve worker safety, and enhance your shops' image in the community.

Wastes-Overview

Woodworking and refinishing businesses generate:



- spent solvents;
- used rags;
- spent spray booth filters;
- wood scraps;
- sawdust;
- used packaging;
- scraps of upholstery;
- empty containers from stains and finishes;
- cans of unused or expired stains and finishes
- air emissions from coating applications; and
- sludges from dip tanks.

What is Pollution Prevention?

Pollution prevention (P2) uses source reduction and environmentally sound recycling to reduce or eliminate hazardous waste and other pollution at the source. P2 includes good operating practices, material substitutions, process changes and recycling. P2 addresses all waste streams (solid and hazardous waste, air and water).

Some of the P2 opportunities available for woodworking and refinishing businesses are highlighted in ***Table 1 - Guide to Managing Woodworking and Refinishing Wastes***.

Examples of cost savings and environmental benefits of implementing P2 can be found in ***Table 2***.

Table 1 GUIDE TO MANAGING WOODWORKING AND REFINISHING WASTES

WASTE STREAM	TOXIC/HAZARDOUS PROPERTIES	POLLUTION PREVENTION ALTERNATIVE
Used solvents	Flammables, other toxics	Evaluate purchase of a gun washer; implement good housekeeping measures; purchase distillation unit to allow reuse of solvents; and send used solvents off site for recycling. Extend solvent life by using a two stage cleaning process.
Used shop towels, wipers and rags	May contain flammables,	Consider off-site laundry service for rags and shop towels. Minimize generation by improving housekeeping. Use hand-operated wringers to recover solvents for reuse.
Used paper filters from spray booths	May contain flammables	Evaluate the use of plastic or metal filters that may be cleaned and reused, or styrofoam filters that can be dissolved into used solvent.
Cans of unused or expired stains and finishes	May contain flammables	Develop an inventory control system to keep track of supplies and use only what is needed; work with suppliers to take back unused product
Partially emptied cans of coating materials	May contain flammables	Completely empty containers and return to supplier; send off for recycling.
Air emissions from finishes, stains, and adhesives	Toxic volatile organic compounds (VOCs) released	Purchase high volume low pressure (HVLP) guns to increase transfer efficiency (TE) and decrease overspray; purchase a heater instead of adding solvent to change the viscosity for proper application; train gun operators to increase TE by 10 percent, and evaluate the use of a water-based adhesive.

Benefits of Implementing Pollution Prevention Measures

- ☑ *Improve worker safety*
- ☑ *May reduce insurance premiums*
- ☑ *Reduce waste disposal costs*
- ☑ *Reduce raw materials costs*
- ☑ *Increase environmental benefit*
- ☑ *Reduce regulatory burden*

Hazardous Wastes

Some of the hazardous wastes that woodworking and refinishing shops generate are spent solvents, used rags, used filters from spray booths, cans of unused or expired stains and finishes, and partially emptied cans of coating materials.

The Resource Conservation and Recovery Act (RCRA) is a federal environmental law that regulates solid and hazardous wastes from generation through disposal. Hazardous wastes are classified into two categories—listed and characteristic. Characteristic hazardous wastes exhibit one or more of the four hazardous characteristics (ignitability, corrosivity, reactivity and toxicity). Listed hazardous wastes are specifically listed by name or process in the hazardous waste regulations. For more information please contact the Ohio EPA Division of Hazardous Waste Management at (614) 644-2917.

Every woodworking and wood refinishing business that generate hazardous waste is considered a generator. Hazardous waste generators must abide by certain environmental laws and regulations. When disposing of shop wastes, a determination (often referred to as "characterization") as to whether the wastes are hazardous or not must be completed. Documentation of this characterization can be provided through knowledge of the waste stream (material safety data sheet) or appropriate analytical testing.

Cleanup Wastes

Spent solvents are generated during the cleanup process. Solvents are used to clean spray guns, lines and spray booths. They are usually hazardous wastes due to their flammability and/or chemical constituents (e.g., xylene, toluene, acetone, methylene chloride). Before disposing of any spent solvent, it must be determined whether the waste is hazardous. If hazardous, solvent waste must be sent to a permitted hazardous waste disposal or recycling facility.

Often businesses will use their solvent only once before disposing of it. One way to extend solvent life is to use a two-stage cleaning process that uses two cleaning tanks or parts washers (baths). When the first bath doesn't clean, replace it with the second bath and refill the second bath with clean solvent. Allow the solids to settle in the dirty solvent, then pour off and reuse the clean solvent. Use this solvent to do initial cleaning, saving the new solvent (a smaller amount) for the final cleaning.

Another option is to recycle the solvent by distilling it either on-site or off-site. In the distillation process, solvent wastes are heated, which drives off the solvent in vapor form. The vapor is then converted back to liquid in the condenser, and then collected. Distillation units are available in various sizes. One to five gallon distillation units are available for lease or purchase. If solvent is distilled on-site, the sludge and any filters will likely be a listed hazardous waste, and must be managed and disposed of properly. Air permits may be required for a larger solvent still. Many companies distill spent solvent on-site. One company with an on-site still reclaimed five gallons of solvent for every seven gallons of spent solvent distilled. Other companies ship solvent wastes off-site for distillation. This reduces material and disposal costs.

Purchasing a gun washer to clean spray guns can also minimize solvent use. A gun washer is similar to a dishwasher. It circulates solvent inside a closed chamber. Gun washers clean quickly, extend solvent life, and reduce solvent waste and emissions from evaporation. Depending on the number of spray guns your shop uses, purchasing a gun washer may save considerable operator time and reduce solvent use. Some shops have reduced their solvent usage by 50 percent or more by purchasing a gun washer. Operator time for gun cleanup is also reduced.

P2 Opportunities:

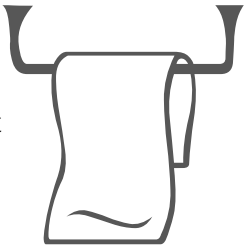
- ✪ *Distill spent solvent*
- ✪ *Evaluate the purchase of a gun washer*
- ✪ *Reuse spent solvent in a two-stage cleaning process for initial cleaning, using new solvent for the final rinse.*

Common Hazardous Waste Violations

- 👎 *Disposing of hazardous waste improperly (for example, throwing spent solvent, sludges or solvent soaked rags into the trash)*
- 👎 *Storing wastes in containers that are leaking or in poor condition*
- 👎 *Not properly evaluating wastes*

Solvent Rags, Wipers or Towels

Solvent soaked rags, wipers or towels used for cleaning may be a hazardous waste because of the contaminants present (e.g., xylene, toluene, acetone) or because of their ignitability. Any solvent-contaminated wipers must be evaluated to determine if they are hazardous waste. They CANNOT be thrown in the dumpster unless they are not hazardous.



Another option for managing solvent wipers or shop towels is to send them to a commercial laundry or dry cleaner. Under Ohio's regulations, this is considered a recycling activity and the wipers/towels would not be considered a hazardous waste. Please note that this does not apply to absorbents used to contain or clean up leaks and spills. The used towels must not contain free liquid prior to laundering. Hand-operated wringers can be used to recover solvents for reuse from rags and towels. Shops should work with their laundry service on proper management of used rags and towels. Larger shops may find a commercial laundry cost-effective. You can get more information on commercial laundry facilities from Ohio EPA's Office of Pollution Prevention, (614) 644-3469.

Floor cleaning wastes, absorbents used for spills or leaks, and shop rags are common waste streams generated by shop cleanup activities. Although used absorbents may contain only very small amounts of contaminants, they must also be characterized before being disposed.

P2 Opportunities:

- ✪ *Send shop towels or rags to off-site laundry service*
- ✪ *Use hand-operated wringers to recover solvents for reuse*

Empty Cans and Containers

Stains, finishes, topcoats and other materials that are left in cans and containers may be a hazardous waste unless the containers are considered "RCRA empty." A can or container is considered RCRA empty if all the material has been removed using practices (e.g., pouring or pumping) commonly employed to remove the

material from that type of container, and no more than one inch of residue remains on the bottom; OR no more than three percent by weight of the total capacity of the container remains in the container if the container is less than or equal to 100 gallons; OR no more than 0.3 percent by weight of the total capacity of the container remains in the container if the container is greater than 110 gallons.

Metal containers that are RCRA empty can usually be recycled as scrap metal or disposed of in the dumpster (as solid waste). You should note, though, that landfills won't accept any waste liquids, including stains, finishes, and topcoats, so you must ensure that the containers have no free liquids. If a container is not RCRA empty and you want to dispose of it, you'll have to evaluate the contents of the container and, if hazardous, properly dispose of this waste. Checking with your raw material suppliers may also be an option; many companies will take back containers for reuse.

P2 Opportunities:

- *Contact suppliers and work with them to take back used containers for reuse or establish a returnable container program*
- *Ensure containers are empty; non-empty containers not only create a disposal problem, but also waste raw materials*

Paint Booth Filters

The most common paint booth filters are paper, which are used until they are filled with coating material, and then disposed of as hazardous or solid waste. A generator needs to determine if the filters are hazardous. To help filters last longer and keep them from becoming a hazardous waste, spray guns should not be sprayed into the filters to empty. If your filters are nonhazardous, they can be disposed of as solid waste. Generators should be aware that the local solid waste landfill may ask for documentation, as related to waste characterization, to prove that the filters are nonhazardous.

Filters are now available in metal, plastic and styrofoam. One advantage of metal and plastic filters is that they can be reused many times. Filters can be brushed-off and reused. In some cases the laquer collected from brushing may be recycled. Metal filters may have to be soaked in solvent for cleaning. Styrofoam filters may be reused and then dissolved into used solvent.

Spraying sealer and topcoat generates lacquer dust, which may be a hazardous waste due to its flammability. The dust accumulates on spray booth filters, other spray booth surfaces and the floor. Some woodfinishing shops collect this dust, screen it, and and mix it with solvent to reformulate a coating which they then use to coat the insides of drawers, the underside of tables, the backs of bookcases. This saves money in disposal costs and raw material costs.

P2 Opportunities:

- *Don't clean paint guns by spraying into spray booth filters*
- *Evaluate using metal, plastic or styrofoam filters*
- *Evaluate the implementation of a lacquer dust recycling program*

Cans of Unused or Expired Stains and Finishes

Developing an inventory system that implements a first-in, first-out policy can save unused raw materials from expiring. Some companies have found it helpful to assign one person the responsibility of ordering and distributing supplies. Companies can also

work with suppliers to take back unused, off-specification raw materials and empty containers for reuse. Shops may also work with their supplier to establish a "just-in-time" purchase policy where a company only buys what they need, and the supplier delivers it "just-in-time" for use, so minimal inventory is kept.

P2 Opportunities:

- *Implement an inventory control system to keep track of supplies*
- *Purchase and use only what is needed*
- *Work with suppliers to take back off-specification materials and deliver materials "just-in-time"*

Air Emissions

Air emissions are generated from the solvents contained in stains, finishes and topcoats applied by spray guns used in the finishing process. Other sources of air emissions are adhesives used for gluing, solvents used to clean spray guns, spray booths and other equipment, and solvents used to strip old finish off furniture for refinishing.

Common Solvents Used in Woodfinishing

Toluene, xylene, methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), and methanol are commonly found solvents used in stains, finishes and solvents used for equipment clean up. These compounds evaporate quickly into the air. They are considered by U.S. EPA to be hazardous air pollutants (HAPs) that can cause adverse health effects. These chemicals are also volatile organic compounds (VOCs) that react with sunlight to form ground-level ozone. This ozone can affect human respiratory functions, especially people with asthma. Breathing these solvents can cause headaches, fatigue, nausea and other symptoms.

One way to reduce air emissions is by using a more efficient spray gun. The amount of coating that reaches the object covered is called the Transfer Efficiency (TE). For example, a TE of 25 percent means that 25 percent of the coating sprayed is actually deposited on the object, and the remaining 75 percent is lost to the air and/or captured by the paint booth filters. ***Table 3, Types of Paint Guns, Advantages and Disadvantages***, outlines some of the transfer efficiencies, advantages and disadvantages of the of various types of spray guns. Increasing TE reduces the waste generated by overspray and decreases the amount of raw material that must be purchased. Cost savings is generated by lowering the raw material cost and the waste disposal cost.

Training operators on the proper techniques can also increase TE. Some companies have increased TE by 10 percent through training programs. Operator technique training focuses on spray patterns, gun speed, distance of the gun from the part, positioning of the gun and triggering the gun at the beginning and end of each stroke. One of the newest advances in operator training has been the development of a manual laser targeting device. This device assists the operator in achieving the optimal distance to the target. Contact your gun supplier for additional information on these new devices.

Another way to decrease air emissions from coating operations is to evaluate a change to a lower VOC coating or water-based coating. However, one of the challenges of water-based coating for wood finishing applications is that they may cause the grain to rise on the wood, and the colors of the finish do not change with age like the solvent-based coatings. Some companies have successfully changed over to water-based coatings. Advantages to water-based coatings are lower VOC emissions and less worker exposure to VOCs. Companies that have successfully switched to water-based coatings have worked closely with their suppliers to determine the best

water-based formula for their specific use. Many advances are being made on new coating formulations, so this is an area to keep up-to-date on in trade journals and with suppliers. In the near future, newer coating formulations containing less VOCs may perform comparably to solvent-based ones.

Air emissions may be reduced by switching to water-based adhesives for gluing. Some wood finishers have switched and found that these adhesives perform as well as the solvent-based adhesives.

Purchasing a heater to increase the viscosity of the coating before application can reduce the amount of solvent that needs to be added to the coating. Paint heaters are usually constructed of stainless steel, and are placed between the pump and spray gun. They work best on systems that recirculate heated material to the coating container when the operator is not spraying. This keeps the temperature and viscosity consistent when the spraying stops. The benefits of a heater are less solvent use, low solvent emissions, consistent viscosity and a faster curing rate.

Implementing good housekeeping practices can also reduce air emissions. Some examples are keeping containers closed, improving material handling and storage to avoid spills, using drip pans, using spigots or pumps when transferring materials from storage containers to smaller containers, and moving drums of material properly to prevent damage that could lead to spills or leakage.

Taking these steps to reduce air emissions in the workplace will have both economic and environmental benefits. Reducing air emissions may also reduce the regulatory burden of a company.

P2 Opportunities:

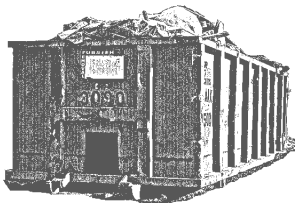
- *Evaluate spray gun efficiency, purchase a more efficient spray gun*
- *Implement an operator training program*
- *Evaluate a switch to lower VOC coatings and water-based adhesives, stains and finishes*
- *Purchase a heater to thin coatings to increase the viscosity of the coating instead of adding solvent*
- *Implement good housekeeping practices to control raw material loss, such as keeping containers closed when not in use to prevent evaporation*

Common Air Violations

- *Open burning wood scraps for disposal*
- *Failure to obtain a permit for a spray booth*
- *Failure to keep proper operating records of coating usage*

Solid Wastes

Wood scraps, sawdust, used packaging, scraps of upholstery, and empty containers from stains and finishes are solid wastes that may be generated from woodworking and refinishing.



Local trade schools may take wood scraps for reuse in their woodworking programs. Composting facilities reuse sawdust for filler material in the composting process.

Local Solid Waste Management Districts (SWMDs) may be able to provide wood finishing businesses with contacts to nearby trade schools and composting facilities. This Web site lists all SWMDs in Ohio along with their phone numbers: **www.epa.state.oh.us/dsiwm/document/general/swmd_list.pdf**

Sawdust may also be reused for animal bedding. Ohio State University (OSU) Extension Agents or Soil and Water Conservation District staff may be able to direct business to local farmers that use sawdust for animal bedding. This Web site lists all of the OSU Extension Agent numbers and addresses: **www.ag.ohio-state.edu/%7Eohioline/county/index.html**

The Ohio Materials Exchange (OMEx) is another option for companies to find a home for unused wood waste. A materials exchange program provides a mechanism for recycling and reusing unwanted materials. It is an information clearing-house for available by-products, raw materials and other forms of unwanted industrial materials. A materials exchange identifies both producers and markets for solid and hazardous materials. The exchange service provider maintains and distributes listings of materials available and wanted from participants. Through a materials exchange, one company's "waste" can become another company's raw material. Any material that is available from one business and potentially wanted by another can be a part of a materials exchange.

OMEx lists wood wastes that are available and companies that are looking for wood materials. Their Web site can be found at **www.epa.state.oh.us/opp/recyc/omex.html**, and their phone number is (740) 397-7649. There are several other materials exchanges that operate in Ohio; they can be found on the following web site; **www.epa.state.oh.us/opp/recyc/omexother.html** or by contacting the Office of Pollution Prevention at (614) 644-3469.

When recycling wood wastes, remember to keep the wastes segregated. Sawdust that contains stains, finishes or adhesives will not be able to be used for composting. Wood wastes can be easily segregated by using separate containers.

P2 Opportunities:

- *Contact local Solid Waste Management Districts (SWMDs) and trade schools that teach woodworking; they may take wood scraps for reuse.*
- *Contact local Ohio State Extension Agent or Soil and Water Conservation Districts for local farming contacts who use sawdust as animal bedding Contact composting facilities that use sawdust for filler material*
- *Use the Materials Exchanges to find other businesses looking for wood waste, or to find wood materials for your business*

WWW links to other wood working and refinishing sites

www.epa.state.oh.us/opp/tarp/woodprod.html
(Ohio EPA's Office of Pollution Prevention Web links to wood finishing sites and equipment vendors)

http://outreach.missouri.edu/polsol/furn.htm
(Missouri's Web links on wood finishing)

http://es.epa.gov/oeca/sector/#wood
http://es.epa.gov/oeca/sector/sectornote/pdf/wdfurnsn.pdf
(U.S. EPA Office of Compliance Sector Notebook, Profile of the Wood Furniture & Fixture Industry, 1995)

http://wrrc.p2pays.org/furniture.htm
(Web site joint effort with U.S. EPA and North Carolina's P2 program)

http://es.epa.gov/techinfo/facts/refinish.html
(An Industry Overview of Furniture/Wood Manufacturing and Refinishing by EnviroSense, U.S. EPA)

http://woodweb.com/index.html
(Wood web, a site with links to suppliers and forums to ask technical questions.)

www.epa.state.oh.us/opp/recyc/omexother.html
The Air Pollution Prevention and Control Division of U.S. EPA's National Risk Management Research Laboratory conducted a study to identify wood furniture manufacturing facilities that converted to low-VOC/HAP wood furniture coatings and to develop case studies for those facilities.

www.pprc.org/pprc/sbap/wood.html
Wood Furniture Manufacturing Industry Resources by the Pacific Northwest Pollution Prevention Resource Center

References

The Northeast Waste Management Official's Association (NEWMOA) and the Northeast States for Coordinated Air Use Management (NESCAUM), 1997. Wood Furniture: The Clean Air Act Amendments of 1990 and Pollution Prevention Opportunities. NEWMOA, 129 Portland Street, 6th Floor, Boston, MA, 02114 (617) 367-8558, 89 pp.

The Pacific Northwest Pollution Prevention Research Center, 1992. Transfer Efficiency and VOC Emissions of Spray Gun and Coating Technologies in Wood Finishing. The Pacific Northwest Pollution Prevention Research Center (PPRC), 1218 Third Ave., Suite 1205, Seattle, WA 98101, (206) 223-1151, 16 pp.

Ohio EPA, 1999. Fact Sheet: Running a Woodworking or Refinishing Business? Know Your Ohio EPA Regulations.... Ohio EPA, 122 South Front Street, Columbus, OH 43215, (614) 644-3020, 4 pp.

Ohio EPA, 2000. Fact Sheet: Handling Paint Waste from Your Business. Ohio EPA, 122 South Front Street, Columbus, OH 43215, (614) 644-3020, 6 pp.

Ohio EPA, 1997. Fact Sheet: Getting in Touch with Air Pollution Requirements for Wood Manufacturing. Ohio EPA, 122 South Front Street, Columbus, OH 43215, (614) 644-3020, 2 pp.

Trade Association

Trade associations also have information helpful to businesses. The American Furniture Manufacturers Web site can be found at:
www.afmahp.org/
American Furniture Manufacturers Association (AFMA), PO Box HP-7, High Point, NC 27261, (336) 884-5000

The Office of Pollution Prevention (OPP) is a non-regulatory office at Ohio EPA and has been assisting Ohio's businesses since 1993. OPP works with businesses to modify their processes, materials and practices to generate less pollution in a cost-effective and technically feasible manner. OPP can provide phone assistance, on-site assistance, web searches and vendor information. For free assistance, please call our office at (614) 644-3469 or go to www.epa.state.oh.us/opp

Table 2

Example of Cost Savings & Environmental Benefits of P2

Significant coating losses can occur from overspray during wood finishing. Increasing he transfer efficiency is the most effective way to reduce overspray. The amount of coating that reaches the object covered is called the transfer efficiency (TE). For example, a TE of 25 percent means that 25 percent of the coating sprayed is actually deposited on the object, and the remaining 75 percent is lost to the air and/or captured by the paint booth filters. The following example provides an estimate of cost savings that can be achieved by increasing TE by 20 percent (reducing coating losses by 20 percent).

The purpose of this example is to show how to calculate cost savings and environmental benefits. You can insert your company's material usage numbers and calculate your potential cost savings and environmental benefits.

Key Assumptions:

Stain Use: 35 gal/mo **x** 12 mo/yr = 420 gal/yr
Stain Cost: $7/gal
Volatile organic compounds (VOCs) in Stain: 6.9 lbs/gal VOC content

Topcoat Use: 75 gal/mo **x** 12 mo/yr = 900 gal/yr
Topcoat Cost: $10/gal
VOCs in Topcoat: 5.7 lbs/gal VOC content

Sealer Use: 55 gal/mo **x** 12 mo/yr = 660 gal/yr
Sealer Cost: $10/gal
VOCs in Sealer: 5.6 lbs/gal VOC content

Cost of Raw Materials:

Stain
420 gal/yr **x** $7/gal = $2,940/yr

Topcoat
900 gal/yr **x** $10/gal = $9,000/yr

Sealer
660 gal/yr **x** $10/gal = $6,600/yr

Total raw material cost: $2,940 + $9,000 + $6,600 = $18,540

Cost Savings of Increasing TE by 20 percent (Reduce coating loss by 20 percent)

Stain
420 gal/yr **x** 0.20 = 84 gal/yr material saved
84 gal/yr **x** $7/gal = $588

Topcoat
900 gal/yr **x** 0.20 = 180 gal/yr material saved
180 gal/yr **x** $10/gal = $1,800

Sealer
660 gal/yr **x** 0.20 = 132 gal/yr material saved
132 gal/yr **x** $10/gal = $1,320.

Savings

$588 + $1,800 + $1,320 = **$3,708/year** is saved in raw material costs instead of being wasted as overspray.

Table 2 continued

Environmental Benefits of Increasing TE by 20 percent

These figures illustrate the reduction in VOCs by increasing TE by 20 percent.

Stain
420 gal/yr **x** 6.9 lbs/gal **x** 0.20 = 580 lbs

Topcoat
900 gal/yr **x** 5.7 lbs/gal **x** 0.20 = 1,026 lbs

Sealer
660 gal/yr **x** 5.6 lbs/gal **x** 0.20 = 739 lbs

VOCs reduced by increasing TE 20%
580 lbs + 1,026 lbs + 739 lbs = **2,345 lbs/yr (approximately 1 ton VOC reduction)**

Cost Savings of Extending Life of Solvent by 50 percent

Allowing solids to settle and reusing spent solvents can save raw material costs. Another option is to purchase an on-site distillation unit. The figures below estimate cost savings by reducing solvent use by 50 percent.

25 gal/mo **x** 12 mo = 300 gal/yr
300 gal/mo **x** $5/gal = $1,500 yearly solvent cost
300 gal/yr **x** .50 = 150 gal/yr
150 gal/yr **x** $5/gal = **$750 annual raw material savings**

These numbers do not include disposal cost. Small distillation units for solvents recover approximately 80 percent of the solvent. There are seven gallon batch units that recover five gallons of solvent for a capital cost of $4,500.

By implementing these two P2 options, increasing TE by 20 percent and extending solvent life, the yearly cost savings can be $4,458. This does not include other potential cost savings from improving TE including reduced spray booth clean up, increased life of spray booth filter, and labor saved from fewer clean up activities.

Table 3 **Types of Paint Guns, Advantages and Disadvantages**

Gun Type	Advantages	Disadvantages
Conventional TE: approximately 25 percent	✓ High production rates ✓ Excellent atomization-high quality finish	⊗ Extensive overspray ⊗ Booth cleanup cost ⊗ Filter cleanup cost ⊗ High VOC and HAP emissions ⊗ Approximately 75 percent of coating is wasted
Airless Spray TE: approximately 40 percent Approximate cost: $2,800-4,300	✓ High rates of paint flow ✓ Relatively high transfer efficiency ✓ Gun handling versatility ✓ Can apply highly viscous fluids	⊗ Relatively poor atomization ⊗ Expensive nozzles ⊗ Reduced fan pattern control ⊗ Tendency for tip plugging ⊗ Skin injection danger ⊗ Increased operating training required ⊗ Increased maintenance required
Air-Assisted Airless TE: approximately 40 percent Approximate cost: $3,100-4,750	✓ Good atomization ✓ Varied fluid delivery ✓ Low bounce back	⊗ Capital cost ⊗ Skin injection danger ⊗ Increased operating training ⊗ Increased maintenance
High Volume Low Pressure (HVLP) TE: approximately 65 percent Approximate cost $1,300-1,800	✓ Sprays well in recesses/cavities ✓ Reduced paint waste ✓ Lower booth clean up costs ✓ Lower filter replacement costs ✓ Lower overspray, VOC, and HAPs	⊗ Atomization may be insufficient for fine finishes ⊗ May lower production rates ⊗ May have difficulty spraying high solids coating at ambient temperature, a heater may be needed

Definitions:
TE: transfer efficiency
VOC: volatile organic compound
HAPs: Hazardous Air Pollutants

This information was compiled from several sources of information. TE numbers are based on the averages from several sources. TE varies widely due to operator technique.