Note: This is a reference cited in *AP 42, Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources.* AP42 is located on the EPA web site at www.epa.gov/ttn/chief/ap42/

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United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/2-78-015
OAQPS No. 1.2-101
June 1978

Air

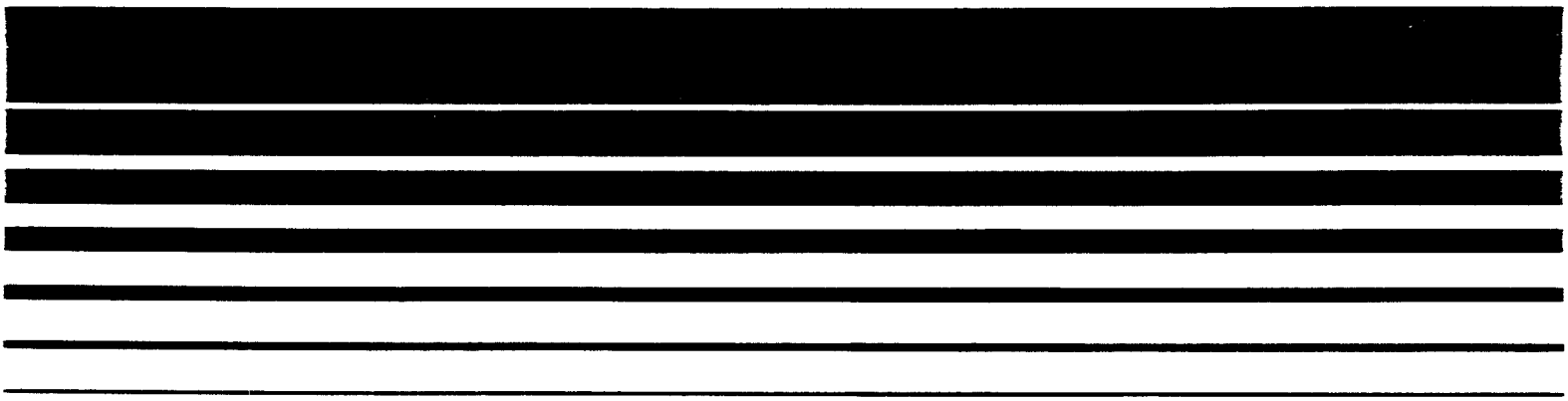
EPA

Guideline Series

OTHER METAL
COATING
AP-42
Section 4.2.2.5
Reference Number
1

Control of Volatile Organic Emissions from Existing Stationary Sources -

Volume VI: Surface Coating of Miscellaneous Metal Parts and Products



EPA-450/2-78-015
(OAQPS No. 1.2-101)

CONTROL OF VOLATILE ORGANIC EMISSIONS FROM EXISTING STATIONARY SOURCES VOLUME VI: SURFACE COATING OF MISCELLANEOUS METAL PARTS AND PRODUCTS

Emissions Standards and Engineering Division
Chemical and Petroleum Branch

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

June 1978

PREFACE

This document is one of a series designed to inform Regional, State, and local air pollution control agencies of techniques available for reducing emissions of volatile organic compounds (VOC) from existing stationary sources. This document deals with the surface coating of miscellaneous metal parts and products, and is intended to provide guidance on VOC emission control for job shop and original equipment manufacturing (OEM) industries which apply coatings on metal substrates which have not been the subject of more specific previous documents in this series. Reports have already been published which identify control options for the following industries: can, coil, automobile and light duty truck, metal furniture, magnet wire, and large appliances.*

This report describes the types of coating operations found in this broad industrial category, identifies the sources and types of VOC emissions, and reports the available methods and costs for minimizing these emissions. Monitoring techniques for coatings which are low in organic solvents are suggested. More detailed discussions of coatings low in organic solvent and add-on control technologies are found in, "Control of Volatile Organic Emissions from Existing Stationary Sources - Volume I: Control Methods for Surface Coating Operations," EPA-450/2-76-028, November, 1976. ASTM test methods for monitoring the organic solvent content of coatings are summarized in, "Control of Volatile Organic Emissions from Existing Stationary Sources - Volume II: Surface Coating of Cans, Coils, Paper, Fabrics, Automobiles and Light Duty Trucks," EPA-450/2-77-008, May, 1977.

*Earlier volumes in this series are available from the National Technical Information Service.

OAQPS GUIDELINE SERIES

The guidelines series of reports is being issued by the office of Air Quality Planning and Standards (OAQPS) to information to state and local air pollution control agencies; for example, to provide guidance on the acquisition and processing of air quality data and on the planning and analysis requisite for the maintence of air quality. Reports published in this series will be available - as supplies permit - from the Library Services Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711; or, for a nominal fee, from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

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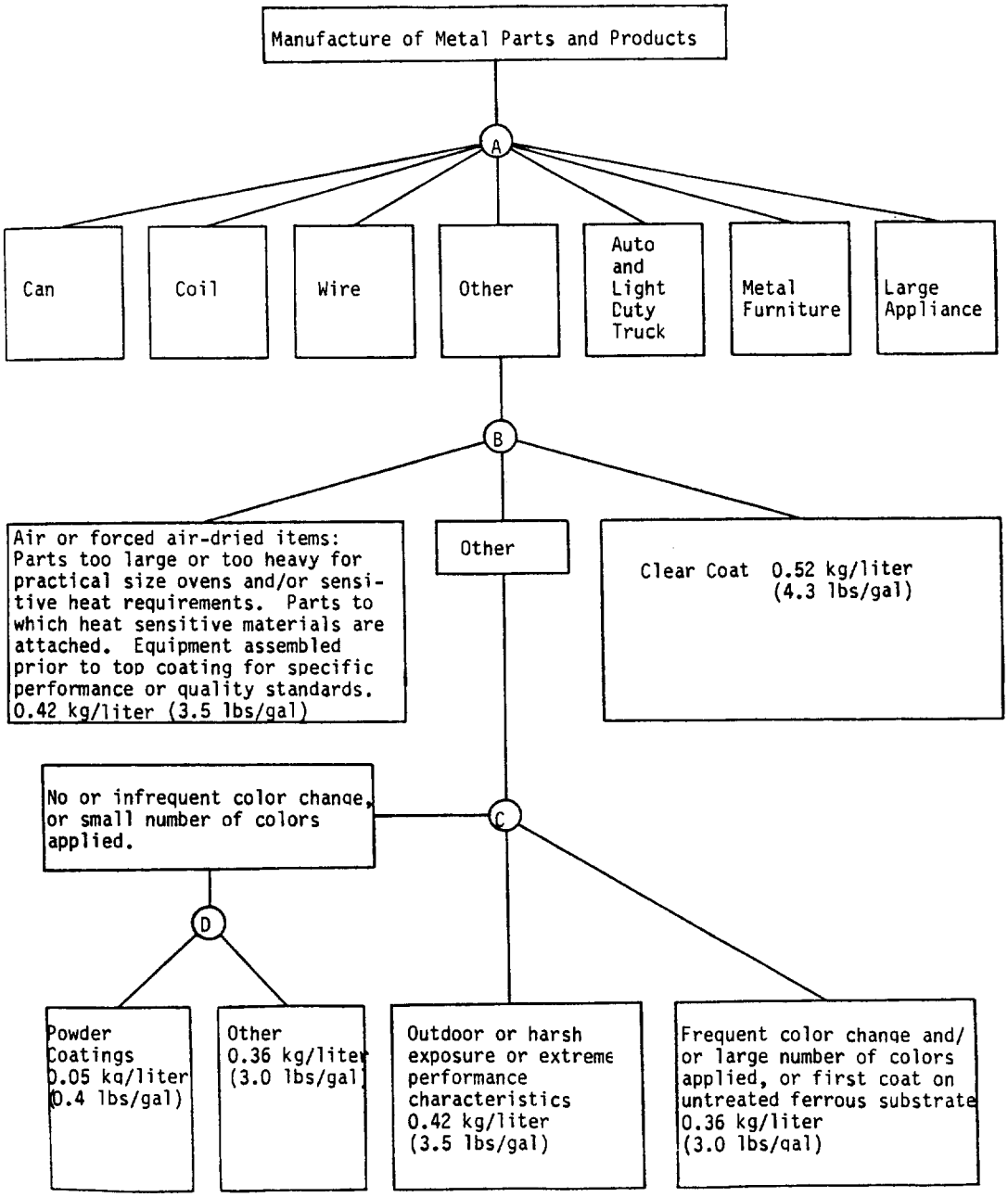
The miscellaneous metal part and product category includes hundreds of small to medium size industries for which writing individual guideline documents would be impractical. After reviewing these industries, EPA prepared this report to assist local agencies in determing the level of VOC control that represents the presumptive norm that can be achieved through the application of reasonably available control technology (RACT). Reasonably available control technology is defined as the lowest emission limit that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility. It may require technology that has been applied to similar, but not necessarily identical source categories. It is not intended that extensive research and development be conducted before a given control technology can be applied to the source. This does not, however, preclude requiring a short-term evaluation program to permit the application of a given technology to a particular source. This latter effort is an appropriate technology forcing aspect of RACT. The diagram on the next page provides emission limits that represent RACT for the industries included in the miscellaneous metal parts and products category of the surface coating industry.

It must be cautioned that the limits reported in the diagram are necessarily based on a general consideration of the capabilities and problems of the hundreds of industries which coat their products. It will not be applicable to every plant or even every industry within the many industries which coat. For example, the level of control which is herein recommended for a particular source may be based on a type of coating which cannot meet the specifications required of another product from a similar source.



Logic diagram for derivation of emission limits for coating of miscellaneous metal parts and products.

The recommended emission limits are based on the use of coatings low in organic solvents. They range from 0.05 to 0.52 Kg per liter (0.4 to 4.4 lbs/gal). Equivalent reductions in VOC emissions can be achieved by the use of add-on control devices such as incinerators and carbon adsorbers. Many coating applicators, however, have expressed that they plan to meet future VOC regulations through the use of coatings low in organic solvents rather than resort to add-on control devices.

GLOSSARY

- Single coat means only one film of coating is applied to the metal substrate.
- Prime coat means the first of two or more films of coating applied in an operation.
- Topcoat means the final film or series of films of coating applied in a two-coat (or more) operation.
- Faraday caging means a repelling force generated in corners and small enclosed areas of the metal substrate during electrostatic spraying of powders.
- Blocking agent means an organic agent which blocks or inhibits certain cross-linking or polymerization reactions. It is designed to separate from the monomer at some elevated temperature thereby allowing the reactions to proceed.
- Low organic solvent coating (LOSC) refers to coatings which contain less organic solvent than the conventional coatings used by the industry. Low organic solvent coatings include water-borne, higher solids, electrodeposition and powder coatings.
- Heat sensitive material means materials which cannot be exposed to temperatures greater than 80° to 95°C (180° to 200°F).
- Transfer efficiency means the portion of coating which is not lost or wasted during the application process expressed as percent.

CONVERSION FACTORS FOR METRIC UNITS

Metric Unit	Metric Name	Equivalent English Unit
Kg	kilogram (10^3grams)	2.2046 lb
liter	liter	0.0353 ft^3
dscm	dry standard cubic meter	35.31 dry std. $ft.^3$
scmm (Nm^3)	standard cubic meter per min.	35.31 ft^3/min.
Mg	megagram (10^6grams)	2,204.6 lb
metric ton	metric ton (10^6grams)	2,204.6 lb
Gj	gigajoules (10^9joules)	9.486 x 10^5BTU

In keeping with U.S. Environmental Protection Agency policy, metric units are used in this report. These units may be converted to common English units by using the above conversion factors.

Temperature in degrees Celsius (C^o) can be converted to temperature in degrees Fahrenheit (^oF) by the following formula:

$$t^o_f = 1.8\ (t^o_c) + 32$$

t^o_f = temperature in degrees Fahrenheit

t^o_c = temperature in degrees Celsius or degrees Centigrade

Kg. per liter x 8.34 = lbs/gal

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1.0 SOURCES AND TYPES OF EMISSIONS

This chapter provides general information on the miscellaneous metal parts and products industries, the methods by which conventional coatings are applied, and the volatile organic compound (VOC) emissions which can be expected from the coatings.

1.1 GENERAL DISCUSSION

A wide variety of metal parts and products are coated for decorative or protective purposes. These are grouped into hundreds of small industrial categories for which writing individual guideline documents would be unreasonable. This guideline document is intended to provide information on industries which coat metal parts and products, with the exception of the can, coil, magnet wire, automobiles and light duty truck, metal furniture and large appliance industries. These have been reported previously in "Control of Volatile Organic Emissions from Existing Stationary Sources - Volumes II, III, IV, and V."

The industrial categories for which this guideline is intended and some examples of each category are listed in Table 1.1.

There are far more dissimilarities than similarities between both the many plants and various industries represented by this category. For example, the geographic distribution of these industry categories is market-dependent and varies greatly. Some industries such as large farm machinery are located primarily in agricultural areas of the country such as EPA Regions V and VII. Others, like small appliances may be scattered throughout the country

Table 1.1 LIST OF INDUSTRIAL CATEGORIES COVERED BY THIS GUIDELINE DOCUMENT[a]

- large farm machinery (harvesting, fertilizing and planting machines, tractors, combines, etc.)
- small farm machinery (lawn and garden tractors, lawn mowers, rototillers, etc.)
- small appliances (fans, mixers, blenders, crock pots, dehumidifiers, vacuum cleaners, etc.)
- commercial machinery (computers and auxiliary equipment, typewriters, calculators, vending machines, etc.)
- industrial machinery (pumps, compressors, conveyor components, fans, blowers, transformers, etc.)
- fabricated metal products (i.e., metal covered doors, frames).
- any other industrial category which coats metal parts or products under the Standard Industrial Classification Code of Major Group 33 (primary metal industries), Major Group 34 (fabricated metal products), Major Group 35 (non-electrical machinery), Major Group 36 (electrical machinery), Major Group 37 (transportation equipment), Major Group 38 (miscellaneous instruments), Major Group 39 (miscellaneous manufacturing industries), Major Group 40 (railroad transportation) and Major Group 41 (transit passenger transportation).

[a] Architectural and maintenance coatings are planned as the subject of a future guideline.

although greater numbers of small appliance manufacturers may be located near large population centers. Within some industries, large variations in manufacturing techniques and procedures exist. Some facilities manufacture and coat metal parts, then assemble them to form a final product to be sold directly for retail. Others often called "job shops", manufacture and coat products under contract; specifications differ from product to product. The metal parts are then shipped to the final product manufacturer to be assembled with other parts into some product. Such facilities are often located in the vicinity of the manufacturers for whom they perform this service.

The size of metal coating facilities and their mode of operation varies not only between industries but also within each industry. Two facilities coating the same product may apply different coatings using completely different application methods. The size of the facility is dependent on several things: number of coating lines, size of parts or products coated, type of coating operation (i.e., spray, dip, flow or roll coat), and number of coats of paint applied.

The coatings are a critical constituent of the metal coating industry. In many cases the coatings must provide esthetic appeal, but in all cases, they must protect the metal from the atmosphere in which it will be used. Adverse conditions may include moisture, sunlight, extreme temperature, abrasion and corrosive chemicals. A wide variety of coatings are applied by the many industries considered by this document. Both enamels (at about 30-40 volume percent solids) and lacquers (at 10-20 volume percent solids) are used, although enamels are more common. Coatings are often shipped by the manufacturer as a concentrate but thinned prior to application. Typical coatings are alkyds, acrylics, epoxies, polyesters, vinyls, silicones,

plastisols and phenols.

Most coatings contain several (up to 10) different solvents. Typical solvents are ketones, esters, alcohols, aliphatics, ethers, aromatics and terpenes.

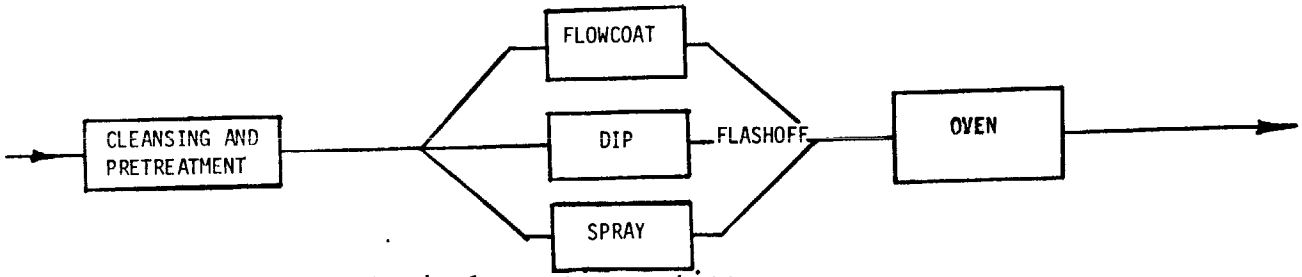
1.2 PROCESSES AND EMISSION POINTS

Each metal coating line tends to be somewhat unique because of its age, product coated, design, and application technique. Figure 1.1 portrays common features found in many coating lines, and the following comments summarize these features.

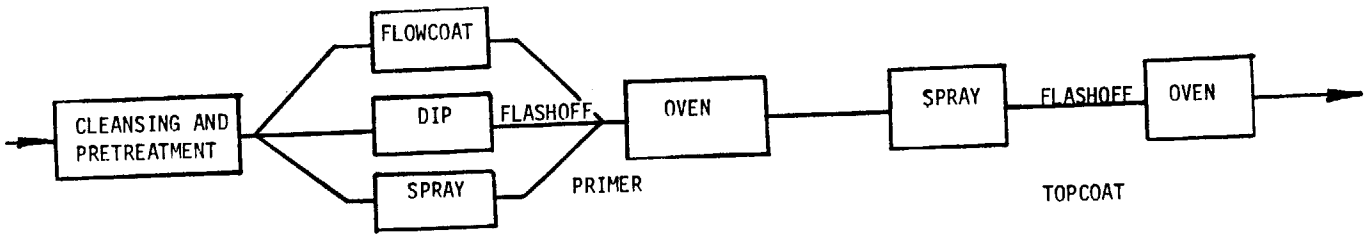
Flow diagrams a and b of Figure 1.1 show common methods of applying coatings on miscellaneous parts and products in both a conveyorized and batch, oven-baked single coat and two-coat operations. These methods typically include spray, dip, or flow coating for both single coats and primers. Spray is usually used for the topcoat.

First the metal substrate is cleansed to remove grease, dust, mill scale or corrosion. Often it is pretreated to improve adhesion. The most common method is the five stage cleansing process where the metal is cleaned with an aqueous caustic solution, rinsed with water, cleaned with a non-caustic solution, treated with phosphate and finally rinsed again with water. Chromate rinses or other pretreatments may also be used. Other cleaning methods are also used. The parts may be cleaned in a shot-blasting chamber by using organic solvent cleansers. (See Control of Volatile Organic Emissions from Solvent Metal Cleaning) The metal often passes through an oven to remove water before the coating is applied.

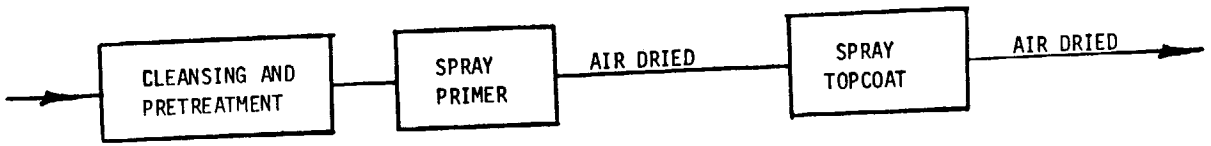
Spraying is the more common method of applying coatings, for single coat operations, but flow coating and dipping are also used. For two coat operations,



a) Conveyorized or batch single coat operation.



b) Conveyorized two-coat operation.



c) Manual two-coat operation air dried.

Figure 1-1. Techniques commonly used in coating miscellaneous metal parts and products.

the primers are more likely to be applied either by flow or dip coating while the topcoats are almost always sprayed.

To apply a flow coating, the metal parts are moved by a conveyor through an enclosed booth. Inside, a series of nozzles (which may be stationary or may oscillate), located at various angles to the conveyor, shoot out streams of coating which "flow" over the part. The excess coating drains into a sink located on the botton of the booth, is filtered and pumped back into a holding tank for reuse. Flow coating provides about a 90 percent transfer efficiency. Additional solvents are added to control the viscosity due to evaporation in the flow coater.

The coated parts are often conveyed through a flashoff tunnel to evaporate solvent and allow the coating to flow out properly. The flow coater and flashoff tunnel are often located in a separate room in the facility and vented either through roof fans or by means of an exhaust system which maintains a slight negative pressure to capture the organic vapors. Exhaust gas flow is maintained at a rate sufficient to keep organic levels below 25 percent of the lower explosive level or lower if necessary to protect the employees.

One or two color single coat applications or primers for two coat applications may also be applied by dipping. The metal parts are briefly immersed either manually or by conveyor into a tank full of coating. The excess coating is allowed to drip from the part and drain back into the tanks. This method also provides about 90 percent transfer efficiency of the coating. The viscosity in dip coating, as on flow coating is very critical. The dip coating tank and drain board may be completely enclosed in a separate room and vented through roof fans, or through a ventilation system adjoining the tank and drain board. The flow rates from such a ventilation system will

depend on the size of the dip tank.

Spraying is the most common technique for applying single coat, some primer and most topcoat applications. It provides a transfer efficiency of 40 to 70 percent. Electrostatic spraying with disc, bell and other types of spray equipment are commonly used to increase the transfer efficiency to 70 to 90 percent. Transfer efficiencies will vary with the part being coated and if manual, the expertise of the operator. "Touch-up" of assembled parts is usually performed manually.

Spray coating is performed in a booth to contain overspray, to minimize contamination, and sometimes to control the atmosphere in which the coating is applied. The spray booths must be maintained at a slight negative pressure to capture overspray. Minimum acceptable air quality for spray booths are prescribed by OSHA.

After coating and flashoff, the parts are baked in single or multi-pass baking ovens at 150-230^{o}C (275-450^{o}F). Since the cost of reducing organic emissions in the exhaust stream are proportional to the volume of gas exhausted, it is important to minimize the infusion of air into the oven. Several factors, however, must be considered. An inlet air velocity of 15 to 45 mpm (50 to 150 fpm) is required to prevent back convection and escape of emissions. Since the entry and exit openings are usually sized for the largest parts that may be baked on the line, this may result in greater oven exhaust rates than needed to meet 25 percent of the LEL. Dilution air and VOC levels have a strong effect on air pollution control costs. For example, halving the air flow doubles the organic concentration and reduces the capital and operating cost of add-on control equipment. Air curtains may be used at the openings to sweep the openings and minimize the air volume required to contain the emissions within the oven.

Flow diagram c of Figure 1.1 shows a manual two-coat operation often used for items such as large industrial, construction, transportation equipment where the coatings are air or forced air dried. Ovens cannot be used because these assembled products include heat sensitive materials (i.e., tires, rubber tubing, plastic parts, etc.). Also, these products are often too large to be cured in an oven. Other air or forced air dried items include parts which are too thick or heavy to be cured in an oven and parts where production dictates that installation of ovens to cure coatings would not be economically feasible. For many of these items, the coatings must be resistant to steam cleaning, the outdoor elements as well as the corrosive coastal salt environment, and to the hazards of oil, gasoline, chemical spills, fertilizer, moisture and other miscellaneous exposures.

The assembled unit is cleaned to remove dirt, grease, or mill scale. The unit is usually moved to another room where it is spray coated with a primer, allowed to dry, spray coated with a topcoat and again allowed to air or forced air dry. These rooms which may be often as large as 8 x 8 x 18 meters (25 x 25 x 60 feet). A draft fan prevents escape of overspray and maintains the concentration of organics within the worker safety limits prescribed by OSHA. Some of these items may even be coated outdoors.

In summary, organic emissions from the coating of miscellaneous metal parts and products are emitted from the application and flashoff areas and the ovens (if used). For spray and flow coating, the bulk of the VOC is evaporated in the application and flashoff areas as noted in Table 1.2.

Figure 1.2 displays the relationship between VOC emissions and exhaust flow rate with isopleths of organic concentration in terms of the LEL. It emphasizes the effect of solvent concentration on the volume of exhaust gases

that must be treated. Note that if a given coating line evaporates 140 pounds of solvent per hour, the exhaust rate at one percent of the LEL (80,000 SCFM) is 10 times that of the same stream at 10 percent of the LEL (8,000 SCFM). Since operating at higher LEL's clearly reduces the exhaust stream flow rate, the related capitol and operational costs of VOC emission control equipment are reduced.

The flow rates and concentrations are influenced by several factors including the type of application system and the conditions within the flashoff area or oven which is the actual source of emissions. Unfortunately, flow rates are often designed for the most difficult combination of circumstances. As a result, the rate may be excess of many items coated on a specific line and as a result, VOC levels are usually well below 25 percent of the LEL.

Table 1.2 SOURCE OF VOC EMISSIONS FROM COATING MISCELLANEOUS METAL PARTS AND PRODUCTS

Application Method	PERCENT OF TOTAL VOC	
	Application and Flashoff	Oven
Dip	40-50	50-60
Flow coat	50-60	40-50
Spray (oven cured)	70-80	20-30
Spray (air dried)	100	not applicable

[a]This assumes a coating applied at 25 volume percent solids, 75 percent organic solvent which is equivalent to a VOC emission factor of 0.66 kg of organic solvent emitted per liter of coating (5.5 lbs/gal) minus water.

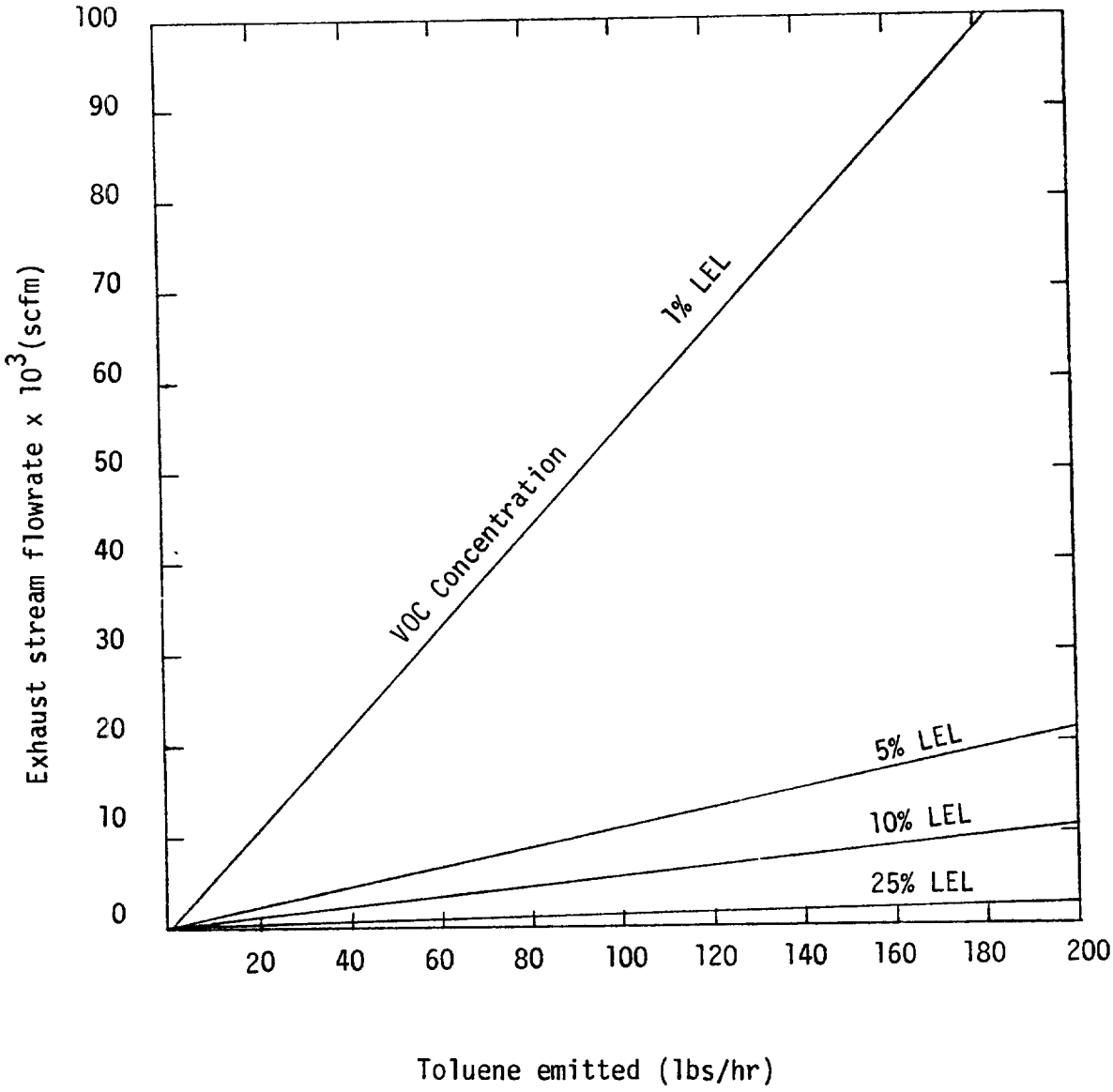


Figure 1-2. Data for toluene, LEL = 1.2% ($^{v}/_{v}$), showing the relationship between VOC emission, exhaust flowrate and VOC concentration.

2.0 APPLICABLE SYSTEMS OF EMISSION REDUCTION

This chapter discusses coatings low in organic solvents (LOSC) and add-on equipment for the control of VOC from conventional coating applications used in the miscellaneous metal part and product industries.

Table 2-1. SUMMARY OF APPLICABLE CONTROL TECHNOLOGY FOR MISCELLANEOUS METAL PARTS AND PRODUCTS

Control Technology	Application	Percent Reduction in Organic Emissions
Water-Borne (spray, dip or flow coat)	Oven baked single coat, primer and topcoat; air dried primer and topcoat	60-90[a]
Water-Borne (electrodeposition)	Oven baked single coat and primer	90-95[a]
Higher-Solids (spray)	Oven baked single coat, and topcoat; air dried primer and topcoat	50-80[a]
Powder (spray)	Oven baked single coat and topcoat	95-98[a]
Carbon Adsorption	Oven baked single coat, primer and topcoat application and flash-off areas; air dried primer and topcoat application and drying areas	90[b]
Incineration	Ovens	90+[b]

[a]These figures reflect only the range in reduction possible. The actual reduction to be achieved will depend on the composition of the coating and the replacement low organic solvent coating, transfer efficiency and the relative film thicknesses of the two coatings.

[b]This reduction in VOC emissions is only across the control device and does not take into account the capture efficiency.

2.1 WATER-BORNE (SPRAY, DIP OR FLOW COAT)

The application of water-borne coatings is similar to organic solvent-borne coatings thus conversion to water-borne coatings does not necessarily require extensive replacement of the existing coating application equipment. A reduction of 60 to 90 percent in organic emissions may be achieved by switching to water-borne coatings. The actual reduction, however, will depend on several variables: the composition of the original organic solvent-borne coating, the composition of the water-borne coating replacement, relative transfer efficiencies, and the relative film thicknesses required. The transfer efficiency of water-borne coatings is similar to that of conventional coatings. Although water is the major carrier, some organic solvents must be included to temper the evaporation rate, provide the coating with the desired properties, and provide film coalescence. Some small appliance manufacturers have converted their electrostatic spray and dip coating lines to apply water-bornes.[1] Water-borne coatings are now being applied on some farm machinery, on fabricated metal products and commercial machinery by flow coating, dipping, and both electrostatic and conventional spraying methods.[2]

Further technical details on the use of water-borne coatings may be found in Volume I, Sections 3.3.1 and 3.3.5.[3]

2.2 WATER-BORNE (ELECTRODEPOSITION)

Although converting to electrodeposited water-borne coatings will require new application equipment (i.e., tank, ultrafilter, rinsing stations, etc.), it results in increased corrosion protection and can deposit thin coatings uniformly at greater transfer efficiency (about 99 percent) than any other application system. Electrodeposited coatings may be applied at 0.3 to 1.2 mils thickness, and film thickness may be adjusted by voltage and immersion time.

Farm and commercial machinery, and fabricated metal product facilities have been reported to apply coatings by electrodeposition.[4]

One major advantage of water-borne coatings is that, unlike solvent-borne coatings, the pretreatment dry-off oven may no longer be required. After an additional rinse with deionized water, the parts are subsequently grounded and immersed into the coating bath which may contain from 8 to 15 volume percent solids, 2 to 4 volume percent organic solvent, and the balance deionized water. An electrical potential causes the suspended solids to migrate and adhere to the part. (Coatings are available for application by either anodic or cathodic electrodeposition.) As the coated parts emerge from the bath, the coating is primarily solids with some water and trace quantities of organic solvent. These solvents control the flow of the coating during the curing process. The parts are then rinsed in several stages to remove any excess paint. (The rinse is then ultrafiltered to remove the water and organics. The paint solids are returned to the bath.)

A complicating factor in determining the emission factor for electrodeposition is the very limited information now available on the final disposition of organic solvent. If the emission factor considers only the coating applied to the metal substrate (which would be emitted from the oven), it is only about 0.024 to 0.06 kg/liter (minus water). This factor does not consider any organic emissions which may occur from the tank or the rinsing stages. If the emission factor is based on the bath composition, it is much greater (i.e., .31 to .38 kg/liter minus water). This factor, however, does not consider the effect of solvent recycled to the bath or purged from the system. It appears that the methods by which ultrafilter residue is treated and how the coatings are replenished in the bath vary considerably from coater to coater. A conservative emission factor for electrodeposited coatings is 0.36 kg/liter less water. Certainly, however, with

effect of improved transfer efficiency included, use of electrodeposited coatings can reduce VOC emissions by at least 90 to 95 percent over conventional coatings.

Electrodeposited coatings are normally baked at 150-200°C (257-400°F). Research is currently underway to eliminate the intermediate baking step now used to cure electrodeposited primers prior to topcoat application. Both the primer and topcoat would be baked as a one-coat system. This would provide attendant savings in capital and operating costs and fuel requirements.

For further technical details on the use of electrodeposition coating technology, see Volume I, Section 3.3.1.[5]

2.3 HIGHER-SOLIDS COATINGS

The reduction in volatile organic emissions achievable by converting to coatings which contain higher solids ranges from 50 to 80 percent. Coatings with 45 to 60 volume percent solids are currently being applied with spray or roll coating technology. Coatings with even greater solids content (60 to 80 volume percent) are making inroads due to the development of new spray application technologies. Research is underway on higher solids coatings which will cure at ambient temperatures. These will be very attractive for applications such as large farm and industrial machinery.

Higher-solids coatings can be applied by roll coating, or by spraying, either with automated electrostatic techniques, or manually. The first two are the more efficient application methods. Due to the higher viscosity of high-solids coatings, additional mechanical, thermal or electrical energy may be necessary for pumping and adequate atomization.[6] Transfer efficiencies with high-solids coatings are often better than with conventional solids coatings particularly with electrostatic sprays.[7]

Further technical details on the use of high-solids coatings may be found in Volume I, Section 3.3.2.[8]

2.4 POWDER COATINGS

Powder coatings have been sprayed as a single coat on small appliances, small farm machinery, fabricated metal product parts, and industrial machinery component parts.[9] Powders can be applied by electrostatic spraying at thicknesses from 0.9 to 5 mils,* and thicknesses of much less than 1 mil have been achieved on experimental interior can lines. Powder coatings are also applied by dipping but the resultant film is much thicker, a minimum of about 6 mils. After application of the coating, the metal part is moved to an oven where the powder particles melt and flow to form a continuous, solid film. Powders are essentially 100 percent solids, but they can release about 0.5 - 3.5 weight percent of volatile organic compounds due to unblocking and crosslinking reactions during the curing process.[10]

Powder coatings are applied by electrostatic spray with almost the same technique used for solvent-borne coatings, although different equipment must be used. Film thickness can be controlled by the voltage potential. Powder coatings wrap around edges of complicated metal parts and are self-leveling on flat parts, but do not (as some of the liquid counterparts also do not) coat small recesses well. Depending on the application, this could be an advantage or disadvantage. This problem may be reduced or eliminated by preheating the parts, but may result in a thicker film.

Powder coatings may be applied in smaller spray booths than the ones used for conventional coatings. As a result, the air requirements necessary for proper ventilation may be greatly reduced. Use of powders may not only conserve space but may also reduce the energy

*At least one firm has one year of production experience applying a coating thickness of 1 mil. Because thicker films are more common, the cost estimates in Chapter 3 are based on coating thicknesses of 2 mils.

required to heat the spray booth make-up air during the winter months.

Changing colors when applying powder coatings requires slightly more time than conventional coatings since any color contamination does not blend. If the operator tries to segregate the overspray color in order to recycle it, the booth and recovery unit should be cleaned thoroughly to avoid color contamination. This will require greater downtime.

Two methods have evolved for minimizing the time required to change colors. Some facilities have several overspray recovery units available that may easily be attached to a single spray booth. Others have installed several mobile spray booths and associated recovery equipment[11] to minimize the number of changeovers that must be made. Still another approach has been to use the multicolored overspray on parts that do not have critical color specifications.

Although curing temperatures, 170° to 230°C (275-450°F) are often higher than with conventional coatings, powders do not require a flashoff zone, the air flow from the ovens may be reduced since no solvent is present. Further technical details on the application of powder coatings may be found in Volume I, Sections 3.3.3 and 3.3.5.[12]

2.5 CARBON ADSORPTION

As discussed in Chapter 1, at least one-half of the volatile organic compounds from coating miscellaneous metal products is emitted from the application and flashoff areas. The remainder is emitted from the ovens. The use of carbon adsorption to collect the emissions from the application and flashoff areas can reduce those emissions by 90 percent across the adsorber.

Carbon adsorption is considered a viable control option for these

areas although there are no known installations in facilities that coat miscellaneous metal parts or products. Carbon adsorption is technically feasible for these applications[13] (no new inventions are required for its implementation), but pilot studies may be necessary before this control technology is installed.

The requisite size of a carbon adsorption unit is dependent on the exhaust flow rate, organic concentration, and the desorption period. Design parameters vary with each application because of the variety of metal parts coated and coatings used. About 95 percent efficiency reportedly is effected by dry filters or by water or oil wash curtains.[14] Additional particulate removal may be necessary, however, if the remaining 5 percent is significant enough to render the bed inefficient.

Flashoff areas have to be enclosed to maximize capture of the volatile organic emissions. The flow rates and VOC concentrations depend on the configuration of the coating line and the "tightness" of the enclosure. If the coating application areas are located on the first floor of the plant, for example, and the ovens are mounted on the roof, it may be difficult and expensive to try to contain the VOC that flashes off as the substrate traverses from the applicator to the oven. In other cases the application areas may be located near the oven where enclosing the flashoff areas would be less difficult. In some situations, the exhaust system on an oven will draw the solvent-laden air from the flashoff areas into the oven.

Further technical details on the use of carbon adsorption may be found in Volume I, Section 3.2.1.[15]

2.6 INCINERATORS

Incinerators are the most universally applicable control system for VOC. There are no serious technical problems associated with the use of either catalytic or noncatalytic incinerators on miscellaneous metal product coating facilities. Incinerator heat recovery efficiencies have improved and operating costs have been reduced significantly in recent years.

Incineration systems may be more desirable (less costly and perhaps more efficient) than adsorption for reducing VOC emissions from the baking ovens for several reasons:

1. No cooling system is required. High temperature (150^{o} to $230^{o}C$) exhaust gases have to be cooled to $40^{o}C$ or lower before entering a carbon bed.

2. VOC in the exhaust stream can provide appreciable heat energy eg. $350^{o}C$ at 25 percent of the LEL. Thus at significant VOC levels, auxiliary fuel use can be minimized or sometimes even eliminated by the proper use of heat exchangers.

3. Particulate and condensible matter from volatilization and/or degradation of resins, may coat the carbon bed. These materials will not affect an incinerator.

It is desirable but not always feasible to incorporate secondary heat recovery systems to minimize fuel consumption and overall operating costs. Waste heat may be recovered for use in many process areas; for example, cleansing and pretreatment sections, the ovens, and for space heating during the colder months.

Incineration of the exhaust from application and flashoff areas

is certainly technically feasible. Its economic practicality may depend on minimizing the volume to be burned and recovering sufficient heat to keep fuel consumption at an acceptable level.

Further technical details on the use of incineration may be found in Volume I, Section 3.2.2.[16]

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3.0 COST ANALYSIS

3.1 INTRODUCTION

3.1.1 Purpose

The purpose of this chapter is to present capital and annualized costs for alternative ways of controlling solvent emissions at existing coating lines in the metal coating industry. A cost-effective analysis is included as an extension of the cost development.

3.1.2 Scope

Estimates of capital and annualized costs are presented for controlling volatile organic compounds (VOC) from application areas and curing ovens associated with conveyorized single-coat lines and conveyorized two-coat lines. Control costs for manual two-coat lines are also estimated; in this process coated parts are air-dried, and only application area emissions require control. Flow, dip, and electrostatic-spray coating are application techniques considered for the single-coat lines and for the prime coat in two-coat applications. Electrostatic-spray coating only is considered for the topcoat in two-coat lines. The following control alternatives are analyzed for the three-coat lines:

Alternative I - Process Modification

Emissions can be controlled by modifying coating equipment to accommodate one of the following low-solvent coating processes:

1. Use of coating with a higher solids (60 percent or above) content
2. Use of waterborne coatings
3. Powder deposition
4. Electrodeposition (EDP)

Alternative II - Exhaust Gas Treatment

1. Carbon adsorption
2. Thermal incineration (35% and 90% primary heat recovery)
3. Catalytic incineration (35% primary heat recovery)

3.1.3 Use of Model Plants

Cost analyses are presented for three model sizes of existing coating lines. Coating rates analyzed for conveyorized single-coat and conveyorized two-coat operations are 139,000 m^2/yr, 743,000 m^2/yr, and 1,486,000 m^2/yr; the rates analyzed for manual two-coat operations are 418,000 m^2/yr, 604,000 m^2/yr, and 790,000 m^2/yr. The plant operating time assumed for each type of application is 2880 hours/yr.

It must be emphasized that model coating lines used in this analysis are very simple in that they involve a one-color, single-coat or two-coat application. Analyzing multicolor coating systems is beyond the scope of this analysis. Also, although control cost estimates based on the model plant approach may differ from actual costs incurred, they

are nevertheless considered the best means of comparing relative costs and cost effectiveness of alternative control measures.

3.1.4 Bases for Capital Cost Estimates

Capital costs represent the investment required for retrofitting a control system, including costs of equipment, material, labor for installation, and other associated costs. Capital cost estimates are based on cost surveys of various installations presented in the references (1, 2). Most of the surveyed costs represent new installations. These costs have been modified to apply to retrofit installations.

All capital costs are expressed in mid-1977 dollars. In addition to basic control equipment, capital costs include auxiliary equipment such as hoods, ducts, etc., as well as indirect expenses such as contingencies, contractor's fee, and taxes.

3.1.5 Bases for Annualized Costs

Annualized costs represent the cost of operating and maintaining the control system and that of recovering the capital investment. Operating costs include costs for materials, utilities, and normal maintenance. Net annualized costs for process changes, i.e., line conversions, are incremental costs incurred in converting from high-solvent to low-solvent coatings. The bases for these projected incremental costs are available in the referenced material (1, 2). Again, it must be emphasized that these analyses of model coating lines are provided as a means of comparing the relative costs of alternative control measures. Various coating industries have devoted considerable resources to the development of incremental costs of low-solvent coating conversions.

However, a comparison of these estimates may show a wide variation due to differences in some key assumptions. Specifically, coating material costs appear to have the greatest impact on annual costs. Differences in coating thickness requirements, transfer efficiencies, raw material costs, and coating specifications will influence these incremental costs.

General cost factors used to estimate annualized costs for model coating lines are provided in Table 3-1.

3.2. SOLVENT EMISSION CONTROL IN METAL COATING OPERATIONS

3.2.1 Model Plant Parameters

Table 3-2 presents technical parameters for the model sizes selected. The estimated exhaust flow rates are based on solvent usage in the operation; and the estimated solvent coatings thickness and transfer efficiencies are based on typical practice.

Add-on control systems can provide overall emission control efficiencies of the order of 80 to 90 percent. Separate control systems are assumed for application/flash-off areas and drying ovens. Emission control efficiencies for process modifications range from 70 to 99 percent (3, 4), depending on the type of coating selected.

The cost analysis is based solely on model sizes. Generally no consideration has been given to detailed design characteristics of the model lines in terms of process equipment requirements, line speed, etc. However, it was necessary to consider gas flow rate, required dry coating thickness, and coating transfer efficiencies to estimate capital and

Table 3-1. COST FACTORS USED IN COMPUTING ANNUALIZED COSTS

I. Direct operating costs	
1. Materials (as purchased):	
- Conventional prime coating (40% solids)[a]	$1.72/liter ($6.50/gal)
- Alkyd conventional top coating (40% solids)	$2.11/liter ($8/gal)
- Solvent thinner	$0.28/liter ($1.07/gal)
- Polyester high solids coating (60% solids)[a]	$3.17/liter ($12/gal)
- Alkyd waterborne coating (40% solids)[a]	$2.38/liter ($9/gal)
- Epoxy powder coating	$3.30/kg ($1.50/lb)
- Electrodeposition waterborne (60% solids)[a]	$2.91/liter ($11.0/gal)
2. Utilities	
- Electricity	$0.03/kw-hr
- Natural gas	$1.90/GJ ($2.00/million Btu)
- Steam	$5.50/thousand Kg ($2.50/thousand lb)
3. Direct labor	$10/man-hr
4. Maintenance labor	
- Process modifications	$10/man-hr
- Add-on systems	0.02 x capital cost
5. Maintenance Materials	0.02 x capital cost
II. Annualized capital charges	
1. Depreciation and interest (process modification)	0.1468 x capital cost
- Depreciation and interest (add-on)	0.1630 x capital cost
2. Taxes, insurance, and administrative overhead	0.04 x capital cost

[a] By volume.

Table 3-2. TECHNICAL PARAMETERS FOR MODEL COATING LINES

Conveyorized single-coat and two-coat operation			
Line size, m^2/yr (ft^2/yr)	139,000 (1,500,000)	743,000 (8,000,000)	1,486,000 (16,000,000)
Exhaust rate, Nm^3/sec (scfm)			
- Flow coat booth	0.20 (420)	1.07 (2245)	2.15 (4555)
- Flow coat oven	0.85 (1800)	0.85 (1800)	0.85 (1800)
- Dip coat booth	0.28 (590)	1.47 (3100)	2.97 (6300)
- Dip coat oven	0.85 (1800)	0.85 (1800)	0.90 (1900)
- Spray coat booth	3.02 (6400)	16.05 (34,000)	32.10 (68,000)
- Spray coat oven	0.85 (1800)	0.85 (1800)	0.85 (1800)
Manual two-coat operation			
Line size, m^2/yr (ft^2/yr)	418,000 (4,500,000)	604,000 (6,500,000)	790,000 (8,500,000)
Exhaust rate, Nm^3/sec (scfm)			
- Prime coat booth	28.55 (60,500)	40.78 (86,400)	53.05 (112,400)
- Top coat booth	28.55 (60,500)	40.78 (86,400)	53.05 (112,400)
Process conversion data			
	Dry coating thickness, μm (mils)/coat		Transfer efficiency, %[a]
- Conventional solvent	25 (1)		80[b]
- High solids solvents	30 (1.2)		80
- Powder deposition	50 (2)		95
- EDP	18 (0.7)		95
- Waterborne solvents	25 (1)		80-90[b]

[a] Reference 3.

[b] 80 percent for spray coating, 90 percent for dip and flow coatings.

operating costs of the control alternatives considered. Therefore, any changes in these parameters (gas flow rate, dry coating thickness, coating transfer efficiency) will produce considerable impact on control costs and cost-effectiveness of different options.

3.2.2 Control Costs

Table 3-3 through 3-9 present details of control cost estimates for seven coating operations. Tables 3-3, 3-4, and 3-5 present control costs for the conveyorized single-coat operation; Tables 3-6, 3-7, and 3-8 for the two-coat conveyorized operation; and Table 3-9 for the manual two-coat operation.

Capital costs of converting lines to higher-solids coatings or to waterborne coatings are those related to application equipment modifications only. Suppliers indicate that conversion to high-solids (60 percent or more solids content) coatings, particularly a high speed turbine bell or disc high-solids coating, requires installation of new pumps and fluid transfer equipment. The cost estimates include this equipment (5). Capital cost estimates change radically for waterborne coating operations if paint sources are not located close to application equipment and if stainless steel piping is used for paint recirculation systems (6).

Capital costs of converting to a powder coating are associated with installation of powder application and recovery systems. Because model lines are one-color systems, only one recovery system is included in capital cost estimates. Some energy, waste disposal, and direct labor

Table 3-3. INCREMENTAL COSTS OF SOLVENT EMISSION CONTROL OPTIONS FOR CONVEYORIZED SINGLE-COAT OPERATION, FLOW-COAT APPLICATION
(Mid-1977 thousand dollars)

Cost item	Applicable control option														
	Waterborne coatings source size[a]			Electrodeposition (EDP) source size			Carbon adsorption and thermal incineration with 35% primary heat recovery[b] source size			Carbon adsorption and catalytic incineration with 35% primary heat recovery[b] source size			Thermal incineration with 90% primary heat recovery[c] source size		
	small	medium	large	small	medium	large	small	medium	large	small	medium	large	small	medium	large
° Capital investment	12	20	28	65	178	270	199	275	328	178	255	308	59	104	156
° Annual costs (credits)[d]															
Material	2	11	22	(9)	(46)	(93)	0	0	0	0	0	0	0	0	0
Electricity	0	0	1	2	9	18	1	1	2	1	1	2	0	1	1
Fuel	0	(2)	(3)	0	(1)	(2)	8	8	8	2	2	2	4	8	12
Maintenance	1	1	1	3	8	12	9	12	15	8	12	14	3	5	7
Capital charges	2	4	5	12	33	50	40	55	66	36	51	62	12	21	31
° Total annualized cost (credit)	5	14	26	8	3	(15)	58	76	91	47	66	80	19	35	51
° Solvent emissions controlled, Mg/yr	6	35	69	7	39	78	7	37	73	7	37	73	7	39	78
° Emission reduction, %	80	80	80	90	90	90	85	85	85	85	85	85	90	90	90
° Cost effectiveness (credit), $/Mg of solvent controlled	833	400	377	1143	77	(191)	8286	2054	1247	6714	1784	1096	2714	897	654

[a] See Table 3-2 for source sizes.

[b] Carbon adsorption on flow-coat booth and incineration with 35 percent primary heat recovery on drying oven.

[c] Thermal incineration with 90 percent primary heat recovery on flow-coat booth and drying oven.

[d] Increments of waste disposal costs, labor costs, and labor overhead are insignificant; these are not included in the annual costs.

Table 3-4. INCREMENTAL COSTS OF SOLVENT EMISSION CONTROL OPTIONS FOR CONVEYORIZED SINGLE-COAT OPERATION, DIP-COAT APPLICATION

(Mid-1977 thousand dollars)

Cost item	Applicable control option														
	Waterborne coatings source size[a]			Electrodeposition (EDP) source size			Carbon adsorption and thermal incineration with 35% primary heat recovery[b] source size			Carbon adsorption and catalytic incineration with 35% primary heat recovery[b] source size			Thermal incineration with 90% primary heat recovery[c] source size		
	small	medium	large	small	medium	large	small	medium	large	small	medium	large	small	medium	large
° Capital investment	12	20	28	65	178	270	209	296	357	188	276	337	64	126	201
° Annual costs (credits)[d]															
Material	2	11	22	(9)	(46)	(93)	0	0	0	0	0	0	0	0	0
Electricity	0	0	1	2	9	18	1	1	2	1	1	2	0	1	1
Fuel	0	(2)	(3)	0	(1)	(2)	8	8	9	2	2	2	5	10	16
Maintenance	1	1	1	3	8	12	9	13	16	9	13	15	3	6	9
Capital charges	2	4	5	12	33	50	42	59	71	38	55	68	13	25	40
° Total annualized cost (credit)	5	14	26	8	3	(15)	60	81	98	50	71	87	21	42	66
° Solvent emissions controlled, Mg/yr	6	35	69	7	39	78	7	37	73	7	37	73	7	39	78
° Emission reduction, %	80	80	80	90	90	90	85	85	85	85	85	85	90	90	90
° Cost effectiveness (credit), $/Mg of solvent controlled	833	400	377	1143	77	(192)	8571	2189	1343	7143	1919	1192	3000	1077	846

[a] See Table 3-2 for source sizes.

[b] Carbon adsorption on dip-coat booth and incineration with 35 percent primary heat recovery on drying oven.

[c] Thermal incineration with 90 percent primary heat recovery on dip-coat booth and drying oven.

[d] Increments of waste disposal costs, labor costs, and labor overhead are insignificant; these are not included in the annual costs.

Table 3-5. INCREMENTAL COSTS OF SOLVENT EMISSION CONTROL OPTIONS FOR CONVEYORIZED SINGLE-COAT OPERATION, SPRAY-COAT APPLICATION
(Mid-1977 thousand dollars)

Cost item	Applicable control option																	
	Waterborne coatings source size[a]			High solids coatings source size			Powder deposition source size			Carbon adsorption and thermal incineration with 35% primary heat recovery[b] source size			Carbon adsorption and catalytic incineration with 35% primary heat recovery[b] source size			Thermal incineration with 90% primary heat recovery[c] source size		
	small	medium	large	small	medium	large	small	medium	large	small	medium	large	small	medium	large	small	medium	large
° Capital investment	12	20	28	30	43	59	56	76	101	380	698	971	369	648	957	220	918	1713
° Annual costs (credits)[d]																		
Material	2	9	19	3	16	32	13	71	142	0	0	0	0	0	0	0	0	0
Electricity	0	0	1	0	0	0	0	0	0	2	9	17	2	9	17	1	6	12
Fuel	0	(2)	(3)	0	(1)	(3)	0	(2)	(3)	8	10	12	2	4	6	16	70	130
Maintenance	1	1	1	1	2	3	3	3	5	17	31	44	16	31	43	10	41	77
Capital charges	2	4	5	6	8	11	10	14	19	76	140	195	72	136	190	44	184	343
° Total annualized cost (credit)	5	12	23	10	25	41	26	86	163	103	190	268	92	180	256	71	301	562
° Solvent emissions controlled, Mg/yr	8	41	82	7	36	72	9	46	93	8	41	81	8	41	81	8	44	88
° Emission reduction, %	80	80	80	70	70	70	90	90	90	79	79	79	79	79	79	85	85	85
° Cost effectiveness (credit), $/Mg of solvent controlled	625	293	280	1429	695	597	2889	1870	1753	12875	4634	3309	11500	4390	3161	8875	6841	6386

[a] See Table 3-2 for source sizes.

[b] Carbon adsorption on spray-coat booth and incineration with 35 percent primary heat recovery on drying oven.

[c] Thermal incineration with 90 percent primary heat recovery on spray-coat booth and drying oven.

[d] Increments of waste disposal costs, labor costs, and labor overhead are insignificant; these are not included in the annual costs.

Table 3-6. INCREMENTAL COSTS OF SOLVENT EMISSION CONTROL OPTIONS FOR CONVEYORIZED TWO-COAT OPERATION, FLOW- AND SPRAY-COAT APPLICATION
(Mid-1977 thousand dollars)

Cost item	Applicable control option														
	Waterborne coatings source size[a]			Powder deposition source size			Carbon adsorption and thermal incineration with 35% primary heat recovery[b] source size			Carbon adsorption and catalytic incineration with 35% primary heat recovery[b] source size			Thermal incineration with 90% primary heat recovery[c] source size		
	small	medium	large	small	medium	large	small	medium	large	small	medium	large	small	medium	large
° Capital investment	24	40	56	56	76	101	580	974	1299	539	903	1259	279	1002	1869
° Annual costs (credits)[d]															
Material	8	43	86	(4)	(21)	(42)	0	0	0	0	0	0	0	0	0
Electricity	0	1	1	0	(2)	(3)	3	10	19	3	10	19	2	7	13
Fuel	(1)	(3)	(6)	(1)	(6)	(13)	16	18	20	4	6	8	20	78	149
Maintenance	1	2	3	3	3	5	26	44	58	25	42	57	13	46	54
Capital charges	4	7	10	10	14	19	116	195	260	108	187	252	56	204	374
° Total annualized cost (credit)	12	50	94	8	(12)	(34)	161	267	357	140	245	336	91	335	590
° Solvent emissions controlled, Mg/yr	14	76	152	16	85	171	15	78	155	15	78	155	15	82	165
° Emission reduction, %	80	80	80	90	90	90	82	82	82	82	82	82	87	87	87
° Cost effectiveness (credit), $/Mg of solvent controlled	857	658	618	500	(141)	(199)	10734	3423	2303	9333	3141	2167	6067	4085	3578

[a] See Table 3-2 for source sizes.

[b] Carbon adsorption on coating booth and incineration with 35 percent primary heat recovery on drying oven.

[c] Thermal incineration with 90 percent primary heat recovery on coating booth and drying oven.

[d] Increments of waste disposal costs, labor costs, and labor overhead are insignificant; these are not included in the annual costs.

Table 3-7. INCREMENTAL COSTS OF SOLVENT EMISSION CONTROL OPTIONS FOR CONVEYORIZED TWO-COAT OPERATION, DIP- AND SPRAY-COAT APPLICATION
(Mid-1977 thousand dollars)

Cost item	Applicable control option														
	Waterborne coatings source size[a]			Powder deposition source size			Carbon adsorption and thermal incineration with 35% primary heat recovery[b] source size			Carbon adsorption and catalytic incineration with 35% primary heat recovery[b] source size			Thermal incineration with 90% primary heat recovery[c] source size		
	small	medium	large	small	medium	large	small	medium	large	small	medium	large	small	medium	large
° Capital investment	24	40	56	56	76	101	589	994	1328	548	924	1288	285	1044	1914
° Annual costs (credits)[d]															
Material	8	43	86	(4)	(21)	(42)	0	0	0	0	0	0	0	0	0
Electricity	0	1	1	0	(2)	(3)	3	10	19	3	10	19	2	7	13
Fuel	(1)	(3)	(6)	(1)	(6)	(13)	16	18	21	4	6	9	21	80	152
Maintenance	1	2	3	3	3	5	26	45	60	25	43	58	13	47	86
Capital charges	4	7	10	10	14	19	118	199	266	110	191	258	57	209	383
° Total annualized cost (credit)	12	50	94	8	(12)	(34)	163	272	366	142	250	344	93	343	634
° Solvent emissions controlled, Mg/yr	14	76	152	16	85	171	15	78	155	15	78	155	15	82	165
° Emission reduction, %	80	80	80	90	90	90	82	82	82	82	82	82	87	87	87
° Cost effectiveness (credit), $/Mg of solvent controlled	857	658	618	500	(141)	(199)	10867	3487	2361	9460	3205	2219	6200	4183	3842

[a] See Table 3-2 for source sizes.
[b] Carbon adsorption on coating booth and incineration with 35 percent primary heat recovery on drying oven.
[c] Thermal incineration with 90 percent primary heat recovery on coating booth and drying oven.
[d] Increments of waste disposal costs, labor costs, and labor overhead are insignificant; these are not included in the annual costs.

Table 3-8. COSTS OF SOLVENT EMISSION CONTROL OPTIONS FOR CONVEYORIZED TWO-COAT OPERATION, SPRAY-COAT APPLICATION
(Mid-1977 thousand dollars)

Cost item	Applicable control option																	
	Waterborne coatings source size[a]			High solids solvents source size			Powder deposition process source size			Carbon adsorption and thermal incineration with 35% primary heat recovery[b] source size			Carbon adsorption and catalytic incineration with 35% primary heat recovery[b] source size			Thermal incineration with 90% primary heat recovery[c] source size		
	small	medium	large	small	medium	large	small	medium	large	small	medium	large	small	medium	large	small	medium	large
° Capital investment	24	40	56	60	86	118	56	76	101	761	1397	1943	720	1296	1902	439	1837	3425
° Annual costs(credits)[d]																		
Material	8	43	86	11	56	112	(7)	(36)	(71)	0	0	0	0	0	0	0	0	0
Electricity	0	1	1	0	0	1	0	(2)	(3)	4	17	34	4	17	34	3	12	23
Fuel	(1)	(3)	(6)	0	(3)	(5)	(1)	(6)	(13)	16	20	24	4	8	12	32	140	273
Maintenance	1	2	3	3	4	5	3	3	5	34	63	87	33	61	86	20	83	154
Capital charges	4	7	10	12	16	22	10	14	19	152	279	389	144	271	380	88	367	685
° Total annualized cost (credit)	12	50	94	26	73	135	5	(27)	(63)	206	379	534	185	357	512	143	602	1135
° Solvent emissions controlled, Mg/yr	15	82	165	14	72	144	17	93	186	15	81	163	15	81	163	16	88	175
° Emission reduction, %	80	80	80	70	70	70	90	90	90	79	79	79	79	79	79	85	85	85
° Cost effectiveness (credit), $/Mg of solvent controlled	800	610	570	1857	1014	938	294	(290)	(339)	13733	4679	3276	12233	4407	3140	8938	6841	6486

[a] See Table 3-2 for source sizes.

[b] Carbon adsorption on spray-coat booth and incineration with 35 percent primary heat recovery on drying oven.

[c] Thermal incineration with 90 percent primary heat recovery on spray-coat booth and drying oven.

[d] Increments of waste disposal costs, labor costs, and labor overhead are insignificant; these are not included in the annual costs.

Table 3-9. COSTS OF SOLVENT EMISSION CONTROL OPTIONS FOR MANUAL TWO-COAT OPERATION
(Mid-1977 thousand dollars)

Cost item	Applicable control option											
	Waterborne coatings source size[a]			High solids coatings source size			Carbon adsorption source size			Thermal incineration with 90% primary heat recovery source size		
	small	medium	large	small	medium	large	small	medium	large	small	medium	large
° Capital investment	34	37	41	72	78	86	1740	2226	2596	1619	2216	2758
° Annual costs (credits)[b]												
Material	24	35	46	50	66	91	0	0	0	0	0	0
Electricity	0	0	1	0	0	0	15	21	27	5	7	10
Fuel	(2)	(3)	(3)	(1)	(2)	(3)	4	5	7	59	85	110
Maintenance	2	2	2	3	4	4	78	100	117	73	100	124
Capital charges	6	7	8	14	15	16	174	223	260	162	222	276
° Total annualized cost (credit)	30	41	54	66	83	108	232	299	353	262	364	458
° Solvent emissions controlled, Mg/yr	12	18	24	10	15	20	13	18	24	13	19	25
° Emission reduction, %	80	80	80	70	70	70	80	80	80	85	85	85
° Cost effectiveness (credit), $/Mg of solvent controlled	2500	2278	2250	6600	5533	5400	17841	16611	14708	20154	19158	18320

[a] See Table 3-2 for source sizes.

[b] Increments of waste disposal costs, labor costs, and labor overheads are insignificant; these are not included in the annual costs.

savings are estimated for powder coating conversions (1, 2); however, a higher coating thickness of 50 μm (2 mils) assumed for powder coating diminishes possible savings.

For electrodeposition, lower applied film thickness helps override some of the associated increased electrical costs (1).

Annualized costs of incineration of oven emissions primarily represent fuel required to raise the temperature of the exhaust gases from 160°C (320°F) to 760°C (1400°F).

3.3 COST EFFECTIVENESS

Figures 3-1 through 3-7 present cost-effectiveness curves for the options analyzed: Figures 3-1, 3-2, and 3-3 for conveyorized single-coat operation; Figures 3-4, 3-5, and 3-6 for conveyorized two-coat operation; and Figure 3-7 for manual two-coat operation. These curves represent the effect of line size on the cost per unit weight of solvent controlled. The cost per unit weight of solvent controlled decreases with the increasing line size in all cases.

The two most cost-effective options evaluated for conveyorized single flow-coat and single dip-coat operations appear to be conversion to waterborne coatings and conversion to the electrodeposition process. The most costly options appear to be add-on control devices. Conversion to waterborne coatings seems to be a cost-effective option for spray coating in a conveyorized single-coat operation; carbon adsorption combined with thermal incineration with 35 percent primary heat recovery is the most costly.

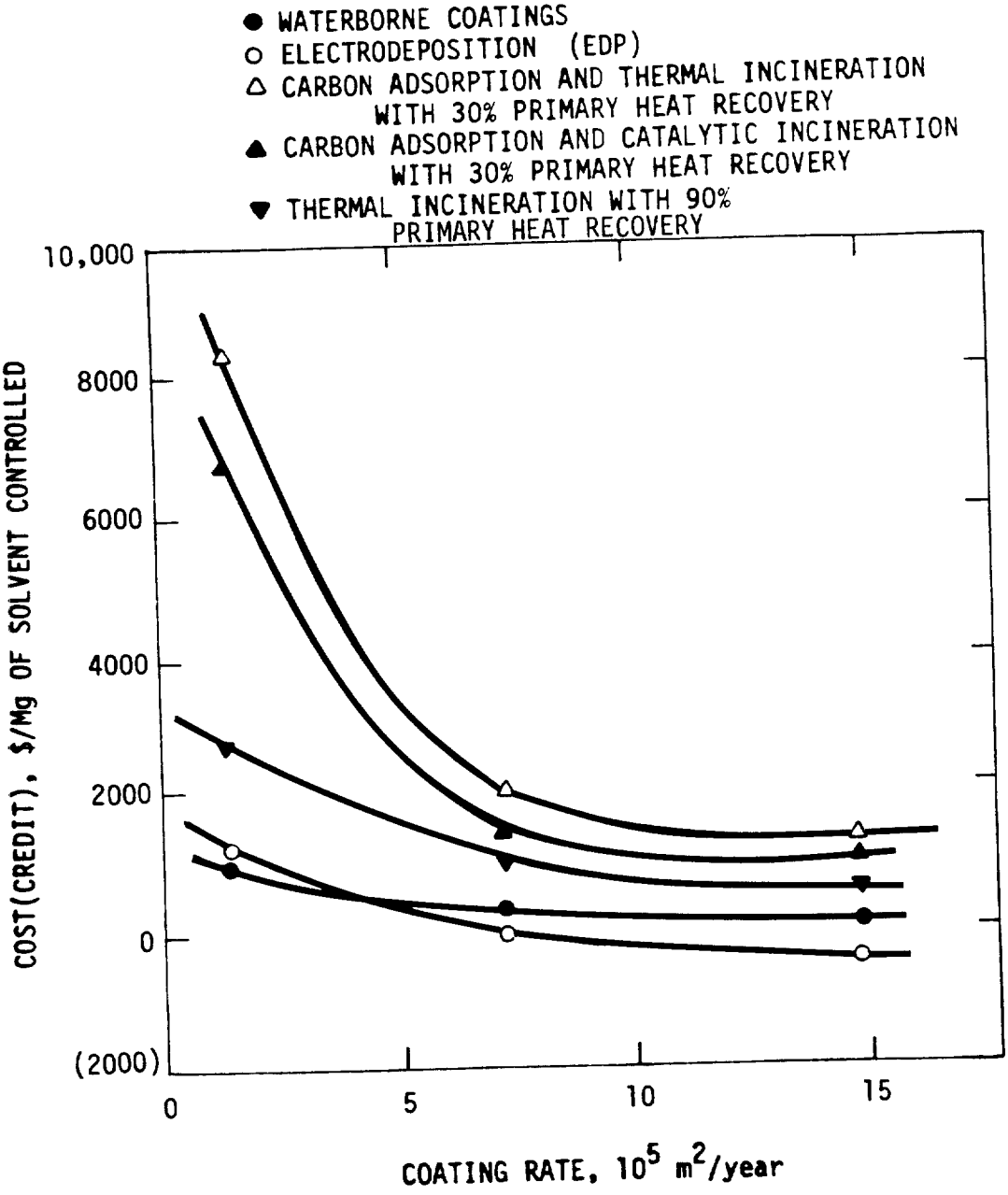

FIGURE 3-1. Cost-Effectiveness Comparison of Solvent Emission Control Options

Conveyorized Single-Coat Operation

Flow-Coat Application

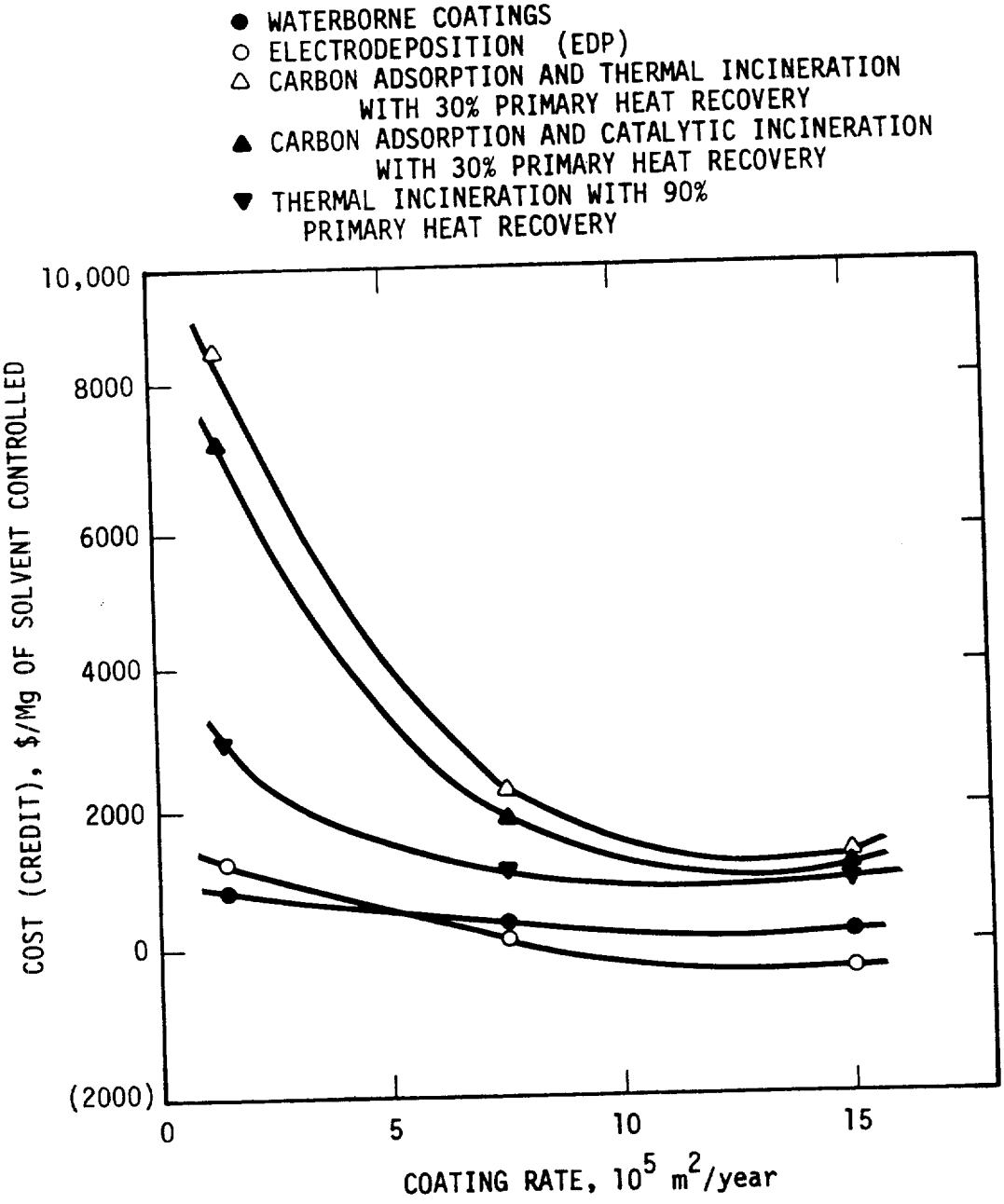

FIGURE 3-2. Cost-Effectiveness Comparison of Solvent Emission Control Options

Conveyorized Single-Coat Operation

Dip-Coat Application

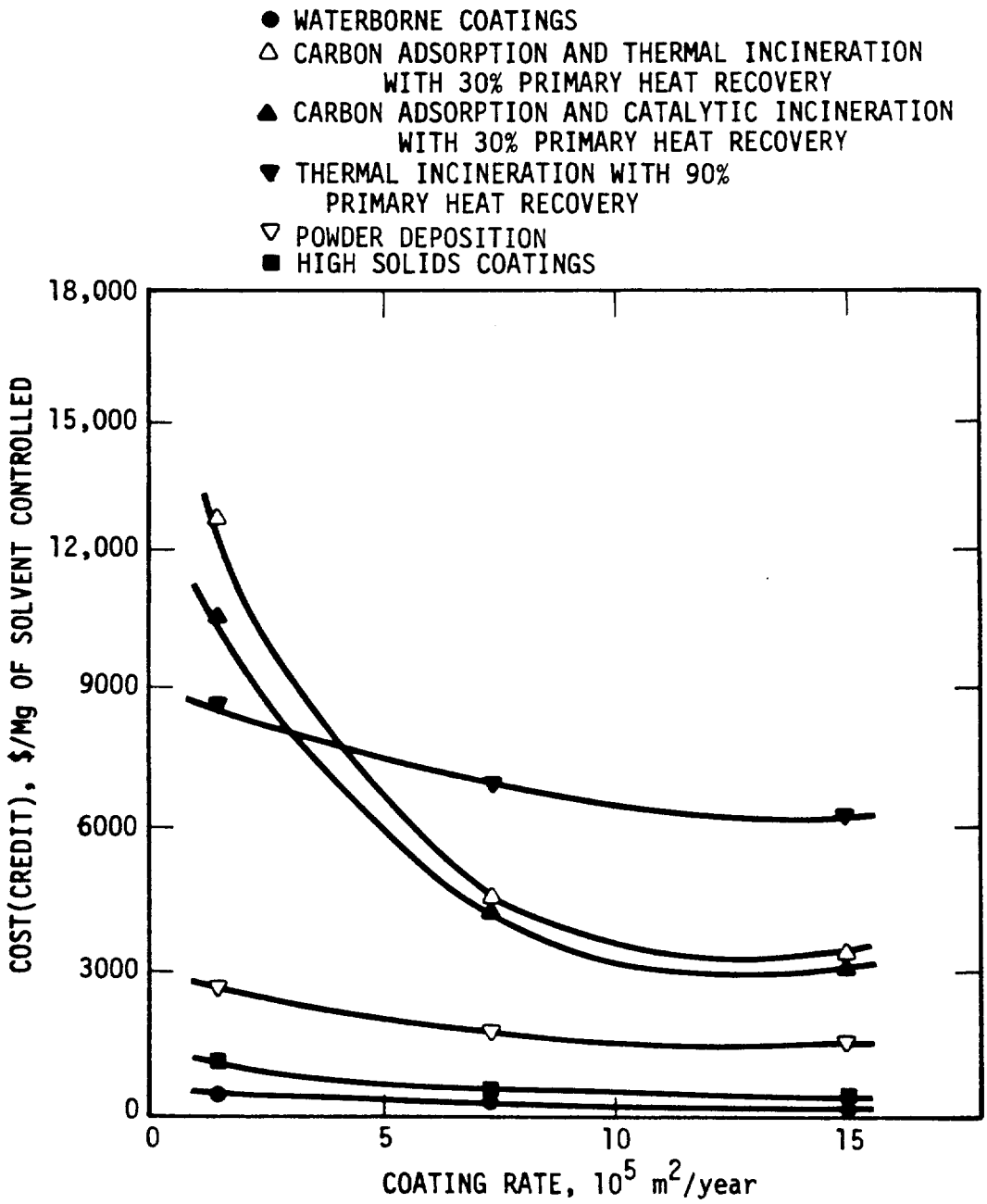

FIGURE 3-3. Cost-Effectiveness Comparison of Solvent Emission Control Options

Conveyorized Single-Coat Operation

Spray-Coat Application

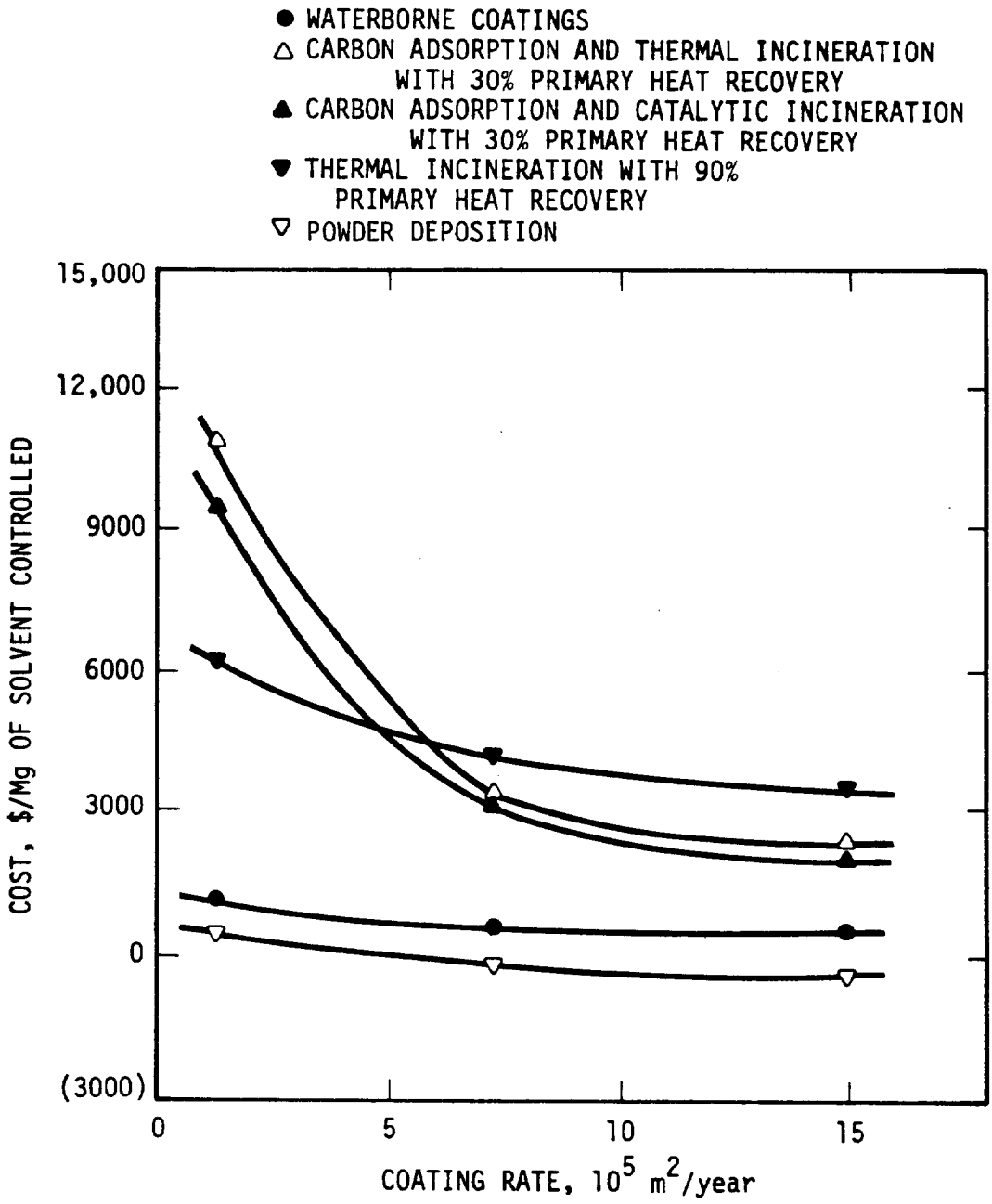

FIGURE 3-4. Cost-Effectiveness Comparison of Solvent Emission Control Options

Conveyorized Two-Coat Operation

Flow- and Spray-Coat Application

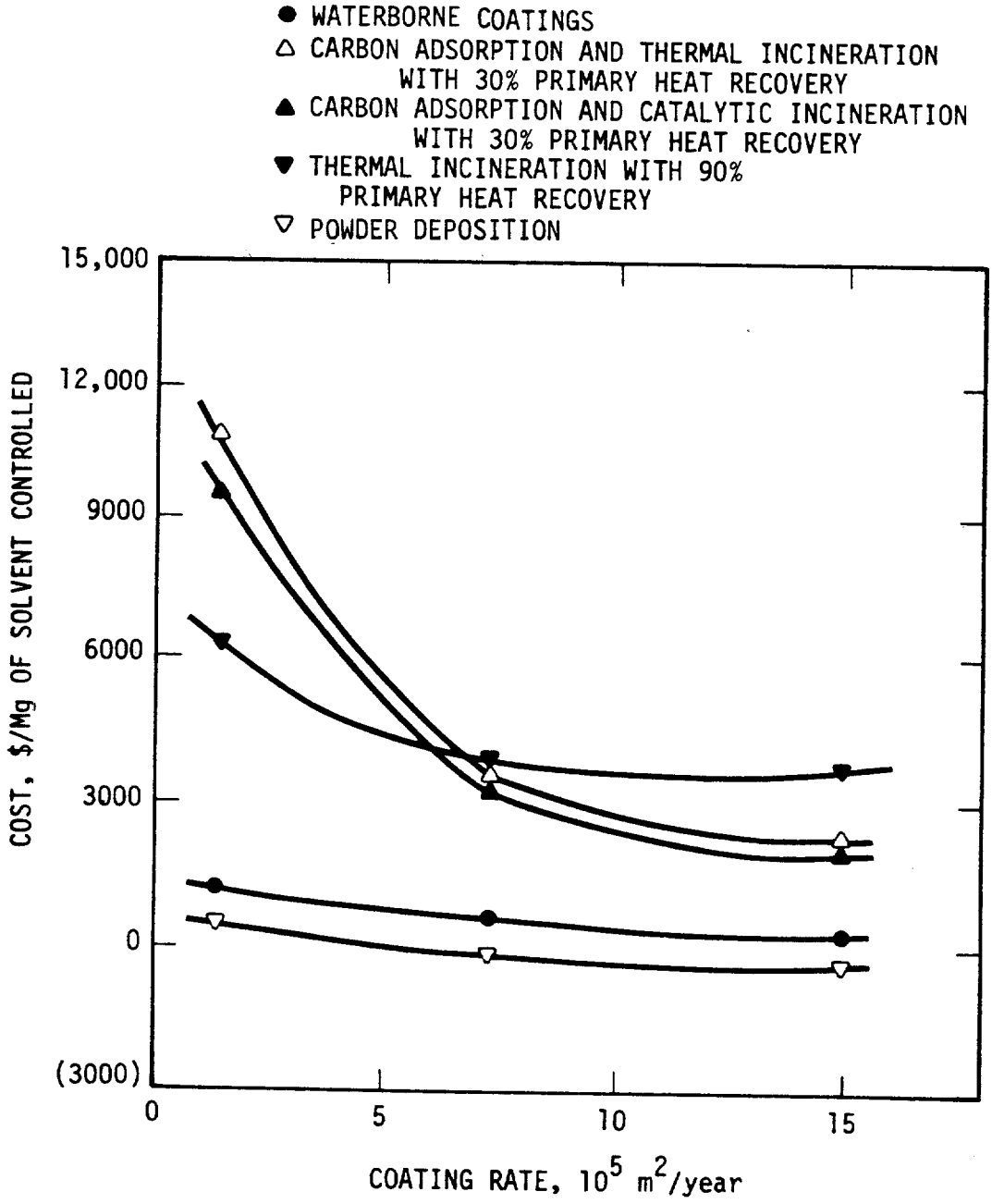

FIGURE 3-5. Cost-Effectiveness Comparison of Solvent Emission Control Options

Conveyorized Two-Coat Operation

Dip- and Spray-Coat Application

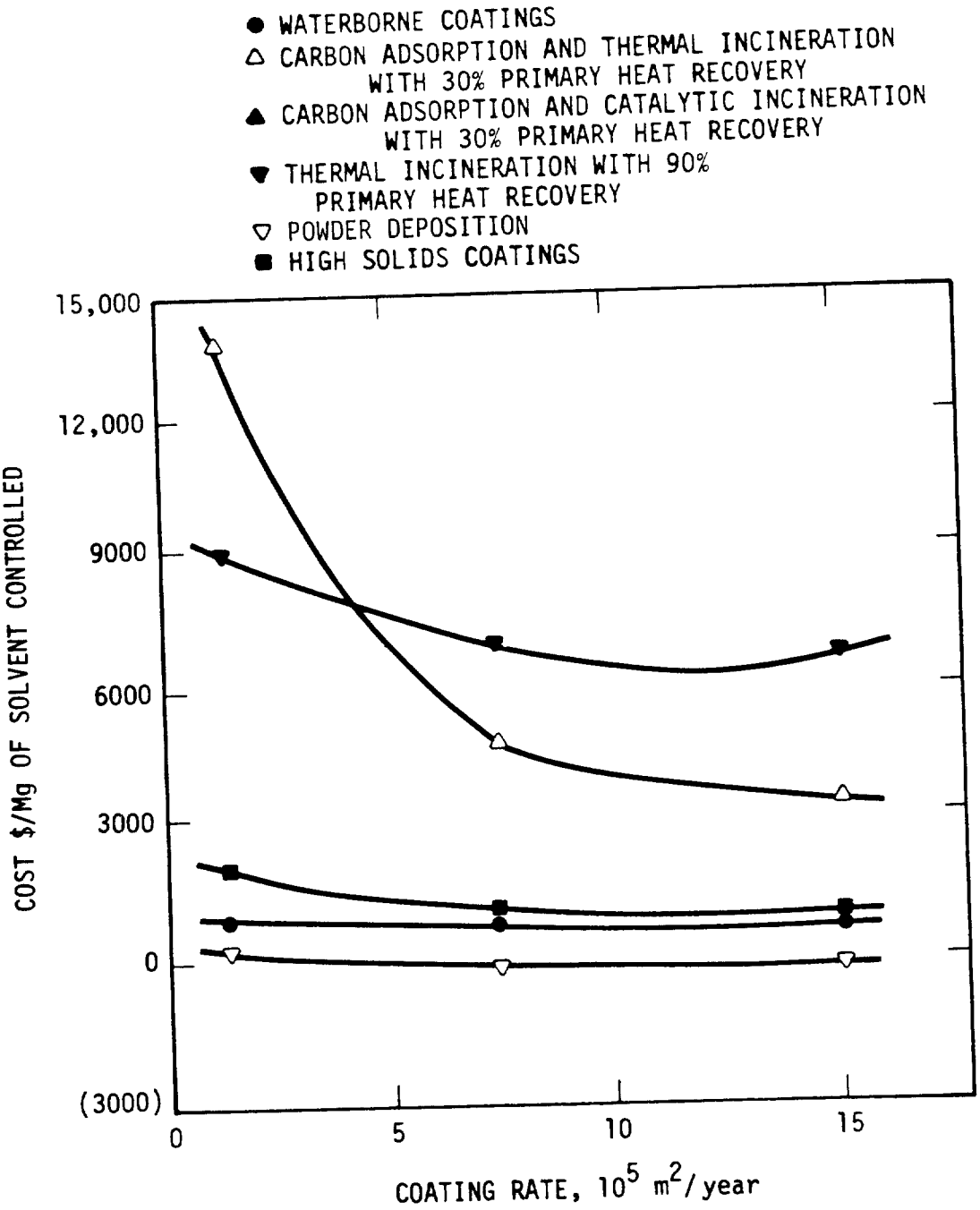

FIGURE 3-6. Cost-Effectiveness Comparison of Solvent Emission Control Options

Conveyorized Two-Coat Operation

Spray-Coat Application

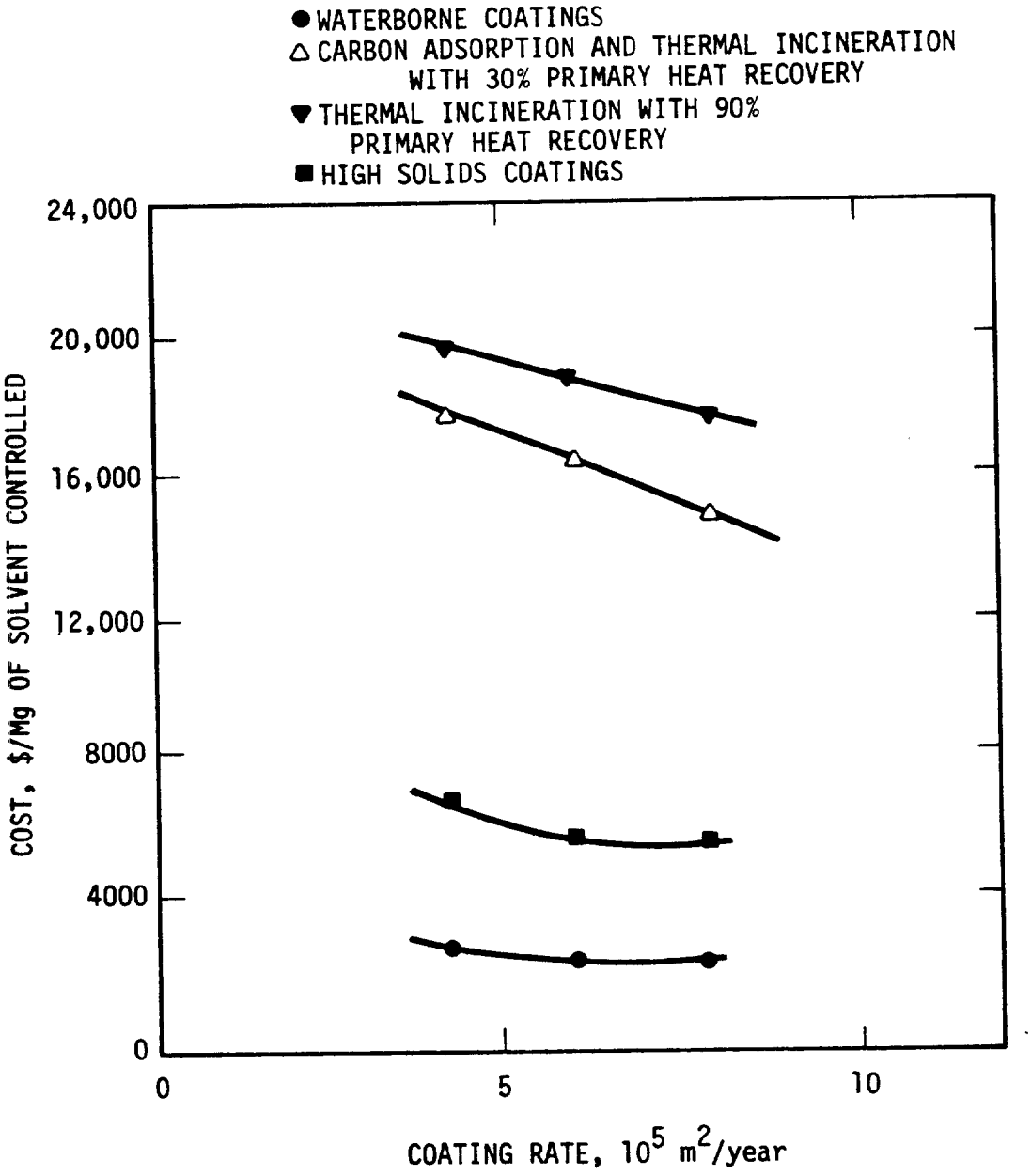

FIGURE 3-7. Cost-Effectiveness Comparison of Solvent Emission Control Options

Manual Two-Coat Operation

Conversion to a powder-coating process is the most cost-effective control option evaluated for conveyorized two-coat operations. Add-on control systems appear to be considerably more expensive than process modification options.

Conversion to waterborne coatings is the least costly option evaluated for manual two-coat operations. Again, add-on control systems cost much more than process changes.

In flow and dip coating in conveyorized single-coat operations, thermal incineration with 90 percent primary heat recovery* appears to be a more cost-effective add-on control than carbon adsorption with either thermal or catalytic incineration+ with 30 percent primary heat recovery. This system also appears to be the most cost-effective for small size lines only in all other operations (spray-coating in conveyorized single-coat operations and all coatings in conveyorized two-coat operations); however, it is the least cost-effective for medium size and large size lines. For these applications, carbon adsorption with thermal incineration at 30 percent primary heat recovery seems to be more cost-effective than carbon adsorption with catalytic incineration at 30 percent primary heat recovery.

The carbon adsorption system appears to be more cost-effective than thermal incineration, with 90 percent primary heat recovery on manual two-coat operations.

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* Thermal incineration with 90 percent primary heat recovery is applied on coating booth and drying oven.

+ Carbon adsorption on booth and thermal/catalytic incineration on drying oven.

3.4 SUMMARY

Cost analyses of the model lines indicate that modification of the coating process to a low-solvent coating usually appears to be more cost-effective for control of VOC than add-on control. However, because annualized costs for alternative coating systems are greatly affected by assumptions implicit in the calculation of coating costs, comparisons between alternative coating systems can exhibit significant case by case variations.

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Control of Volatile Organic Emissions from Existing Stationary Sources, Volume II: Surface Coating of Cans, Coils, Paper, Fabrics, Automobiles, and Light-Duty Trucks. EPA-450/2-77-008, Research Triangle Park, North Carolina. May 1977 (OAQPS No. 1.2-073).

Report of Fuel Requirements, Capital Cost and Operating Expense for Catalytic and Thermal Afterburners. CE Air Preheater, Industrial Gas Cleaning Institute, Stamford, Connecticut. EPA-450/3-76-031. September 1976.

Capital and Operating Costs of Selected Air Pollution Control Systems. GARD, Inc., Niles, Illinois. EPA Contract No. 68-02-2072. May 1976.

4.0 DETERMINATION OF APPLICABLE EMISSION LIMITATIONS

This chapter shows how an agency may use the logic diagram presented as Figure 4.1 to develop a standard appropriate for almost any coating process which applies surface coatings on a metal substrate.

The procedure for determining emission limits which represent the presumptive norm achievable by various processes. It requires some knowledge of the industry, the coating process and the requirements demanded of the coating. The procedure is to start at the top of Figure 4.1 and at each decision node (Indicated by a circle) choose the appropriate option. Until reaching a block that presents the level of control that is presumed to be achievable through the application of RACT by the manufacturer.

As an example, to find the recommended emission limit for a continuous operation that coats phosphate treated machine brackets with a black oven cured dipcoat at 0.7 mils film thickness, the procedure is as follows:

- Beginning at the top, proceed to node B.
- The item is not clear-coated, does not contain any heat sensitive materials and is baked in an oven when coated, so proceed to node C.
- The brackets are marketed in one color, so proceed to node D. Because powder coatings are not applicable in this case, the recommended emission limit for this process is 0.36 kg/liter (3.0 lbs/gal) minus water.

This would then be the level of control presumed to represent RACT for this process. It may be achieved through the use of either water-borne dip or electrodeposited water-borne coatings. Higher solids and powder coatings can also be used but may result in thicker films than

the 0.7 mil obtained from low solids coatings.

Current technology does not provide low-polluting coatings which can successfully replace conventional coatings for all the specialty items coated by the many industrial categories covered by these emission limits. Some low-polluting coatings are being used on production lines while others are in various stages of research. There will be, however, situtations where low-polluting coatings may never be applicable and even the use of add-on control technology may not be feasible either technically or economically.

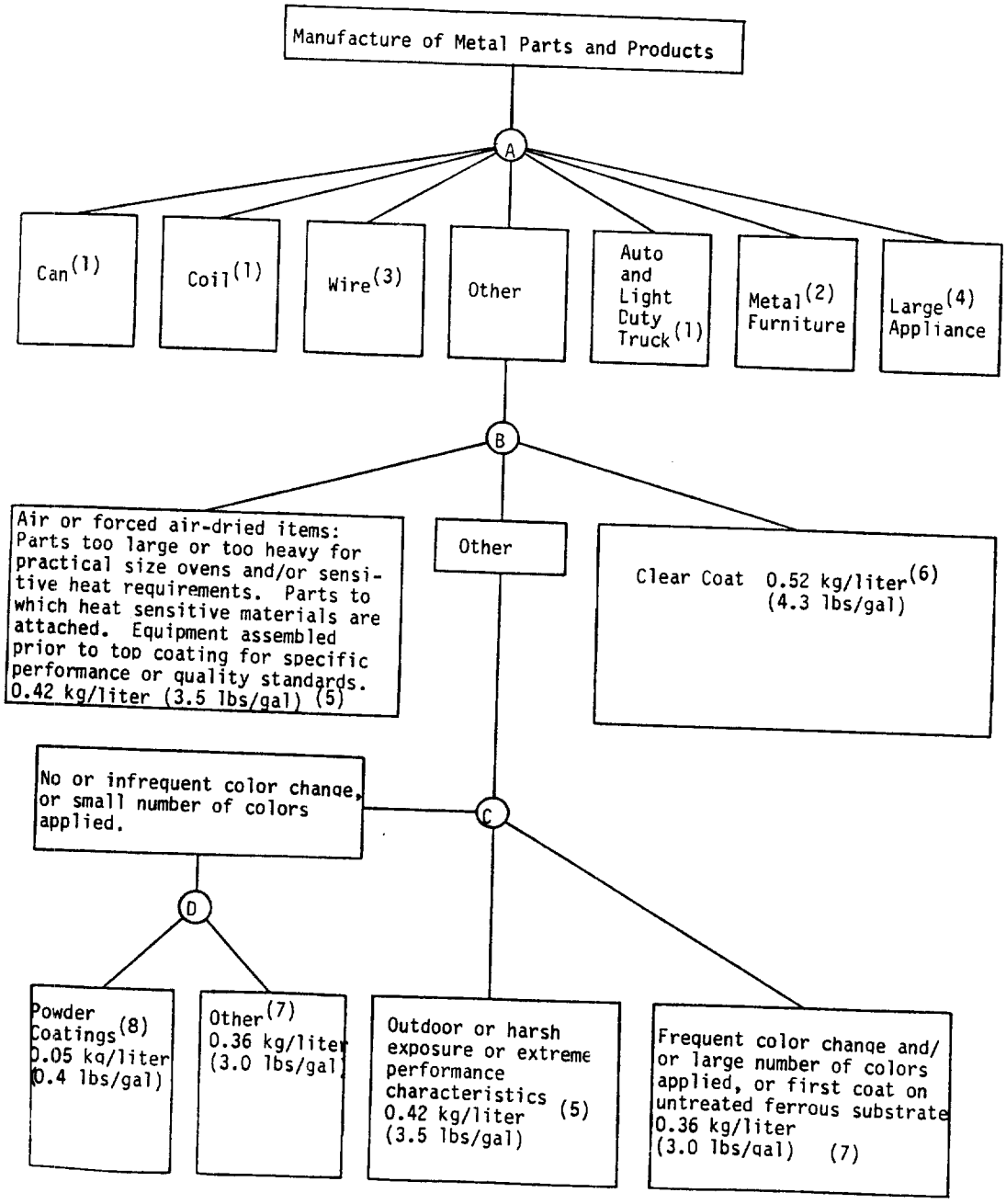

Figure 4.1 Logic diagram for derivation of emission limits for coating of miscellaneous metal parts and products.

4.1 REFERENCES

1. The recommended emission limitations for this category are given in "Control of Volatile Organic Emissions from Existing Stationary Sources - Volume II: Surface Coating of Cans, Coils, Paper, Fabric, Automobiles and Light Duty Trucks," EPA-450/2-77-008, May, 1977.

2. The recommended emission limitations for this category are given in "Control of Volatile Organic Emissions from Existing Stationary Sources - Volume III Surface Coating of Metal Furniture," EPA-450/2-77-032, December, 1977.

3. The recommended emission limitations for this category are given in "Control of Volatile Organic Emissions from Existing Stationary Sources - Volume IV: Surface Coating for Insulation of Magnet Wire," EPA-450/2-77-033, December, 1977.

4. The recommended emission limitations for this category are given in "Control of Volatile Organic Emissions from Existing Stationary Sources - Volume V: Surface Coating of Large Appliances," EPA-450/2-77-034, December, 1977.

5. This emission limit is achievable by use of about 52 volume percent solids organic solvent-borne coating. Units for this and other limitations are kilograms of solvent emitted per liter of coating applied (minus water).

6. This limit is achievable by use of a 41 volume percent solids organic solvent-borne or a water-borne equivalent coating.

7. This emission limit is acheivable by use of a 59 volume percent higher solids or a water-borne equivalent coating, or powder or electrodeposited water-borne coatings. DuPont Comments to the First Draft of Control of Volatile Organic Emissions from Existing Stationary Sources - Volume VI: Surface Coating of Miscellaneous Metal Parts and Products, Letter Dated April 20, 1978.

8. There are some products for which a coating thickness greater than 2 mils is required but other coating quality or performance requirements preclude the use of powder coatings. Comments from Deere and Company on the First Draft of Control of Volatile Organic Emissions from Existing Stationary Sources - Volume VI: Surface Coating of Miscellaneous Metal Parts and Products, Letter dated March 29, 1978.

5.0 ADVERSE AND BENEFICIAL EFFECTS OF APPLYING TECHNOLOGY

This chapter reviews the adverse and beneficial effects of each technique which reduces VOC emissions. This includes not only environmental aspects but also energy and cost. It also highlights any limitations of low organic solvent technology as compared to conventional high organic solvent coatings.

5.1 WATER-BORNE (SPRAY, DIP, OR FLOW COAT)

There are several advantages to converting to water-borne coatings.

- Conversion to water-borne coatings will likely be the first option considered by many facilities because of the possibility that these coatings can be applied with minimal modification of existing equipment.
- Converting to water-borne coatings provides a potential decrease in toxicity and flammability.
- Water-borne coatings may be thinned with water.
- Coating equipment can be cleaned or flushed with water rather than organic solvent. (If water-borne coatings are allowed to dry, however, they are then no longer soluble in water and must be cleaned with solvent.
- Use of water-borne coatings may allow a decrease in oven temperature.
- Use of water-borne coatings will permit some reduction in air flow since the amount of organics which must be evaporated in the oven is reduced.[1] (The permissible reduction may be limited, however, by high humidity within the oven which will result in condensation on the oven walls and possibly cause improper curing of the film.
- In some cases the dry-off oven may no longer be necessary.[2]

There are some potential disadvantages to water-borne coatings when compared with conventional organic-borne coatings.

- Spraying with water-borne coatings may require closer attention to detail than with organic-borne coatings because temperature, humidity, gun-to-metal-part distance, and flashoff time may affect the appearance and performance of the coating.

- On many large electrostatic spray lines, use of water-borne coatings may be impractical because of the difficulties involved in electrically insulating the entire system.

- Water-borne coatings applied by dip and flow coating application equipment will need to be monitored more closely due to their more sensitive chemistry.

- An additional rinse may be needed. Cleansing and pretreatment of the substrate are more critical because of possible coating contamination and pH changes within the dip or flow coating tank.[3]

- Some equipment may have to be replaced or adjusted (due to different surface tension of water than that of organic solvent) or protected from corrosion.[4] (In one converted flow coating operation, the only change was that the number of nozzles had to be doubled to obtain the same coverage as with conventional coatings.)[5]

- The coating bath, flashoff time, temperature, air circulation, and humidity may have to be controlled and frequently monitored, because changes in weather conditions may affect the application of water-borne coatings.[6]

5.2 ELECTRODEPOSITION

Several other advantages, in addition to reduced VOC emissions, accrue from converting to electrodeposition.

- The major one is improved quality control, a consequence of the fully automated process.

- It provides excellent and uniform coating coverage and corrosion protection because the paint particles are able to get into small recesses of parts.

- Fire hazards and potential toxicity are decreased in electrodeposition due to the minimal organic solvent content.

- If electrodeposition replaced a spray coating operation, the solid and liquid wastes associated with spraying operations will be reduced drastically.

- The lower organic content permits lower ventilation rates, resulting in reduced energy consumption.

There are some disadvantages to the electrodeposition process.

- Electrodeposition may increase electrical consumption. The amount will depend on the original application system, the size of the electrodeposition bath, and the thickness of the coating applied. Electrical energy is required for the coating system, the refrigeration to overcome the temperature rise from the electrical process, for good paint circulation in the bath, and to operate the ultrafilter. Electrodeposition may consume three times as much energy in the application area as water-borne flow or dip coating operations.[7] It does not, however, appear as energy inefficient when compared to a spraying operation because the high air volumes are no longer required. Energy consumption will also be less in the baking process. The air flow in the oven may be reduced and the flashoff tunnel may be omitted.

- A poor electrical connection will result in a poor coating (for example, if the hooks which hold the metal parts are not properly cleaned or hung and inadvertently provide an electrical insulation, the quality of the coating will suffer.)

- The coverage is so uniform that electrodeposited coatings will not hide imperfections in the substrate.

- Conversion to electrodeposition will require a change of equipment at significant capital cost and can be relatively expensive on small scale production lines.

5.3 HIGHER SOLIDS COATINGS

One of the greatest advantages of converting to higher solids coatings as a means of reducing emissions of VOC is that they may be applied with little change to existing equipment. Some application equipment (i.e., spray guns) may have to be replaced or a paint heater may have to be installed to reduce the viscosity of the higher solids coatings but these are relatively inexpensive changes. Conversion to high solids coatings can reduce a plant's energy consumption. Air flow in the spray booth can be decreased because less organic solvent must be evaporated from a high solids coating when applying the same volume of coating. Since the energy required by the oven is largely dependent on the air flow (and it, in turn, is heavily influenced by the organic concentration limitations imposed for safety reasons)[8], the use of higher solids coatings will reduce energy requirements. Solid and liquid wastes may also decrease since less coating is applied per dry mil. However, the tackiness of high solid coatings may make cleanup more difficult.[9]

Some two-component high solids coatings may contain isocyanate compounds which are potentially toxic and must be handled and applied with caution. These also require installation of special application equipment.

5.4 POWDER COATINGS

There are several advantages obtained after a facility is converted to powder coatings.

- VOC emissions are almost completely eliminated.
- There are no solid or liquid wastes to be disposed of as compared to solvent-borne coatings.
- Powder does not require the purchase, or use of solvents to control the viscosity of the coating or to clean the equipment.
- Powders can mask imperfections and weld marks.
- Conversion to powder coatings may reduce the energy requirements in a spray booth because the large volumes of fresh air required for application of solvent-borne coatings may not be required. Energy requirements for the ovens may also be reduced because little organics are being evaporated requiring less dilution. (It has been estimated that a 35-70 percent overall reduction in energy requirements will result when a conventional single coat spray application is replaced with powder and 55-70 percent reduction will occur for a two-coat spray application.)[10]
- The exhaust air from the spray booth can be filtered and returned to the working area.
- Up to 98 percent transfer efficiency of powder coatings can be realized since the overspray can be reclaimed. Not all overspray is always reusable, however, because a buildup of powder fines may have to be discarded, and the larger and heavier granules may have to be reprocessed again before they are suitable for reuse.[11]

There are several disadvantages to converting to the use of powder coatings.

- The conversion is non-reversible since all application equipment, spray booths, and associated equipment (and often ovens) used for liquid systems must be replaced. This will then limit the flexibility of the facility to apply other coatings.

- Coating film thicknesses of less than 0.9 mils have not been successfully obtained with powders on a production line basis.
- Metallic powder coatings are not as esthetically pleasing as conventional metallics.
- Color matching of a powder coating is difficult because its color cannot be changed by the applicator. Solvent borne coatings can be.
- Powder films have appearance limitations for some applications.
- Uncured powder coatings must be kept dry since their subsequent performance can be affected.
- Powder coatings are subject to explosions (as are many particulate dusts).[12]
- Color changes for powder require about half an hour downtime if powder is recovered for reuse. This may greatly curtail production capacities. Color changes may be shortened if powders are not reclaimed in their respective colors, but this results in a coating usage efficiency of only 50 to 60 percent.

5.5 CARBON ADSORPTION

Although the technology is well documented and considered technically feasible, there are not miscellaneous metal part or product facilities known to be using carbon adsorption systems to reduce organic emissions from coating application of flashoff areas. The energy required to operate a carbon adsorption system is a potential disadvantage. The actual quantity will depend on the size of adsorber(s) and the concentration of the solvents entering the carbon bed. Any reduction which can be made in the amount of air flow from the coating application and flashoff areas will permit purchase of a smaller adsorber with an attendant reduction in energy requirements.

The amount of solid and liquid waste generated by the use of a carbon adsorber will depend on the type of coating application system. For example, emissions from flow and dip coating operations do not require filtration or scrubbing. Emissions from spray booths, however, may require pretreatment by filtration or scrubbing since the overspray may foul the adsorber bed. Water miscible solvents may produce a water pollution problem if the adsorber is regenerated with steam. This, however, can be avoided by incinerating the regeneration stream, by stripping the organics from the condensate or using nitrogen gas as a stripping medium. Each will increase the cost and energy consumption of a carbon adsorption unit. Since there is little possibility that the recovered solvents may be reused in the miscellaneous metal part and product industries, any recovery or solvents would be for fuel value only.

An important factor when considering installation of a carbon adsorption system is plant space. Large facilities may require many dual-bed carbon adsorption units in parallel which will need a relatively large area within the plant.

5.6 INCINERATION

The most common and widely applicable technique for the reduction of organic emissions is incineration. Incinerators (or afterburners) have been used for many years for reducing organic emissions. One disadvantage is the quantity of additional fuel required unless heat recovery is used. The use of primary heat recovery to preheat the inlet gas stream to near incineration temperature will minimize and can even eliminate fuel requirements. If secondary heat recovery can be used for other energy-using processes, fuel requirements can be reduced even further. If there are enough areas where secondary heat may be utilized, an incineration system

may even reduce the plant's overall fuel consumption. Table 5-1 shows the potential decreases in energy usage when using incinerators followed by tube and shell heat exchangers with heat recovery efficiencies of 38 percent to 55 percent. Some examples where secondary heat from the incinerator exhaust may be used are: oven makeup air, boiler, cleaning processes, dryoff ovens, and plant room heating. Greater primary heat recovery efficiencies (80 to 95 percent) are shown in Table 5-2 using other types of heat exchangers such as ceramic wheel stone packed beds. These are reportedly very attractive even for low organic concentration streams because of their low fuel requirements.

TABLE 5-1

BURNER REQUIREMENTS FOR INCINERATORS

IN 10^6 BTU/HR[a,b,13]

NON-CATALYTIC INCINERATORS	5 percent LEL	15 percent LEL
No Heat Recovery		
5000 scfm	5.82	4.05
15,000 scfm	17.48	12.16
30,000 scfm	34.95	24.31
38% Efficient Primary Heat Recovery		
5000 scfm	3.32	1.56
15,000 scfm	10.09	4.73
30,000 scfm	19.97	9.38
Primary and 55% Efficient Secondary Heat Recovery		
5000 scfm	1.42	-0.34
15,000 scfm	4.40	-0.66
30,000 scfm	8.67	-1.82
CATALYTIC INCINERATORS		
No Heat Recovery		
5000 scfm	1.69	1.69
15,000 scfm	5.07	5.07
30,000 scfm	10.14	10.14
38% Efficient Primary Heat Recovery		
5000 scfm	0.79	0.26
15,000 scfm	2.38	0.77
30,000 scfm	4.76	1.54
Primary and 55% Efficient Secondary Heat Recovery		
5000 scfm	-0.21	-1.07
15,000 scfm	-0.62	-3.22
30,000 scfm	-1.24	-6.46

a) Based on 300°F oven outlet temperature; 1400°F outlet temperature for non-catalytic and 600°F inlet temperature for catalytic incinerators.

b) (-) indicates net overall fuel savings.

c) These heat recovery efficiencies are based on sensible heat.

TABLE 5-2

BURNER REQUIREMENTS FOR NONCATALYTIC INCINERATORS
WITH STONE PACKED BED HEAT EXCHANGERS
in 10^6 BTU/HR[a,b,c,14]

85% EFFICIENCY PRIMARY HEAT RECOVERY	5 percent LEL	15 percent LEL
5,000 scfm	0.29	- 0.91
15,000 scfm	0.87	- 2.73
30,000 scfm	1.75	- 5.45

90% EFFICIENCY PRIMARY HEAT RECOVERY	5 percent LEL	15 percent LEL
5,000 scfm	- 0.01	- 1.21
15,000 scfm	- 0.02	- 3.62
30,000 scfm	- 0.04	- 7.24

a) These heat recovery efficiencies include sensible heat and the heat of combustion of the VOC.

b) Energy value of VOC used is 1.2 MM/BTU/HR per 10,000 scfm.

c) (-) indicates overall fuel savings

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6.0 MONITORING TECHNIQUES AND ENFORCEMENT ASPECTS

This chapter discusses the recommended emission limits, the monitoring techniques and enforcement aspects for both coatings which are low in organic solvents and add-on control equipment.

Limitations in VOC may be expressed in terms of mass or volume and may be based on the entire coating (including organic solvent) or only on paint solids. In this guideline, limitations are expressed as the allowable mass of organic solvent per unit volume of coating (kgs per liter of coating or lbs per gallon of coating - minus water) as it is delivered to the coating applicator. The water content of the coating is not included in the ratio. The principal advantage of this format is that enforcement is relatively simple. Field personnel can draw samples and have them analyzed quickly. A disadvantage is that the relationship between the solvent fraction and organic emissions is not linear. If the organic solvent content is expressed in terms of mass of organic solvent per unit volume of paint solids (kgs per liter or lbs per gallon of solids), the disparity disappears. This relationship is linear and more readily understood, e.g., a coating containing 2 lbs of organic solvent per gallon of solids releases twice as much organic solvent as one with one pound per gallon. The disadvantage of this format, however, is that the analytical methods are more complex. Appendix A of Volume II of this series, "Control of Volatile Organic Emissions from Existing Stationary Sources - Volume II: Surface Coating of Cans, Coils, Paper, Fabrics, Automobiles, and Light-Duty Trucks," presents ASTM test methods that permit determination of the organic solvent per gallon of coating (minus water).

For miscellaneous metal part and product coating facilities, it is recommended that, if possible, emission limitations should be expressed in terms of the organic solvent content of the coating since these values can be determined with relatively simple analytical techniques. Alternative compliance procedures should permit operators to use add-on control equipment if they so choose. (Sample calculations to verify compliance with this type of emission limit are shown in Appendix A of this document.)

Other options such as mass or volume of organic solvent per mass of coating are generally less desirable although they may be entirely appropriate for a given industry. Basing limitations on the mass of coating or paint solids is not generally recommended because the specific gravity of a coating solids tends to vary widely with the degree and type of pigment employed. Highly pigmented paints have much greater density than unpigmented clear coats or varnishes.

The recommended limitations assume the miscellaneous metal part and product facilities merely convert an organic-borne coating to a coating low in organic solvent. They do not consider the reduction in VOC emissions which would result from a decrease in film thickness or an increase in the transfer efficiency of a coating. For example, assume a facility applying conventional coating at 1.2 mils film thickness, converts to a coating which, although it contains less organic solvent, does not quite meet the recommended emission limit. If the new coating is serviceable when applied in a thinner coat, it may result in a reduction in VOC emissions comparable to or even greater than a coating which meets the recommended emission limit.

Another example would be the emission reductions that accrue from improved coating techniques. A facility that converts from a conventional manual spray application (at a transfer efficiency of 40-70 percent) to an

automated electrostatic spray system (at a transfer efficiency of 70-90 percent), or from any spray system to a flow or dip coat system (at a transfer efficiency of at least 90 percent) would realize a significant reduction in VOC emissions. All of these possibilities should be considered in any evaluation of the overall reduction achieved by the operator.

In those few facilities where add-on control equipment is a more likely option, it may be more appropriate to state emission limits in terms of control efficiency across the incinerator, adsorber, etc. Otherwise, where limitations are expressed only in terms of the solvent content of the coating, it would be necessary to determine the mass emission rate from the control system and relate it to the quantity of coating applied during the test period. This is a more complicated procedure since it may not be easy to determine the amount of coating consumed during the test period and an analysis by mass of the organic solvent directed to the control device would be even more difficult. Chapter 5 of "Control of Volatile Organic Emissions from Existing Stationary Sources - Volume I: Control Methods for Surface Coating Operations" presents approaches which may be used. When add-on type devices are selected as the compliance method, the air pollution control agency should require that the coating lines be equipped with an approved capture device to assure effective containment. The capture system will likely have to be custom designed to accommodate the individual plant variables which affect performance. When reviewing the design of such a system, however, the air pollution control official must also consider requirements imposed by the Occupational Safety and Health Administration and the National Fire Prevention Association.

It is recognized that some coatings will emit more VOC than merely its solvent content. This incremental VOC may come from three possible sources.

The first is the possibility that some of the monomer may evaporate. Also, if the film forms by condensation polymerization, the evolution of by-products may be a compounding factor. Finally, it has been reported that the industry is using increasing quantities of "blocking agents" which are released from the polymer matrix during the curing process.

There are now no approved analytical methods certified by the agency for determining the quantity of VOC emitted by such reactions although certainly the organic mass emission rate could be determined by expensive and sophisticated analytical techniques. The more practical means of quantifying the contribution of the polymerization reaction to the overall emission problem would be by contacting the manufacturer of the coating. Certainly, his knowledge of the fundamental chemical mechanisms involved would allow calculation of an emission rate based on the chemical reaction.

This emission will occur during the cure (if at all) which is usually temperature initiated by the oven. If the oven is controlled by an incinerator, then verification of the efficiency of the device should be sufficient to assure compliance with the coating regulations.

APPENDIX A

SAMPLE CALCULATIONS OF CONTROL OPTIONS

This appendix will aid the local agency in determining if a coating proposed for use by a miscellaneous metal part or product facility will meet a recommended emission limit. It also explains how to compare the actual VOC emissions from a facility regardless of the type of low-polluting coating or add-on control device used.

The purpose of all coating operations is to cover a substrate with a film that provides both corrosion resistance to the substrate and esthetic appeal. Therefore, the rational basis for specifying an allowable VOC emission limit would be in units of coating volume (e.g., grams of VOC per square meter (lbs/sq. ft) per unit thickness of film). However, the complexity of any analytical method which would provide a measurement of the volume of a cured coating precludes this approach. As a compromise, the limitations were developed in terms of mass of VOC per unit volume of uncured solids and organic solvent. Mathematically, then, the emission factor (ef) for a coating would be expressed as:

$$(1)\quad ef = \frac{(\text{volume fraction organic solvent})(\text{average organic solvent density})}{\text{volume fraction of solids} + \text{volume fraction of organic solvent}}$$

$$\text{or}\quad (2)\quad ef = \frac{(\text{volume fraction organic solvent})(\text{average organic solvent density})}{1 - \text{volume fraction of water}}$$

The following examples show the use of these equations to determine the emission factor for both organic solvent-borne and water-borne coatings. We will assume the applicable emission limitation is 0.34 kg/liter. This represents a low solvent coating with 0.62 v/v solids content.

CASE 1: Determine the emission factor for an organic solvent-borne coating which contains 35 volume percent organic solvent.

Therefore: $ef = \frac{(.35)(0.88\ kg/liter^*)}{1 - 0}$

$= 0.31$ kgs/liter (2.6 lbs/gal)

Since the emission factor is less than the recommended limit of 0.34 kg/liter (2.8 lbs/gal), this coating is in compliance.

CASE 2: Determine the emission factor for a water-borne coating containing 25 volume percent solids. Of the 75 percent solvent, 80 volume percent is water and 20 percent is organic solvent.

Since 80 percent of the solvent is water, the respective volumes of water and organic solvent may be calculated as shown:

Volume water = .80 x .75 liter = .6 liter

Volume organic solvent = 0.75 liter - .6 liter = .15 liter

Therefore: $ef = \frac{(0.15)(0.88\ kg/liter)^*}{1 - 0.6}$

$= 0.32$ kg/liter (2.64 lbs/gal)

This coating also has an emission factor less than the recommended limit and would comply.

The level of control represented by 0.34 kg/liter of coating (2.8 lbs/gal) less water can also be achieved with a conventional high organic solvent coating if suitable add-on control equipment is installed. However, this method of determining the equivalent emission limit factor is not as straightforward as the previous two cases and must also consider the volume of solids in the coating.

CASE 3: Determine the emission factor for a conventional organic-borne coating containing 75 volume percent organic solvent.

*This density is considered typical and is equal to 7.36 lbs/gal.

Therefore: $ef = \frac{(.75)(.88\ kg/liter)}{1 - 0}$

$= 0.66$ kg/liter (5.5 lbs/gal)

However, this liter of coating contains only 0.25 liter of solids whereas the low-solvent coating which the recommended emission limit of 0.34 kg/liter (2.8 gal) represented would contain 0.62 liter of solids.

(The fraction of solids in the low solvent coating can be back calculated from the recommended emission limit in the following manner.)

i.e., $0.34 = \frac{(x)(0.88\ kg/liter)}{1 - 0}$

$x = 0.38$, volume percent organic solvent

Therefore, fraction of solids = $1 - x = 0.62$.

On a unit volume of solids basis, the conventional coating contains:

$$\frac{0.66\ kg\ organic\ solvent}{0.25\ liter\ solids} = \frac{2.64\ kg\ organic\ solvent}{liter\ solids}\ or\ \frac{22\ lbs\ VOC}{gal\ solids}$$

And the recommended limit reference coating contains only:

$$\frac{0.34\ kg\ organic\ solvent}{0.62\ liter\ solids} = \frac{0.55\ kg\ organic\ solvent}{liter\ solids}\ or\ \frac{4.6\ lbs\ VOC}{gal\ solids}$$

Consequently, in order for a facility to use the conventional coating yet emit no more VOC than the reference coating, the add-on control device must capture and destroy (or collect) 2.09 kg of solvent per liter of solids applied (2.64 - 0.55). This will require a control system that is at least 79 percent efficient. Since the add-on control devices can often operate at 90 percent efficiency or greater, the agency must insure that at least 88 percent of the VOC emitted by the coating is captured and delivered to the add-on control device. Since it will often not be practical to attempt the complex analytical program essential to develop a material

balance around the coating application and flashoff areas and ovens, the agency may certify an acceptable capture system based on good engineering practice.[1]

APPENDIX A REFERENCE

1. Young, Dexter E., Environmental Protection Agency, memorandum concerning requirements for ventilation of spray booths and ovens. Dated March 10, 1977.

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16. ABSTRACT

This document provides the necessary guidance for development of regulations to limit emissions of volatile organic compounds (VOC) from the coating operations of miscellaneous metal parts and products. This guidance includes emission limits which represent Reasonably Available Control Technology (RACT) for the miscellaneous metal part and product industries, describes the industries, shows the methods by which VOC emissions can be reduced in these industries and describes the monitoring and enforcement aspects.

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