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Alternative Control Techniques Document: Surface Coating of Automotive/Transportation and Business Machine Plastic Parts

ACT

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Emissions Standards Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Radiation
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1.0 INTRODUCTION

1.1 BACKGROUND

The purpose of this document is to provide information on alternative control techniques (ACT) for volatile organic compound (VOC) emissions from the surface coating of plastic parts for automotive/transportation and business machine/electronic products.

This document contains information on emissions, controls, control options, and costs that States can use in developing rules based on reasonably available control technology (RACT). The document presents options only, and does not contain a recommendation on RACT.

2.0 PROCESS DESCRIPTION

This chapter presents an overview of the plastic parts surface coating industry (Section 2.1) and a description of plastic parts substrates (Section 2.2). Section 2.3 describes the coating process. Coating selection is discussed in Section 2.4. Section 2.5 contains a summary of current emissions regulations.

2.1 INDUSTRY OVERVIEW

Plastic parts are coated to provide color, texture, and protection; improve appearance and durability; attenuate electromagnetic interference/radio frequency interference (EMI/RFI signals); and conceal mold lines and flaws. The plastic parts surface coating industry is complex, but it can be categorized into three general sectors: (1) automotive/ transportation, (2) business machines, and (3) miscellaneous. The automotive/transportation sector includes the interior and exterior plastic components of automobiles, trucks, tractors, lawnmowers, and other mobile equipment. The business machines sector includes plastic housings for electronic office equipment such as computers, copy machines, and typewriters, and for medical and musical equipment. The miscellaneous sector includes the plastic components of such items as toys, sporting goods, outdoor signs, and architectural structures (e.g., doors, floors, and window frames). The plastic parts used in all these sectors have similar coating types and are typically made of the same group of substrates.

Plastic parts surface coating facilities are typically one of the following:

- An in-house process located at the end-product manufacturing site (e.g., business machine manufacturing plant, automobile plant, etc.);
- A contractor that specializes in plastic parts molding and coating; or
- A job shop that only does coating.

Regardless of who actually performs the coating step, the characteristics of the finish (i.e., color, gloss, adhesion, and chemical resistance) are usually specified by the part's end-user.

The types of coatings currently in use include conventional solvent-based coatings, higher-solids coatings, and waterborne coatings, all of which emit VOC's to the atmosphere during the coating and curing processes.

2.2 CHARACTERISTICS OF PLASTIC PARTS

The properties of the different plastics determine the types of coatings that can be used on them. Some plastics are damaged by the organic solvents in some solvent-based or waterborne coatings. Another important property of plastics is their tendency to deform at the temperatures often used to cure coatings on metal parts (see Tables 2-1 and 2-2 for maximum temperatures for particular substrates). Plastics have lower surface tensions than metals and, therefore, it is more difficult to wet them and obtain adhesion. Adhesion characteristics of plastics can differ from plastic to plastic and even between grades of plastic.[1]

Plastic parts are formed from a resin by applying pressure or heat or both. The two main categories of resins used to produce plastic parts are thermoplastic resins and thermoset resins. Thermoplastic resins become soft or molten when heated; however, they do not undergo basic structural alterations, so they can be reground and reused. Thermoset resins "set" or become fixed in shape when first heated and assume irreversible properties.

TABLE 2-1. GENERAL PROPERTIES AND USES OF THERMOPLASTIC RESINS

Resin or composite	Maximum bake temp. (°F)	Application[a,b,c] Automotive	Application[a,b,c] Business/miscellaneous	Solvent resistance[a]	Strength[a]	Adhesion[a]	Comments[b,c]
Acetal	185 to 220[b]	INTERIOR: Seat belt components, Handles and cranks EXTERIOR: Electrical switches, Body hardware, Gears	Valves, Fans				-resistant to a wide variety of solvents -pigmented grades can match any translucent color
Acrylic	180[a]	INTERIOR: Instrument covers, Pillar posts, Dials EXTERIOR: Tail lights, Side markers, Escutcheons, Name plates, Trim parts	Outdoor signs, Appliance panels and knobs	Good	Good	Easy	-available in wide range of transparent and translucent colors because the resin is very compatible with dyes and pigments -acrylics should not be used with chlorinated and aromatic hydrocarbons, esters, and ketones -excellent weather resistance and reflex optics
Cellulosics	220[a]	INTERIOR: Decorative signs	Handles	Good	Good	Difficult	
Ketone-based resins	289 to 347	Bearing races, Friction bearings, Piston components	Housings, Handles				-resistant to high temperatures
Nylon	300[a]	EXTERIOR: Windshield wiper gears, Light and mirror housings, Wheel covers, Door and window hardware, Misc. painted body parts	Power tool housings and handles	Good	Good	Easy	-very paintable -heat resistant
Polyarylate		EXTERIOR: Trim parts, Light and mirror housings, Reflectors					-heat resistant -good weatherability -capability for high-gloss surface metalization of parts

TABLE 2-1. GENERAL PROPERTIES AND USES OF THERMOPLASTIC RESINS (Continued)

Resin or composite	Maximum bake temp. (°F)	Application[a,b,c] Automotive	Application[a,b,c] Business/miscellaneous	Solvent resistance[a]	Strength[a]	Adhesion[a]	Comments[b,c]
Polybutylene Terephthalate	284[b]	EXTERIOR: Bumpers, Door and window hardware, Grille opening panels, Distributor caps, Connectors, Conveyor belt segments	Appliance housings	Good[b]			-resistant to automotive fluids -temperature resistance -good resistance to most chemical solutions -at room temperature PBT is unaffected by water, weak acids and weak bases, common organic solvents, greases and oils, and cleaning solutions -addition of other polymers like polycarbonates can improve the surface appearance
Polycarbonate	250[a]	INTERIOR: Instrument panels. EXTERIOR: Windows, Bumpers, Tail and side marker lights, Headlamps and supports, Body panels, Wheelcovers	Housings	Poor	Excellent	Easy	-solvent sensitive
Polycarbonate and Polybutylene Terephthalate (PBT) blend (Xenoy)	200 to 240[a]	EXTERIOR: Bumpers		Fair	Excellent	Fairly easy	
Polyimide		Wiring, Insulation					-highly heat resistant -good electrical properties -used as a coating component -resistant to most commonly organic solvents

TABLE 2-1. GENERAL PROPERTIES AND USES OF THERMOPLASTIC RESINS (Continued)

Resin or composite	Maximum bake temp. (°F)	Application[a,b,c] Automotive	Application[a,b,c] Business/miscellaneous	Solvent resistance[a]	Strength[a]	Adhesion[a]	Comments[b,c]
Polyolefins (blends of polypropylene, polyethylene and its copolymers)	175 to 250[a]	EXTERIOR: Grilles, Rub strips, Air dams, Bumpers, Tanks	Packaging material	Good	Fair/good	Moderately difficult	-requires adhesion promotor -easy to process
Polyethylene	250[a]	INTERIOR: Luggage racks EXTERIOR: Windshield wipers, Motor housing, Blade support					-fillers and reinforcements applied -heat resistant
Polypropylene	250[a]	INTERIOR: Misc. trim, Panels EXTERIOR: Fascia, Hood and dash lining					
Polyphenylene Oxide (PPO) (Modified)	180[a]	INTERIOR: Instrument panels, Seat backs EXTERIOR: Wheel covers, Rear spoilers, Mirror housing, Electrical applications (fuses)	Machines	Fair	Excellent	Fairly easy	-heat resistant
Polyurethane	250[a]	EXTERIOR: Bumpers, End caps, Shock absorber, Misc. trim	Flexible parts	Good	Good	Fairly easy	-very paintable
Polyvinyl Chloride	150 to 210[a,c]	Misc. interior parts	Flexible parts	Good	Variable	Fairly easy	

TABLE 2-1. GENERAL PROPERTIES AND USES OF THERMOPLASTIC RESINS (Concluded)

Resin or composite	Maximum bake temp. (°F)	Application[a,b,c] Automotive	Business/miscellaneous	Solvent resistance[a]	Strength[a]	Adhesion[a]	Comments[b,c]
Styrenic resins							
Acrylic-styrene-acrylonitrile (ASA)	180 to 220[b]	EXTERIOR: Mirror housing, Grilles, Bumper covers					
Acrylonitrile butadiene styrene (ABS)	165 to 170[a]	INTERIOR: Consoles, Trim parts, Instrument panels EXTERIOR: Radiator grilles, Headlight housing, Wheel covers, Mirror housings	Telephones	Poor	Good	Easy	-heat and solvent sensitive -works best with two component urethane coatings
Polystyrene	140[a]		Packaging material	Very poor	Poor	Easy	
Styrene-maleic anhydride (S-Ma)	235[b]	INTERIOR: Door inserts, Seat buckle components, Instrument panels, Floor and roof consoles, Trim parts, heating duct louvers, Fascia	Speaker grilles, Radio parts				-high heat resistance -usage mainly interior
Thermoplastic Polyester (TPE)	220 to 225[c]	Fascia, Misc. trim EXTERIOR: Bumper covers					-very paintable

[a]Lewarchik, R.J., "Low VOC Coatings for Automotive Plastics," Industrial Finishing, No. 11, 1983.
[b]Juran, R., "Modern Plastics, Encyclopedia '91," New York, 1990.
[c]Suss, N., Handout: "GTX Applications," PPG.

TABLE 2-2. GENERAL PROPERTIES AND USES OF THERMOSET RESINS

Resin or composite	Maximum bake temperature (T in °F)	Application[a,b,c] Automotive	Application[a,b,c] Business	Solvent resistance[a]	Strength[a]	Adhesion[a]	Comments[a,b,c]
Epoxy	120 to 140[b]	Specialty applications	Binders				-low heat resistance -rigid -very porous
Melamines	400[a]				Good		
Phenolic	500[a]	Ashtrays, Water pumps, Intake manifolds, Brake pistons, Engine blocks and heads	Dielectric housing of connectors	Excellent	Good	Fairly difficult	-brittle -heat resistant
Polyurethanes	250[a]	Fenders, Fascia		Good			-flexible -high heat resistance
Thermoset Polyester	400[a]	EXTERIOR: Roofs, Doors, Air dams, Spoilers, Panels, Hoods, Head lamp housings, Covers	Motor housings, Light housings	Excellent	Good	Fairly easy	-very rigid -high heat resistance -porosity problems

[a]Lewarchik, R.J., "Low VOC Coatings for Automotive Plastics," Industrial Finishing, No. 11, 1983.
[b]Juran, R., "Modern Plastics, Encyclopedia '91," New York, 1990.
[c]Suss, N., Handout: "GTX Applications," PPG.

2.2.1 Characteristics of Substrates

The selection of a specific plastic for a particular application depends on the part's function or end-use. For example, a golf ball must be impact-resistant, whereas an adding machine housing would require a substrate that can withstand day-to-day wear. Other substrate characteristics to consider include durability, heat sensitivity, chemical stability, flexibility, and hardness.

There are certain trade-offs in selecting a substrate. For example, increased flexibility usually means a loss of chemical resistance, weatherability, and hardness; increased hardness almost always increases brittleness, which results in loss of impact strength and resilience.[2]

Most plastic substrates will distort if heated above a certain temperature. Therefore, the type of coatings applied on a substrate must cure within the temperature limitations of the substrate. Low-bake coatings are designed to cure at lower temperatures (up to 194°F) and are used on substrates such as acrylonitrile-butadiene-styrene (ABS), Xenoy® (polycarbonate and polybutylene terephthalate), polycarbonate, and acrylic.[2]

High-bake coatings cure at temperatures above 194°F (normally between 250°F and 300°F) and are compatible with such substrates as sheet-molded compound (SMC), nylon, polyester, thermoplastic urethane (TPU), thermoplastic olefin (TPO), and reaction injection molded (RIM) plastics (primarily ABS).[2]

The flexibility of the substrate also influences the type of coating required. Substrates considered "nonflexible" include nylon, Xenoy®, ABS, acrylic, and polycarbonate.[2,3,4] Substrates that are considered "flexible" and require flexible coatings are TPO, RIM, vinyl, ABS alloy, and TPU.[3,5] Flexible coatings include higher-molecular-weight components and, therefore, require higher VOC content than nonflexible coatings.[2]

Table 2-1 and Table 2-2 show the physical characteristics and applications of a number of thermoplastic substrates and thermoset substrates, respectively.[2] Table 2-3 lists the abbreviations used in this section for each plastic.

The type of substrate used to produce a plastic automobile part depends on whether the part has an exterior or interior end-use. Typical exterior coated plastic parts for automobiles and trucks are fascias, bumpers, grilles, side panels, mirror housings, body panels, light housings, and lenses. Xenoy®, for example, is used extensively for car bumpers.[6] Xenoy® distorts when heated over 180°F, so low-cure-temperature coatings are required. Typical automobile and truck interior coated plastic parts include instrument panels, glove boxes, consoles, speaker grilles, steering wheels and housings, and dashboard panels.

In general, parts positioned lower on a car body require more rigidity.[4] Reinforced SMC is often used where rigidity is needed, as in bumpers, which absorb much of the impact of a collision. On the other hand, a RIM substrate is adequate for fascias, which function more as decorative covers.

Bumper reinforcements and fuel tanks are composed of polypropylene.[4,5] Polypropylene has been used in Europe for a number of years, and it is expected to be used more in the United States in the future.[6] Polypropylene is less expensive than other substrates but, unlike Xenoy®, it requires a primer to promote adhesion.[7] Other substrates, such as TPO and TPU, are being used more frequently in cars because they allow more flexibility, better design, and a flush fit to metal parts.[5]

Substrates that are commonly used to produce plastic business machines parts include ABS, polycarbonate, polyphenylene oxide (PPO), polystyrene, and polyurethane.[5,7] Other resins used in this industry include Noryl® (a phenylene oxide-based resin), Xenoy®, and Cycloac®, all manufactured by

TABLE 2-3. PLASTICS ABBREVIATIONS

ABS	=	Acrylonitrile Butadiene Styrene
ASA	=	Acrylic Styrene Acrylonitrile
Nylon	=	Polycaprolactam
PBT	=	Polybutylene Terephthalate
PPE	=	Polyphenilin Ether
PPE	=	Polyphenylene Ether
PPO	=	Polyphenylene Oxite
PVC	=	Polyvinyl Chloride
RIM	=	Reaction Injection Molded
S-Ma	=	Styrene-Maleic Anhydride
SMC	=	Sheet Molded Compound
TPE	=	Thermoplastic Polyester Elastomer
TPO	=	Thermoplastic Olefin
TPU	=	Thermoplastic Urethane
Xenoy	=	PC/PBT blend

General Electric, and Geon® (a vinyl-based resin) manufactured by B.F. Goodrich.[8] Other plastics, such as polypropylene and fiberglass-reinforced SMC, are used less frequently.[6]

The conductive plastics used in business machines are thermoplastic resins that contain conductive flakes or fibers composed of materials such as aluminum, steel, metalized glass, or carbon. Resin types with conductive fillers include ABS, ABS and polycarbonate blends, PPO, nylon 6/6, polyvinyl chloride (PVC), and polybutyl terephthalate (PBT).[6]

Substrates used for parts in the miscellaneous category include ABS for telephones, acrylic for outdoor signs, and polystyrene for toys and packaging.[3] Polyurethane is used for exterior window parts.[9]

2.2.2 Plastic Fabrication and Molding

The molding technique used for a particular substrate can affect the type and amount of coating used. Some molds produce parts that require substantial surface coating to hide flaws or defects; other types of molds produce parts that require little or no coating.

Plastics are generally fabricated by one of two approaches: either the product is machined from basic stock forms (sheets, bars, rods) or the parts are formed directly from raw materials by molding or casting.

2.2.2.1 Casting. Nylons, silicones, epoxies, acrylics, polyesters, and styrene are commonly cast by pouring resin into temperature-controlled molds. Casting is well suited for short-run items such as prototypes because molds are relatively inexpensive.[2] Typical products manufactured by casting include toys and sporting goods.

2.2.2.2 Compression Molding. In compression molding, a partially formed thermosetting resin is placed in a temperature-controlled cavity. As heat and pressure are applied to the mold, the plastic material softens and flows to conform to the cavity. Compression molding is applicable to virtually all thermosetting resins and is well suited for large parts such as body panels for automobiles, doors, and furniture parts, but not for intricate parts where tolerances of ±0.0005 inches are required.[4] Because compression-molded parts are composed of thermoset resins, rejected parts cannot be reground and recycled. However, the surface of these parts can be reworked to repair scratches, water spots, and other superficial defects.[4]

2.2.2.3 Injection Molding. In injection molding, a thermoplastic starting material (usually in granular form) is heated until it becomes soft enough to be forced under pressure into a hot temperature-controlled mold. Following the injection molding process, water is introduced into a water jacket around the mold to cool the part. Once cool, the mold separates and the molded part can be removed.[8] Most rejected parts can be reground on site and mixed with virgin materials for reuse.[8] Production rates can be high, and intricate parts may be produced with a high degree of dimensional accuracy.

Structural foam injection molding and straight injection molding are two techniques used to manufacture business machines, medical equipment, and cash teller machines, among other things.[6] Structural foam injection molding produces parts with surface flaws that require a substantial amount of surface coating to hide them, whereas straight injection molding can produce parts with molded-in color and texture that require little or no decorative surface coating.[2] It follows that finishing costs, when considered alone, favor the use of straight injection molding. However, tooling for structural foam molds costs from one-third to two-thirds less than for injection molds.[1] Therefore, molding costs favor the use of structural foam injection molding, especially for large, complex part shapes.

Conductive plastic parts are usually formed by straight injection molding. Structural foam injection molding can reduce the shielding effectiveness of these materials because air pockets within the structural foam separate the conductive particles.[6]

Reaction injection molding is used extensively to produce fascias and other automotive plastic parts.[2,4,5,7] The most common RIM molding machines are vertical, i.e., the two halves of the mold move vertically. However, horizontal RIM molding machines are available and are preferred for producing larger parts such as fascias.

2.2.3 Molded-In Color

In-mold coating (applying the coating directly to the mold) can be performed for some parts. Insert labeling with injection molding paper is a process that was developed to replace a method using insert molding with a plastic film.[8]

A molded-in color process such as that used to coat tractor cab roofs produces a harder, glossier finish than is possible with liquid spray application.[8] The coating is roll-coated on mylar and then transferred to a thin compression molded plastic part that has a shape close to the final part shape. Finally, the thin-coated plastic part is put into an injection mold, where it is fused to injected plastic.[8]

Plastic parts often need to match the color and texture of metal parts or other plastic parts. Color matching is often difficult to achieve with molded-in color. Color reproducibility and color stability of plastic parts are generally more easily controlled by spray coating the parts than by using molded-in color.[6] There is also a move toward molded-in texture plastic parts. This in-mold process is less expensive, and can reduce or eliminate the need for painting.[7,8]

2.2.4 Parts Requiring Surface Coating

The surface characteristics of the molded part and, therefore, the amount of surface finishing required for a part is influenced by the design of the part, the design of the mold, and molding parameters such as injection rate, molding temperature, and injection pressure.[6] Many surface flaws that require sanding, filling, and application of coatings that emit VOC's can be minimized by close interaction among the part designer, molding and coating line personnel, and the suppliers of equipment and materials.[6] Reducing the number and severity of surface flaws can reduce the total film thickness of coating necessary to hide them.

Other molding advances have reduced the amount of coating required. For example, padded dashboards are produced by placing large sheets of vinyl over foam and then heating them.[8] The vinyl is precolored to match various car interiors so that coating is not necessary.

2.3 CHARACTERISTICS OF COATINGS

Coating plastics can be more difficult than coating metals and other substrates because chemical interactions can occur between the coating and a plastic substrate.[6] In fact, the cross-linking reaction of plastic substrate and coating can continue for some time after the coating is applied.[5] In addition to the resin, plastics contain plasticizers, blowing agents, mold releases, conductive media, flame retardants, and fibrous reinforcement fillers that can affect the applied paint.[7]

In the past, plastic parts were often coated with lacquer coatings with very high VOC content, ranging from 85 to 95 percent VOC by volume.[2] These coatings were fast-drying, durable, and relatively inexpensive. New resin systems have since been developed that produce waterborne and higher-solids coatings with similar characteristics. Table 2-4 illustrates an estimate of emissions reductions achieved from 1980 to 1988 by the automobile industry for exterior coatings. Keeping annual coating consumption constant, and assuming a 1980 average VOC content of 6.0 to 6.5 lbs/gal and a 1988 average VOC content of 4.85 lbs/gal, estimated emissions reductions range from 17,000 to 39,000 tons.

Waterborne coatings contain water as the major solvent, and contain 5 to 40 percent by weight organic co-solvents to aid in viscosity control, wetting, and pigment dispersion. They have a much lower VOC content than traditional coatings with the same solids content.[7] Waterborne coatings can have lower VOC emissions and lower toxicity, yet they fulfill

TABLE 2-4. VOC EMISSION REDUCTIONS FOR EXTERIOR AUTOMOTIVE COATINGS FROM 1980 TO 1988

	Total VOC Emissions (tons/year)	VOC in coatings (lb/gal)	Solids in coatings (%, average)
1988[a]	11,470	4.85	33
1980[b]	28,400	6.0	17
1980[c]	50,750	6.5	10

[a]Based on Dames and Moore Report commissioned by the NPCA.

[b]Assuming the same production level as 1988 and assuming an average VOC content of 6.0 lbs/gal.

[c]Assuming the same production level as 1988 and assuming an average VOC content of 6.5 lbs/gal.

color, gloss, impact resistance, and other requirements for many substrates.[2]

One limitation of waterborne coatings is that they are incompatible with conventional steel delivery systems. As a consequence, stainless steel or plastic pipe fittings are recommended for the application equipment. Another limitation is that increased control of booth temperature and humidity may be required. In addition, longer flash-off time may be needed.[2] Also, some waterborne coatings do not adhere well to certain plastic substrates.[2]

Higher-solids coatings are solvent-borne and generally contain a higher solids content than conventional coatings, up to 50 to 65 percent by volume. Because the solids content is higher, less paint is needed to provide a given film build. However, excessive viscosity can be a problem, and paint may need to be heated to around 200°F to achieve sprayability.[2]

One type of higher-solids paint is a two-component polyurethane. The two components (a color component and a catalyst or hardening component) are mixed together immediately before use and, once mixed, the coating must be applied within several hours.[2] Its lower VOC content and ability to air dry (because of the catalyst) make the two-component polyurethane coating attractive for heat-sensitive plastic parts.[4,7]

Both solvent-borne and waterborne coatings are used in electromagnetic interference/radio frequency interference (EMI/RFI) shielding. Solvent-borne conductive coatings contain small flakes of nickel, silver, copper, or graphite, in either an acrylic or polyurethane resin. Nickel-filled acrylic coatings are the most frequently used because of their shielding ability and cost.[6] Nickel-filled polyurethane coatings are more expensive than nickel-filled acrylic coatings, but are reported to give a more durable finish.[6]

Nickel-filled acrylics and polyurethanes that contain from 15 to 25 percent by volume solids at the gun (i.e., at the point of application or "as applied") are being used to coat plastic business machine parts.[7] Waterborne nickel-filled acrylics are being used less frequently than solvent-borne conductive coatings. Some coaters believe that waterborne conductive coatings do not adhere as well to plastic as do organic-solvent-based conductive coatings.[8]

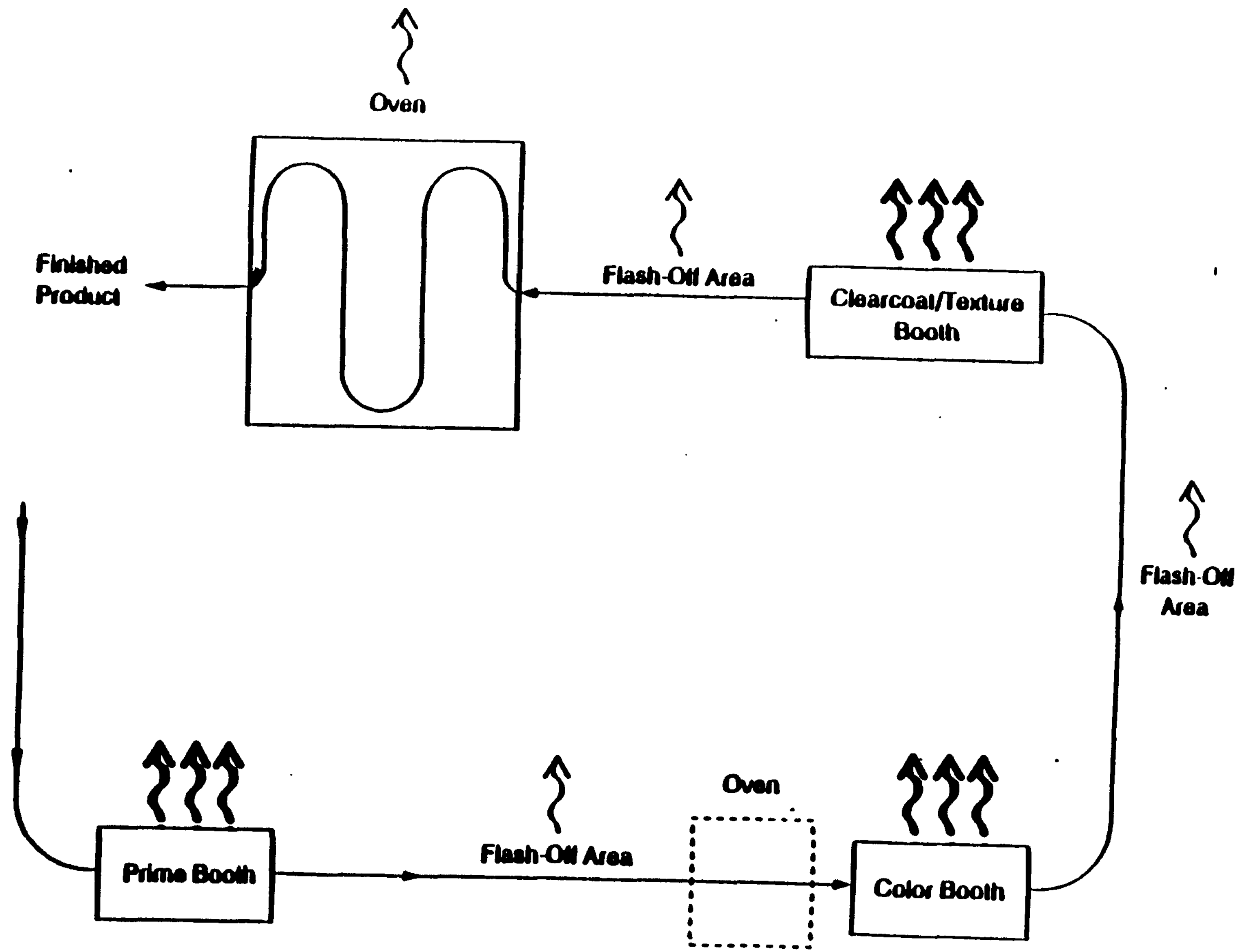
2.4 COATING PROCESS

Typical coating methods for plastic parts include spray, dip, or flow coating, with spray coating being the most widely used. The type of coating used, such as prime coat, color or base coat, topcoat, EMI/RFI shielding, and texture coat will depend on the substrate and end-product. The typical total dry film thickness will usually range from 1 to 5 mils.[3]

Because of their diverse properties, plastic parts are coated in steps to ensure adhesion and finish quality. The general process for coating plastic parts is shown in Figure 2-1.[6] The three basic steps in the process are surface preparation, coating, and curing. Each step may be repeated several times for a given part. A description of these steps follows.

2.4.1 Surface Preparation

The surface preparation step may involve merely wiping off the dust or residue left from the molding stage. A deionizer can be used with enclosed systems to eliminate the need for the manual dust-removal step.[8] Some industries place newly molded parts in ovens prior to painting to promote "gas out," or the boiling off of impurities contained within the substrate.[4] Sanding and puttying may be performed to smooth



Typical Conveyorized Coating Line for Three-Coat Systems the surface on some parts. Parts may also undergo multi-stage washing cycles using specialized soaps and rinsing with deionized water prior to oven drying.[4,5]

To make a part conductive for electrostatic application, a conductive coating (often composed of alcohol, organic salt, water, and other proprietary compounds) may be sprayed on the part and then dried, leaving the conductive salt residue.[5,7] Metal plates located behind conveyorized parts can lend conductance, eliminating the need for a conductive coating.[4]

2.4.2 Spray Coating

To apply the coating, parts are often moved by a conveyor through partially or totally enclosed spray booths. Some conveyorized parts are hung on paint hooks, whereas others are placed on racks. Conveyorized systems are most likely to be found in large facilities because associated capital costs are relatively high.

Spray booths maintain air flow (usually crossdraft or downdraft) to remove overspray in order to minimize contamination and keep solvent concentrations at a safe level. The spray booth exhaust, air flow, temperature, and humidity must be monitored, as these factors can significantly influence the finish quality. Dry filters or water curtains are typically used to remove overspray particles from the booth exhaust.[2] Incinerators or other emissions control equipment can be installed on spray booths to control VOC emissions.

Some coating facilities apply tape or paper to parts to shield or mask areas where coating is not desired. Reusable metal "masks" can also be placed over parts for selective coating.[7] A waterborne acrylic resin is often used for reverse masking.[4] This resin coating is used to protect an area of the part that has previously been coated. The coated part is sprayed with the resin, baked, and then the unmasked area of the part is sprayed with a second or perhaps even a third color. This additional color is added for style or appearance. The masking material dries into a thin film and when it is peeled off, the initial color is preserved.

In all spray coating operations, some coating solids either miss or bounce off the part. Coating solids that do not adhere to the part are called overspray. The greater the overspray, the less efficient the application system. The efficiency of an application system is measured as transfer efficiency. Transfer efficiency is defined as the ratio of the paint solids that adhere to a part divided by the solids directed (in this case, sprayed) at the part.

Numerous factors affect how well paint is transferred to a part, including the type of spray equipment used, the part configuration, and the spray booth ventilation rate. The various spray techniques used to coat plastic parts differ in the manner in which they break up (atomize) the paint. Some methods are associated with inherently better transfer efficiencies than others for a specific part. The more common spray techniques used to coat plastics are discussed below.

2.4.2.1 Conventional Air Spray. Conventional air spray is the traditional method of applying coatings. Compressed air is supplied through an air hose to a spray gun, which atomizes the paint into a fine spray. The pressure supplied to the fluid controls the paint delivery rate, with typical pressures ranging from 5 to 25 pounds per square inch (psi).[2] The air pressure controls the degree of atomization, and is usually 30 to 90 psi.[2] One of the major problems with conventional air spray is the overspray caused by the high volume of air required to achieve atomization. This overspray typically results in relatively poor transfer efficiency.[10]

2.4.2.2 Airless Spray. With airless spray, a pump forces the coating through an atomizing nozzle at high pressure (1,000 to 6,000 psi). Airless spray is ideal for rapid coverage of large areas and when a heavy film build is required. The size of airless spray paint droplets are larger, the spray cloud is less turbulent, and the transfer efficiency is typically superior to conventional air spray.[11] However, airless spray leaves a rougher, more textured surface; therefore, it is generally used on surfaces where appearance is not critical.

2.4.2.3 Air-Assisted Airless Spray. An air-assisted airless system combines the benefits of conventional air spray and airless spray. The system consists of an airless spray gun with a compressed air jet at the gun tip to atomize the coating. It uses lower fluid pressures than airless spray and lower air pressures than conventional air spray (5 to 20 psi versus 30 to 90 psi).[2,12] This fluid/air pressure combination delivers a less turbulent spray than conventional air systems and applies a more uniform finish than airless systems. However, the amount of time needed to apply coatings is greater because of the lower air pressure.[10]

2.4.2.4 High-Volume Low-Pressure Spray. A modification of conventional air spray is high-volume low-pressure (HVLP) spray, which uses large volumes of air under reduced pressure (10 or less psi) to atomize coatings. Because of the lower air pressure, the atomized spray is released from the gun at a lower velocity. Overspray is reportedly reduced 25 to 50 percent over conventional air spray.[13,14,15] The air source for the HVLP can be a turbine or a standard air supply, both of which can handle multiple spray guns.[14,15] Manufacturers have constructed the fluid passages out of stainless steel or plastic so that these guns are compatible with a full range of paints, solvents, and waterbased materials.[16] Many HVLP spray systems are designed to atomize high-, medium-, or low-solids coatings. One limitation of this paint system is the learning curve associated with the new spray technique. When switching to a low-pressure spray, the painter must learn a new spray technique and adjust to the different spray pattern.[17]

2.4.2.5 Electrostatic Spray. In electrostatic spray application, the coating and part are oppositely charged. The part is grounded and attracts the negatively charged coating. Electrostatic spray systems are reported to have the highest transfer efficiency of any of the spray application techniques because of minimal overspray, which also results in lower paint loss and lower VOC emissions.[18,19,20,21,22,23]

One limitation of the electrostatic spray technique is that the part to be coated must be conductive. Plastic parts not made of a conductive substrate are often made conductive by applying compatible polar solutions to the surfaces and/or placing the parts on a metal backing.[3,6,7]

2.4.2.6 Zinc-Arc Spray. Metallic zinc may be applied to plastic to provide a conductive surface or shielding. This two-step process first roughens the plastic surface (usually the interior of a housing) by grit-blasting or sanding, and then spray-coats with molten zinc, either manually or with robotics. The zinc-arc spray gun operates by mechanically feeding two zinc wires into the tip of the spray gun where they are melted by an electric arc. A high-pressure air nozzle blows the molten zinc particles onto the surface of the plastic part.

2.4.3 Curing

The curing process can be separated into flash-off zones, cure zones, and cool-down zones.[5] After a part has been coated, it moves through a flash-off area, where solvent evaporates. The flash-off area may be vented by means of an exhaust system to capture the organic vapors. If the coating requires heat to cure, the part is moved to a curing oven after flash-off. Some coatings that do not require heat to cure may be heated to speed curing, thereby allowing the production rate to increase.[7] Oven temperatures will vary according to the type of substrate and coating, but will range from about 150°F to 300°F.[2] The potential for distortion of the plastic part by curing with temperatures that are too high is a concern for the coater. Some coatings may require as long as 72 hours after baking to be fully cross-linked.[6]

2.5 COATING SELECTION

Coating selection for plastic parts depends on many factors, such as the substrate, the technique used to mold the part, end-use of the product, solvent selection, color-matching, temperature, humidity, and paint adhesion. Thermoplastics, for example, are inherently solvent-sensitive. Often, the best reducing solvents for paints are also the most aggressive in attacking sensitive plastics.[6]

The specific end-use of the part determines which of the following physical characteristics are most critical for the coating: color, gloss, adhesion, impact resistance, pencil hardness, abrasion resistance, flexibility, ultraviolet (UV) light stability, salt resistance, or solvent resistance. For example, durability and salt resistance is critical for a car bumper, whereas stain and cleaning solvent resistance are critical for a desktop computer housing.

2.5.1 Factors Specific to the Automotive/Transportation Segment

Appearance and substrate protection are the major reasons for coating plastic parts in the automotive/transportation industry. Color-matching various plastic parts to coated metal and other plastics in automobiles can be difficult and requires the use of numerous coating variations. The aesthetic quality of the automobile can also be improved by the selective coating of parts. For example, by masking and spraying two colors adjacent to each other, a single part can be made to look like two different parts bonded together.[5] Textured molding is also being used more, such as on interior door panels.[5]

The location and visibility of the automotive plastic part will affect the choice of coating and even the number of coats required.[4] For example, a portion of a bumper that is partially hidden under the car needs to withstand weather changes, impact, and other environmental stresses; however, color-matching this part may be unimportant or even unnecessary.

Application of a waterborne base coat followed by a solvent-borne clearcoat is used on some coated parts located below eye level.[4] Interior plastic parts such as consoles and dashboard panels do not have to withstand the extreme environmental stresses of exterior parts; however, durability is important. Resistance to cleaning solvents and color matching are critical when selecting coatings for interior parts.

Both waterbornes and higher-solids (especially two-component polyurethane coatings) are used extensively in the automotive industry. Although waterborne coatings [with VOC levels of 2.8 to 3.8 pounds per gallon (lb/gal), less water] can be found in the automotive industry, some limitations are associated with these coatings.[24,25] Waterborne coatings require curing to evaporate the water and sometimes the plastic substrate cannot withstand the high curing temperature. In many instances, "accelerators" can be added to the coating to speed up the curing process.[26] Adhesion and finish quality are also potential concerns when using waterbornes.

The higher-solids, two-component polyurethanes are gaining popularity for clearcoats and base coats. Their appearance, durability, and lower baking temperature are said to be superior to those of waterbornes.[26] Using a clearcoat-bake-clearcoat process gives the final coated product a wet look, which is often desired.[4] A high-gloss white polyurethane coating is used on the front grilles of lawnmowers with headlights to improve reflectivity.[8]

Red and black automotive coatings often have unique solvent requirements due to the nature of the pigment and resin systems. Red pigments are typically highly transparent and have a tendency to flocculate (form lumpy or fluffy masses). To control flocculation and evenly disperse the pigment, higher volumes of solvent are required for red coatings than for other typical colors. Black coatings generally use carbon black pigments. The small particles adsorb more resin than other colors. To counterbalance the higher resin loadings and higher viscosity, more solvent is required for black coatings.

Metallic paints for coating plastic automotive parts present several challenges. The thickness of the applied metallic coating is crucial and varies depending on the type of coat (base coat, topcoat, etc.). If the coating is too thick, the metal flakes will float, causing variations in color.[4] On the other hand, constant agitation of the metallic paints in their containers or routing them through a paint recirculation system is necessary to keep the metal flakes floating so they will achieve proper orientation when sprayed.[4]

Some coatings used in the automotive/transportation sector have unusual job performance requirements and are referred to as specialty coatings. These products include gloss reducers, headlamp lens coatings, adhesion primers, electrostatic preparation, resist coatings, stencil coatings, ink pad coatings, texture coatings, soft coatings, vacuum metalizing basecoat and topcoat, black and reflective argent, and coatings for lamp bodies. In some cases, the technology is not available to formulate these specialty coatings with reduced VOC content. In other cases, the coatings are used in such small quantities (accounting for about 4 percent of all automotive plastic parts coatings)[27] that reformulation would not be cost effective.

2.5.2 Factors Specific to the Business Machine Segment

Plastic parts for business machines are coated for three major reasons: (1) to improve their appearance; (2) to protect the plastic part from physical and chemical stress; and (3) to attenuate EMI/RFI signals that would otherwise pass through the plastic housing.

Texture is often molded in to improve the appearance of business machine parts. Color-matching the plastic to coated metal parts is often a requirement. In selecting coatings for business, medical, and other types of machines, resistance to such items as correction fluid, surface cleaners, and inks must be considered.

The final coating thickness will vary, but the industry standard is typically 1.5 to 2 mil dry thickness.[4] Generally speaking, this thickness is achieved with a three-coat system (primer, color, clear coat) using conventional coatings, or with one coat if a higher-solids coating is used.[1] Higher-solids coatings for decorative coating may more readily cover flaws in the substrate.[1]

The EMI/RFI signals emitted from enclosed electronic components can pass through plastic housings. The EMI/RFI signals emitted from business machines can interfere with the performance of other electronic devices such as radios and televisions. Conversely, EMI/RFI signals from outside sources can interfere with performance of the electronic components in an unshielded plastic business machine housing. The increased use of plastics for business machine housings and the increase in circuit density afforded by advances in circuit technology have resulted in a corresponding increase in EMI/RFI interruptions of the airwaves.[7] To combat EMI/RFI propagation, the Federal Communications Commission has placed restrictions on the maximum EMI/RFI emissions from computing devices.[7] Coatings are frequently used to comply with these restrictions.

The two major performance specifications for EMI/RFI shielding materials are conductivity and adhesion. The

EMI/RFI signals are best shielded with grounded, high-conductivity coatings. These coatings usually have a surface resistance of less than 1 ohm per square area. However, protection is best achieved with grounded, low-conductivity coatings with surface resistance of 2 to 20 ohms per square area. Although a high-conductivity surface may prevent a spark from reaching internal electronic components in one area of a housing, the spark may arc to the internal components in another area as it travels to the grounding connection. A low-conductivity surface spreads the energy over a larger area as it travels to ground, preventing a localized charge build-up.[7]

In some cases, copper shielding is used instead of nickel because it achieves better resistance (5 ohms for nickel versus 1.5 ohms for copper).[8] Waterborne copper shielding is available, and sources indicate that it mixes better, sprays better, and lasts longer than some solvent-based shieldings.[8] One disadvantage is that when transporting the waterborne coating in cold weather it must be kept from freezing. Once it freezes it cannot be used.[7] In addition, when switching a paint line from copper shielding to another type of coating, the entire fluid line must be changed; otherwise, copper specks appear in the other coating.[8]

2.5.3 Factors Specific to the Miscellaneous Segment

The coating selections and requirements for the miscellaneous category depend on the individual situation. As with the other categories, appearance and protection are the most important considerations. Plastic window frame and door coatings must withstand the elements but must also be capable of matching the numerous architectural and maintenance coatings. Coatings on sports equipment must be durable and often impact-resistant. Coatings used for toys must be nontoxic and durable.

Some substrates require multiple layers of paint for protection and appearance. For example, the front panels of gas pumps that frame the digital readouts are often made of

Lexan® substrate and may have the following coatings: (1) a clear barrier coat to prevent degassing of entrapped VOC's from the substrate (degassing could distort the color of the final product, producing a mottled effect); (2) a black barrier coat to seal off the paint from degradation due to contact with gasoline in the field; (3) a spray fill, which is a higher-solids paint used to remove surface imperfections; (4) a black colorcoat; and (5) another coat of black color to ensure a final gloss. The more paint layers applied, the greater the gloss.[5]

2.6 EXISTING EMISSIONS REGULATIONS

Several States (including Texas, New York, Missouri, Michigan, Maryland, and California) and local and regional areas have adopted regulations to control VOC's from facilities that surface coat plastic parts. Table 2-5 presents a summary of State and area regulations.[28] All of these States and areas have adopted a limit on the VOC content in coatings. These limits range from 2.3 lb/gal for a general one-component coating to 6.7 lb/gal for vacuum metalizing, optical, and electric dissipating coatings.[28] In addition, Maryland and New York have adopted minimum efficiency requirements in lieu of limits on VOC content if control devices are used. The Bay Area Air Quality Management District in California allows add-on control if it achieves equivalent VOC reduction. Michigan restricts the use of conventional air atomized spray.

In addition to State and area regulations to control VOC emissions from surface coating of plastic parts, federal regulations exist to control emissions from the coating of plastic business machine parts. These New Source Performance Standards (NSPS), found in 40 CFR 60, Subpart TTT, affect facilities constructed after January 1986.

TABLE 2-5. STATE REGULATIONS

State	Name of Regulation	Coating Category	Limit lb VOC/gal of Coating applied	Type of Control	Date into Effect	Report and Recordkeeping Requirements	Notes
California (South Coast Air Quality Management	Rule 1145. Plastic, Rubber, and Glass Coatings	General one-component	2.3	VOC content of coatings applied, excluding water and exempt compounds	05/01/87	Daily record of coating and solvent use, to include:	
		General two-component	3.5				
		Military spec. one-component	2.8			(1) amount and type of coating used by each piece of application equipment	
		Military spec. two-component	3.5				
		Multi-colored	5.7				
		Mold Seal	6.3			(2) amount of VOC in each coating at time of application	
		Vacuum Metalizing	6.7				
		Mirror Backing Curtain	4.2			(3) amount of solvent and exempt solvent	
		Roll coated	3.6				
		Optical	6.7			(4) VOC content of each solvent	
		Electric Dissipating	6.7				
		Metallic	3.5		03/01/87	Records to be retained for 2 years	
		General automotive	4.3				
		Metallic automotive	5.0				
California (Bay Area Air Quality Management District)	Regulation 8. Organic Compounds. Rule 31. Surface Coating of Plastic Parts and Products	General	2.8	VOC content of coatings applied, excluding water, or 85 percent efficient control device		Coating records to include:	Compliance statement required from coating mfgrs.
		Flexible coatings:					
		Flexible primer	4.1			(1) coating catalyst and reducer used	
		Color topcoat	4.1				
		Basecoat/clearcoat (combined system)	4.5			(2) mix ratio of components used	

TABLE 2-5. STATE REGULATIONS (CONTINUED)

State	Name of Regulation	Coating Category	Limit lb VOC/gal of Costing applied	Type of Control	Date into Effect	Report and Recordkeeping Requirements	Notes
California (continued)		Specialty coatings:				(3) VOC content of coatings, as applied	
		Camouflage	3.5				
		Conductive (shielding)	5.8			Daily records to include:	
		Metallic topcoat	3.5				
		Extreme performance	6.3			(1) coating and mix ratio of components in coatings	
		High gloss	3.5				
						(2) quantity of each coating applied	
						(3) oven temperature	
						(4) type and amount of solvent used for clean up, surface preparation	
Maryland--Baltimore and Washington, D. C. Metropolitan Areas	Rule 10.18.21. Volatile Organic Compounds From Specific Processes	Plastic parts coatings	4.8	VOC content of coatings as used as the application equipment after viscosity adjustments, or equipment control. If afterburner used, must achieve 90% efficiency.		Monthly or quarterly reporting: 1) name of coating .ufacturer (2) trade name or manufacturing code (3) volume of coating used (4) VOC, exempt solvent, water, and solids content in lb/gal or kg/L	

TABLE 2-5. STATE REGULATIONS (CONTINUED)

State	Name of Regulation	Coating Category	Limit lb VOC/gal of Costing applied	Type of Control	Date into Effect	Report and Recordkeeping Requirements	Notes
Maryland (continued)	Proposed Air Pollution Regulation (expected ________)	General	2.5	VOC content of coatings		NOTES Only 2 sources in area. One able to meet 2.9 kg/L with waterborne coating and HVLP spray. Trying to make other source meet this limit. too.	
Michigan - 9 County Area	Rule 632. The Coating of Automobiles, Trucks and Business Machines	Automobile and Truck (High Bake)		VOC content of coatings as applied, excluding water and exempt compounds	12/31/89 until 12/31/92	Records to include:	After 12/31/91, air atomized spray equipment is no longer required
		Prime				(1) product process rate	
		-Flexible	5.0				
		-Nonflexible	4.0			(2) application rate for each type coating	
		Topcoat					
		-Basecoat	4.6			(3) VOC content of each type coating, as applied	
		-Clearcoat	4.3				
		-Non-basecoat/clearcoat	4.7			(4) amount of each type coating used	
		(Air-dried, exterior only)					
		Prime	6.1			(5) method and equipment used to apply each type coating	
		Topcoat					
		-Basecoat	5.8				
		-Clearcoat	5.4			(6) type of plastic part coated	
		-Non-basecoat/clearcoat	6.3				

TABLE 2-5. STATE REGULATIONS (CONTINUED)

State	Name of Regulation	Coating Category	Limit lb VOC/gal of Costing applied	Type of Control	Date into Effect	Report and Recordkeeping Requirements	Notes
Michigan (continued)		(Air-dried, interior only)	6.3			(7) capture and control efficiency of approved emission control equipment	
		(Touch up and repair)	6.3				
						Records to be retained for 2 years, submitted upon request	
		Automobile and Truck (High bake)			12/31/92	In addition, acceptable written program for compliance required, to include:	
		Prime					
		-Flexible	4.5				
		-Nonflexible	3.5			(1) available emission test data	
		Topcoat					
		-Basecoat	4.3			(2) material balance calculations	
		-Clearcoat	4.0				
		-Non-basecoat/clearcoat	4.3			(3) control equipment specifications	
		(Air-dried, exterior only)					
		Prime	4.8			(4) timetable for compliance (date equipment ordered, date process change begun, date of initial startup, date final compliance achieved)	
		Topcoat					
		-Basecoat	5.0				
		-Clearcoat	4.5				
		-Non-basecoat/clearcoat	5.0				
		(Air-dried, interior only)	5.0				
		(Touch up and repair	5.2				

TABLE 2-5. STATE REGULATIONS (CONTINUED)

State	Name of Regulation	Coating Category	Limit lb VOC/gal of Coating applied	Type of Control	Date into Effect	Report and Recordkeeping Requirements	Notes
Michigan (continued)		Business Machines		12/31/91			
		Prime	2.9				
		Topcoat	2.9				
		Texture coat	2.9				
		Fog coat	2.9				
		Touch-up and repair	2.9				
Missouri-St. Louis Metropolitan Area	Missouri Air Pollution Rules. 10 CSR 10-5.330 Control of Emissions from Industrial Surface Coating Operations	Plastic fascia topcoat	4.5	VOC content based on weight of VOC/gal coating (minus water and non VOC compounds)	12/31/89	Daily records to include: (1) type and quantity of coatings used (2) type and quantity of solvents used for coating, thinning, purging, and equipment cleaning (3) type and quantity of waste solvents reclaimed or discharged (4) quantity of pieces or materials coated	Siegel Roberts is the only plastic fascia manufacturer. The limit was based on their RACT presentation. The plastic mailbox, shutter facility went out of business, but that limit remains.
		Plastic mailboxes and shutters	3.5				

TABLE 2-5. STATE REGULATIONS (CONTINUED)

State	Name of Regulation	Coating Category	Limit lb VOC/gal of Coating applied	Type of Control	Date into Effect	Report and Recordkeeping Requirements	Notes
Missouri (continued						Other records to include:	
						(1) coating manufacturers formulation data for each coating on forms provided or approved by the Director	
						(2) test results to determine capture and control efficiency, transfer efficiencies, and coating makeup	
						(3) other pertinent information. Records such as daily production rates may be substituted for actual daily coating use measurements, if approved by the Director as appropriate.	
						Records to be retained for 2 years.	

TABLE 2-5. STATE REGULATIONS (CONTINUED)

State	Name of Regulation	Coating Category	Limit lb VOC/gal of Coating applied	Type of Control	Date into Effect	Report and Recordkeeping Requirements	Notes
New York - New York City Metropolitan Area	New York Air Pollution Control Regulations. Part 228. Surface Coating Processes.	Miscellaneous Plastic Parts		VOC content of coatings applied, minus water and excluded VOC. Installed afterburner must be 80 percent efficient	05/15/91	Records to include: (1) certification from coating supplier/ manufacturer to verify parameters used to calculate VOC for each coating used (2) purchase, usage, and/or production records	Applies to facilities emitting ≥ 100 tons VOC/yr. Limits were borrowed from other State regs.
		-Color topcoat	3.8				
		-Clearcoat	4.8				

2.7 MODEL PLANTS

This section describes the model plants developed to represent the plastic parts surface coating industry for purposes of assessing the effects of various VOC emissions control options. Model plants were developed for two general categories of facilities: (1) those that coat automotive/transportation parts, and (2) those that coat business machine parts. Because of the variation in products, substrates and coating requirements, and the small number of facilities of each type, only general information is provided on the miscellaneous plastic parts segment in this document. No specific model plants, or control alternatives are provided for the miscellaneous segment.[28]

Other parameters used in defining the model plants in addition to coating types include facility size, degree of automation and robotics, the type of substrates being painted, end use, and types of spray guns and spray booths used.

Both the automotive/transportation and business machine sectors were divided into various model facility sizes. The automotive/transportation category was divided into four model plant sizes. Because such a variety of substrates and end uses are found in the automotive/transportation sector, each size model plant was evaluated for three different scenarios of plastic part substrates and end use: interior, exterior flexible, and exterior non-flexible.

The business machine category basically uses the same substrate and types of coatings regardless of end use and plant size. Therefore, the business machine sector was divided into three sizes, each using the same types of coatings.

This analysis includes 12 model plants representing automotive/transportation and 3 model plants representing business machines, as shown in Table 2-6. The production and process characteristics that define model plants for the automotive/transportation sector and for the business machine sector are described in Sections 2.7.1 and 2.7.2, respectively.

TABLE 2-6. SUMMARY OF MODEL PLANTS

AUTOMOTIVE/TRANSPORTATION FACILITIES

Model plant #	Size	Plastic part type (coating type)
A1	small	interior (primer, colorcoat)
A2	small	exterior flexible (primer, colorcoat, clearcoat)
A3	small	exterior non-flexible (primer, colorcoat, clearcoat)
B1	medium	interior (primer, colorcoat)
B2	medium	exterior flexible (primer, colorcoat, clearcoat)
B3	medium	exterior non-flexible (primer, colorcoat, clearcoat)
C1	large	interior (primer, colorcoat)
C2	large	exterior flexible (primer, colorcoat, clearcoat)
C3	large	exterior non-flexible (primer, colorcoat, clearcoat)
D1	very large	interior (primer, colorcoat)
D2	very large	exterior flexible (primer, colorcoat, clearcoat)
D3	very large	exterior non-flexible (primer, colorcoat, clearcoat)

BUSINESS MACHINE/MISCELLANEOUS FACILITIES

Model plant #	Size	Coating Type[a]
A	small	primer color coat color coat/texture coat and EMI/RFI
B	medium	primer color coat color coat/texture coat and EMI/RFI
C	large	primer color coat color coat/texture coat and EMI/RFI

[a]Note that only one plastic part type is used in the models for the business machine/miscellaneous sector.

2.7.1 Model Plants for the Automotive/Transportation Sector

Model plants were developed to represent the major equipment and techniques currently being used to surface coat plastic parts for automobiles and other modes of transportation, including trucks, motorcycles, tractors, and lawn mowers. The model plants presented in Tables 2-7 through Table 2-10 were developed from (1) information collected by the EPA from responses to Section 114 letters, during site visits made to representative facilities, and through phone calls to vendors, (2) data compiled by the Michigan Department of Natural Resources during its rulemaking process, (3) information obtained from the State of Ohio Environmental Protection Agency, and (4) information submitted to the EPA in response to its presentation at the National Air Pollution Control Technology Advisory Committee (NAPCTAC) meeting in November 1991.

Four sizes of model plants were selected to represent small (Plant A), medium (Plant B), large (Plant C), and very large (Plant D) facilities. These sizes represent the range of facility types in this segment, from small job shops that perform coating services exclusively up to very large plants with fully automated facilities that perform both molding and coating of plastic parts.

The three basic types of plastic parts coated in the automotive industry were used in the model plant analysis: interior, flexible exterior, and nonflexible (or rigid) exterior. A typical interior part would be a steering wheel assembly constructed from ABS, a typical exterior flexible part would be a fascia or spoiler constructed from RIM, and a typical exterior nonflexible part would be a deflector for a truck cab constructed from SMC.

Most plastic parts coating facilities, especially small ones, specialize in coating only one of these types of plastic. Although some of the larger plants may have the capability to coat two or even all three types of plastic, the analysis would become overly complex if all of the possible

TABLE 2-7. SMALL MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR

Parameter	Plant A-1		Plant A-2		Plant A-3	
Production						
Total volume of coating used at capacity, L/yr (gal/yr)	45,425	(12,000)	45,425	(12,000)	45,425	(12,000)
Total solids sprayed, L/yr (gal/yr)	254,821	(67,317)	1,732,747	(363,392)	2,073,945	(397,203)
Total solids applied, L/yr (gal/yr)	63,705	(16,829)	433,187	(90,848)	518,486	(99,301)
Operating Parameters						
Period of Operation						
• hours/day		16		16		16
• days/week		5		5		5
• weeks/year		50		50		50
Process Parameters						
Interior Parts						
• Air Dry Interior Primer						
- Volume of coating sprayed, L/yr (gal/yr)	10,788	(2,850)				
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating	0.72	(6.0)				
- % solids by volume at gun	15.5	15.5				
- Volume of VOC sprayed, l/yr (gal/yr)	10,335	(2,730)				

TABLE 2-7. SMALL MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant A-1		Plant A-2	Plant A-3
- Volume of solids applied, l/yr (gal/yr)	418	(111)		
• Air Dry Interior Colorcoat				
- Volume of coating sprayed, L/yr (gal/yr)	32,365	(8,550)		
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating	0.72	(6.0)		
- % solids by volume at gun	15.5	15.5		
- Volume of VOC sprayed, l/yr (gal/yr)	31,006	(8,191)		
- Volume of solids applied, l/yr (gal/yr)	1114	(333)		
• High-Bake Interior Primer				
- Volume of coating sprayed, L/yr (gal/yr)	568	(150)		
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating	0.65	(5.4)		
- % solids by volume at gun	23.9	23.9		
- Volume of VOC sprayed, l/yr (gal/yr)	432	(114)		
- Volume of solids applied, l/yr (gal/yr)	34	(9)		
• High-Bake Interior Colorcoat				

TABLE 2-7. SMALL MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant A-1		Plant A-2		Plant A-3
- Volume of coating sprayed, L/yr (gal/yr)	1,703	(450)			
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating	0.55	(4.6)			
- % solids by volume at gun	35.2	35.2			
- Volume of VOC sprayed, l/yr (gal/yr)	1,104	(292)			
- Volume of solids applied, l/yr (gal/yr)	150	(40)			
Exterior Parts					
• High-Bake Exterior Flexible Primer L/yr (gal/yr)					
- Volume of coating sprayed, L/yr (gal/yr)			11,356	(2,000)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.65	(5.4)	
- % solids by volume at gun			23.9	23.9	
- Volume of VOC sprayed, l/yr (gal/yr)			8,637	(1,521)	
- Volume of solids applied, l/yr (gal/yr)			680	(120)	
• High-Bake Exterior Flexible Colorcoat					
- Volume of coating sprayed, L/yr (gal/yr)			22,712	(4,000)	

TABLE 2-7. SMALL MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant A-1	Plant A-2		Plant A-3
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating		0.55	(4.6)	
- % solids by volume at gun		35.2	35.2	
- Volume of VOC sprayed, l/yr (gal/yr)		14,715	(2,591)	
- Volume of solids applied, l/yr (gal/yr)		1,999	(352)	
• High-Bake Exterior Flexible Clearcoat				
- Volume of coating sprayed, L/yr (gal/yr)		7,572	(2,000)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating		0.52	(4.3)	
- % solids by volume at gun		39.4	39.4	
- Volume of VOC sprayed, l/yr (gal/yr)		4,586	(1,212)	
- Volume of solids applied, l/yr (gal/yr)		746	(197)	
• Low-Bake Exterior Flexible Primer				
- Volume of coating sprayed, L/yr (gal/yr)		3,783	(1,000)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating		0.72	(6.0)	
- % solids by volume at gun		15.5	15.5	

TABLE 2-7. SMALL MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant A-1	Plant A-2	Plant A-3
- Volume of VOC volume sprayed, 1/yr (gal/yr)		3,197 (845)	
- Volume of solids applied, 1/yr (gal/yr)		147 (39)	
• Low-Bake Exterior Flexible Colorcoat			
- Volume of coating sprayed, L/yr (gal/yr)		7,572 (2,000)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating		0.68 (5.7)	
- % solids by volume at gun		19.7 19.7	
- Volume of VOC sprayed, 1/yr (gal/yr)		6,079 (1,606)	
- Volume of solids applied, 1/yr (gal/yr)		373 (99)	
• Low-Bake Exterior Flexible Clearcoat			
- Volume of coating sprayed, L/yr (gal/yr)		3,785 (1,000)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating		0.50 (4.2)	
- % solids by volume at gun		40.8 40.8	
- Volume of VOC sprayed, 1/yr (gal/yr)		2,239 (592)	
- Volume of solids applied, 1/yr (gal/yr)		386 (102)	

TABLE 2-7. SMALL MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant A-1	Plant A-2	Plant A-3
• High-Bake Exterior Nonflexible Primer			
- Volume of coating sprayed, L/yr (gal/yr)			11,356 (2,000)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.50 (4.2)
- % solids by volume at gun			40.8 40.8
- Volume of VOC sprayed, l/yr (gal/yr)			6,718 (1,183)
- Volume of solids applied, l/yr (gal/yr)			1,160 (204)
• High-Bake Exterior Nonflexible Colorcoat			
- Volume of coating sprayed, L/yr (gal/yr)			22,712 (4,000)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.55 (4.6)
- % solids by volume at gun			35.2 35.2
- Volume of VOC sprayed, l/yr (gal/yr)			14,715 (2,591)
- Volume of solids applied, l/yr (gal/yr)			1,999 (352)
• High-Bake Exterior Nonflexible Clearcoat			
- Volume of coating sprayed, L/yr (gal/yr)			11,356 (2,000)

TABLE 2-7. SMALL MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant A-1	Plant A-2	Plant A-3	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.52	(4.3)
- % solids by volume at gun			39.4	39.4
- Volume of VOC sprayed, l/yr (gal/yr)			6,878	(1,212)
- Volume of solids applied, l/yr (gal/yr)			1,120	(197)
• Low-Bake Exterior Nonflexible Primer				
- Volume of coating sprayed, L/yr (gal/yr)			3,783	(1,000)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.72	(6.0)
- % solids by volume at gun			15.5	15.5
- Volume of VOC sprayed, l/yr (gal/yr)			3,197	(845)
- Volume of solids applied, l/yr (gal/yr)			147	(39)
• Low-Bake Exterior Nonflexible Colorcoat				
- Volume of coating sprayed, L/yr (gal/yr)			7,572	(2,000)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.68	(5.7)
- % solids by volume at gun			19.7	19.7

TABLE 2-7. SMALL MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant A-1	Plant A-2	Plant A-3
- Volume of VOC sprayed, l/yr (gal/yr)			6,079 (1,666)
- Volume of solids applies, l/yr (gal/yr)			373 (99)
• Low-Bake Exterior Nonflexible Clearcoat			
- Volume of coating sprayed, L/yr (gal/yr)			3,785 (1,000)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.50 (4.2)
- % solids by volume a gun			40.8 40.8
- Volume of VOC sprayed, l/yr (gal/yr)			2,239 (592)
- Volume of solids applies, l/yr (gal/yr)			386 (102)
Coating Equipment			
• Conveyorized lines	0	0	0
• Booths per line	0	0	0
• Off-line booths	3	3	3
• Air Atomized spray guns (25% TE)			
- manual	3	3	3
- robotized	0	0	0
• Electrostatic spray guns (50% TE)			

TABLE 2-7. SMALL MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant A-1	Plant A-2	Plant A-3
- manual	0	0	0
- robotized	0	0	0
• High volume low pressure (HVLP) (50% TE)			
- manual	0	0	0
- robotized	0	0	0
• Dry filter spray booths	3	3	3
• Recirculating waterwash spray booths (Side-draft for automated spray, Down-draft for manual spray)	0	0	0
• Spray booth ventilation rate (manual), m3/s (acfm)	4.7 (10,000)	4.7 (10,000)	4.7 (10,000)
Spray booth ventilation rate (automated), m3/s (acfm)	N/A N/A	N/A N/A	N/A N/A
• Gas-fired curing ovens	0	0	0
Coating Application			
• Average transfer efficiency			
- prime, colorcoat, or clearcoat	25%	25%	25%
• Average dry film thickness			
- primer	1 mil	1 mil	1 mil
- colorcoat	1.5 mil	1.5 mil	1.5 mil
- clearcoat	1.2 mil	1.2 mil	1.2 mil

TABLE 2-7. SMALL MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONCLUDED)

Parameter	Plant A-1	Plant A-2	Plant A-3
- total film thickness applied	3.7 mil	3.7 mil	3.7 mil
• Average flash-off period			
- primer	Variable	Variable	Variable
- colorcoat	Variable	Variable	Variable
- clearcoat	Variable	Variable	Variable
• Curing temperature and time in bake oven			
- primer	air dry	170	250
- colorcoat	air dry	250	250
- clearcoat	air dry	250	250
• Average conveyor speed, m/s (ft/min)	N/A N/A	N/A N/A	N/A N/A

TABLE 2-8. MEDIUM MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR

Parameter	Plant B-1		Plant B-2		Plant B-3	
Production						
Total volume of coating used at capacity, L/yr (gal/yr)	103,152	(27,250)	103,152	(27,250)	103,152	(27,250)
Total solids sprayed, L/yr (gal/yr)	578,656	(152,865)	3,934,779	(825,202)	4,709,585	(901,981)
Total solids applied, L/yr (gal/yr)	202,530	(53,503)	1,377,173	(288,821)	1,648,355	(315,693)
Operating Parameters						
Period of operation						
• hours/day	16		16		16	
• days/week	5		5		5	
• weeks/year	50		50		50	
Process Parameters						
Interior Parts						
• Air dry interior primer						
- Volume of coating sprayed, L/yr (gal/yr)	24,499	(6,472)				
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating	0.72	(6.0)				
- % solids by volume at gun	4.2	4.2				
- Volume of VOC sprayed, l/yr (gal/yr)	23,470	(6,200)				
- Volume of solids applied, l/yr (gal/yr)	360	(95)				

TABLE 2-8. MEDIUM MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant B-1		Plant B-2	Plant B-3
• Air dry interior clearcoat				
- Volume of coating sprayed, L/yr (gal/yr)	73,496	(19,416)		
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating	0.72	(6.0)		
- % solids by volume at gun	4.2	4.2		
- Volume of VOC sprayed, l/yr (gal/yr)	70,409	(18,600)		
- Volume of solids applied, l/yr (gal/yr)	1,080	(285)		
• High-Bake Interior Primer				
- Volume of coating sprayed, L/yr (gal/yr)	1,289	(341)		
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating	0.65	(5.4)		
- % solids by volume at gun	23.9	23.9		
- Volume of VOC sprayed, l/yr (gal/yr)	981	(259)		
- Volume of solids applied, l/yr (gal/yr)	108	(29)		
• High-Bake Interior Colorcoat				
- Volume of coating sprayed, L/yr (gal/yr)	3,868	(1,022)		
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating	0.55	(4.6)		
- % solids by volume at gun	35.2	35.2		

TABLE 2-8. MEDIUM MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant B-1		Plant B-2		Plant B-3
- Volume of VOC sprayed, l/yr (gal/yr)	2,506	(662)			
- Volume of solids applied, l/yr (gal/yr)	477	(126)			
Exterior Parts					
• High-Bake Exterior Flexible Primer					
- Volume of coating sprayed, L/yr (gal/yr)			25,788	(4,543)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.65	(5.4)	
- % solids by volume at gun			23.9	23.9	
- Volume of VOC sprayed, l/yr (gal/yr)			19,613	(3,455)	
- Volume of solids applied, l/yr (gal/yr)			2,161	(381)	
• High-Bake Exterior Flexible Colorcoat					
- Volume of coating sprayed, L/yr (gal/yr)			51,576	(9,082)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.55	(4.6)	
- % solids by volume at gun			35.2	35.2	
- Volume of VOC sprayed, l/yr (gal/yr)			33,416	(5,884)	
- Volume of solids applied, l/yr (gal/yr)			6,356	(1,119)	

TABLE 2-8. MEDIUM MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant B-1	Plant B-2	Plant B-3
• High-Bake Exterior Flexible Clearcoat			
- Volume of coating sprayed, L/yr (gal/yr)		17,194 (4,543)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating		0.52 (4.3)	
- % solids by volume at gun		39.4 39.4	
- Volume of VOC sprayed, l/yr (gal/yr)		10,413 (2,751)	
- Volume of solids applied, l/yr (gal/yr)		2,373 (627)	
• Low-Bake Exterior Flexible Primer			
- Volume of coating sprayed, L/yr (gal/yr)		8,592 (2,270)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating		0.72 (6.0)	
- % solids by volume at gun		15.5 15.5	
- Volume of VOC sprayed, l/yr (gal/yr)		7,261 (1,918)	
- Volume of solids applied, l/yr (gal/yr)		466 (123)	
• Low-Bake Exterior Flexible Colorcoat			
- Volume of coating sprayed, L/yr (gal/yr)		17,194 (4,543)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating		0.68 (5.7)	

TABLE 2-8. MEDIUM MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant B-1	Plant B-2		Plant B-3	
- % solids by volume at gun		19.7	19.7		
- Volume of VOC sprayed, l/yr (gal/yr)		13,803	(3,647)		
- Volume of solids applied, l/yr (gal/yr)		1,187	(314)		
• Low-Bake Exterior Flexible Clearcoat					
- Volume of coating sprayed, L/yr (gal/yr)		8,595	(2,271)		
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating		0.50	(4.2)		
- % solids by volume at gun		40.8	40.8		
- Volume of VOC sprayed, l/yr (gal/yr)		5,084	(1,343)		
- Volume of solids applied, l/yr (gal/yr)		1,229	(325)		
• High-Bake Exterior Nonflexible Primer					
- Volume of coating sprayed, L/yr (gal/yr)				25,788	(4,543)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating				0.50	(4.2)
- % solids by volume at gun				40.8	40.8
- Volume of VOC sprayed, l/yr (gal/yr)				15,255	(2,687)
- Volume of solids applied, l/yr (gal/yr)				3,687	(649)

TABLE 2-8. MEDIUM MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant B-1	Plant B-2	Plant B-3
• High-Bake Exterior Nonflexible Colorcoat			
- Volume of coating sprayed, L/yr (gal/yr)			51,576 (9,082)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.55 (4.6)
- % solids by volume at gun			35.2 35.2
- Volume of VOC sprayed, l/yr (gal/yr)			33,416 (5,884)
- Volume of solids applied, l/yr (gal/yr)			6,356 (1,119)
• High-Bake Exterior Nonflexible Clearcoat			
- Volume of coating sprayed, L/yr (gal/yr)			25,788 (4,543)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.52 (4.3)
- % solids by volume at gun			39.4 39.4
- Volume of VOC sprayed, l/yr (gal/yr)			15,618 (2,751)
- Volume of solids applied, l/yr (gal/yr)			3,559 (627)
• Low-Bake Exterior Nonflexible Primer			
- Volume of coating sprayed, L/yr (gal/yr)			8,592 (2,270)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.72 (6.0)

TABLE 2-8. MEDIUM MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant B-1	Plant B-2	Plant B-3	
- % solids by volume at gun			15.5	15.5
- Volume of VOC sprayed, l/yr (gal/yr)			7,261	(1,918)
- Volume of solids applied, l/yr (gal/yr)			466	(123)
• Low-Bake Exterior Nonflexible Colorcoat				
- Volume of coating sprayed, L/yr (gal/yr)			17,194	(4,543)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.68	(5.7)
- % solids by volume at gun			19.7	19.7
- Volume of VOC sprayed, l/yr (gal/yr)			13,803	(3,647)
- Volume of solids applied, l/yr (gal/yr)			1,187	(314)
• Low-Bake Exterior Nonflexible Clearcoat				
- Volume of coating sprayed, L/yr (gal/yr)			8,595	(2,271)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.50	(4.2)
- % solids by volume at gun			40.8	40.8
- Volume of VOC sprayed, l/yr (gal/yr)			5,084	(1,343)
- Volume of solids applied, l/yr (gal/yr)			1,229	(325)

TABLE 2-8. MEDIUM MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant B-1	Plant B-2	Plant B-3
Coating equipment			
Conveyorized lines	0	0	0
Booths per line	0	0	0
Off-line booths	3	3	3
Air Atomized spray guns (25% TE)			
• manual	3	3	3
• robotized	0	0	0
Electrostatic spray guns (50% TE)			
• manual	0	0	0
• robotized	0	0	0
High-volume low-pressure (HVLP) (50% TE)			
• manual	0	0	0
• robotized	0	0	0
Dry filter spray booths	3	3	3
Recirculating waterwash spray booths (side-draft for automated spray, down-draft for manual spray)	0	0	0
Spray booth ventilation rate (manual), m^3/s (acfm)	4.7 (10,000)	4.7 (10,000)	4.7 (10,000)
Spray booth ventilation rate (automated), m^3/s (acfm)	N/A N/A	N/A N/A	N/A N/A
Gas-fired curing ovens	0	0	0
Coating Application			
Average transfer efficiency			

TABLE 2-8. MEDIUM MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant B-1	Plant B-2	Plant B-3
• primer, colorcoat, or clearcoat	35%	35%	35%
Average dry film thickness			
• primer	1 mil	1 mil	1 mil
• colorcoat	1.5 mil	1.5 mil	1.5 mil
• clearcoat	1.2 mil	1.2 mil	1.2 mil
• total film thickness applied	3.7 mil	3.7 mil	3.7 mil
Average flash-off period			
• primer	Variable	Variable	Variable
• colorcoat	Variable	Variable	Variable
• clearcoat	Variable	Variable	Variable
Curing temperature and time in bake-oven			
• primer	air dry	170	250
• colorcoat	air dry	250	250
• clearcoat	air dry	250	250
Average conveyor speed, m/s (ft/min)	N/A N/A	N/A N/A	N/A N/A

TABLE 2-9. LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR

Parameter	Plant C-1		Plant C-2		Plant C-3	
Production						
Total volume of coating used at capacity, L/yr (gal/yr)	369,229	(97,540)	369,229	(97,540)	369,229	(97,540)
Total solids sprayed, L/yr (gal/yr)	2,071,271	(547,172)	14,084,345	(2,953,768)	16,857,720	(3,228,596)
Total solids applied, L/yr (gal/yr)	869,934	(229,812)	5,915,425	(1,240,583)	7,080,242	(1,356,010)
Operating Parameters						
Period of operation						
• hours/day	16		16		16	
• days/week	5		5		5	
• weeks/year	50		50		50	
Process Parameters						
Interior Parts						
• Air dry interior primer						
- Volume of coating sprayed, L/yr (gal/yr)	87,692	(23,166)				
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating	0.72	(6.0)				
- % solids by volume at gun	4.2	4.2				
- Volume of VOC sprayed, l/yr (gal/yr)	84,009	(22,193)				
- Volume of solids applied, l/yr (gal/yr)	1,547	(409)				

TABLE 2-9. LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant C-1		Plant C-2	Plant C-3
• Air dry interior colorcoat				
- Volume of coating sprayed, L/yr (gal/yr)	263,076	(69,497)		
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating	0.72	(6.0)		
- % solids by volume at gun	4.2	4.2		
- Volume of VOC sprayed, l/yr (gal/yr)	252,027	(66,578)		
- Volume of solids applied, l/yr (gal/yr)	4,641	(1,226)		
• High-Bake Interior Primer				
- Volume of coating sprayed, L/yr (gal/yr)	4,615	(1,219)		
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating	0.65	(5.4)		
- % solids by volume at gun	23.9	23.9		
- Volume of VOC sprayed, l/yr (gal/yr)	3,510	(927)		
- Volume of solids applied, l/yr (gal/yr)	464	(123)		
• High-Bake Interior Colorcoat				
- Volume of coating sprayed, L/yr (gal/yr)	13,846	(3,658)		
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating	0.55	(4.6)		

TABLE 2-9. LARGE MODEL PLANT [illegible]AMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant C-1		Plant C-2		Plant C-3
- % solids by volume at gun	35.2	35.2			
- Volume of VOC sprayed, l/yr (gal/yr)	8,971	(2,370)			
- Volume of solids applied, l/yr (gal/yr)	2,048	(541)			
Exterior Parts					
• High-Bake Exterior Flexible Primer					
- Volume of coating sprayed, L/yr (gal/yr)			92,307	(16,260)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.65	(5.4)	
- % solids by volume at gun			23.9	23.9	
- Volume of VOC sprayed, l/yr (gal/yr)			70,206	(12,367)	
- Volume of solids applied, l/yr (gal/yr)			9,283	(1,635)	
• High-Bake Exterior Flexible Colorcoat					
- Volume of coating sprayed, L/yr (gal/yr)			184,615	(32,510)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.55	(4.6)	
- % solids by volume at gun			35.2	35.2	
- Volume of VOC sprayed, l/yr (gal/yr)			119,609	(21,063)	

TABLE 2-9. LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant C-1	Plant C-2	Plant C-3
- Volume of solids applied, l/yr (gal/yr)		27,302 (4,808)	
• High-Bake Exterior Flexible Clearcoat			
- Volume of coating sprayed, L/yr (gal/yr)		61,544 (16,260)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating		0.52 (4.3)	
- % solids by volume at gun		39.4 39.4	
- Volume of VOC sprayed, l/yr (gal/yr)		37,273 (9,848)	
- Volume of solids applied, l/yr (gal/yr)		10,194 (2,693)	
• Low-Bake Exterior Flexible Primer			
- Volume of coating sprayed, L/yr (gal/yr)		30,753 (8,125)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating		0.72 (6.0)	
- % solids by volume at gun		15.5 15.5	
- Volume of VOC sprayed, l/yr (gal/yr)		25,989 (6,866)	
- Volume of solids applied, l/yr (gal/yr)		2,001 (529)	
• Low-Bake Exterior Flexible Colorcoat			
- Volume of coating sprayed, L/yr (gal/yr)		61,544 (16,260)	

TABLE 2-9. LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant C-1	Plant C-2	Plant C-3
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating		0.68 (5.7)	
- % solids by volume at gun		19.7 19.7	
- Volume of VOC sprayed, l/yr (gal/yr)		49,408 (13,054)	
- Volume of solids applied, l/yr (gal/yr)		5,097 (1,347)	
• Low-Bake Exterior Flexible Clearcoat			
- Volume of coating sprayed, L/yr (gal/yr)		30,765 (8,128)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating		0.50 (4.2)	
- % solids by volume at gun		40.8 40.8	
- Volume of VOC sprayed, l/yr (gal/yr)		18,199 (4,808)	
- Volume of solids applied, l/yr (gal/yr)		5,278 (1,394)	
• High-Bake Exterior Nonflexible Primer			
- Volume of coating sprayed, L/yr (gal/yr)			92,307 (16,260)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.50 (4.2)
- % solids by volume at gun			40.8 40.8

TABLE 2-9. LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant C-1	Plant C-2	Plant C-3
- Volume of VOC sprayed, l/yr (gal/yr)			54,604 (9,619)
- Volume of solids applied, l/yr (gal/yr)			15,604 (2,789)
• High-Bake Exterior Nonflexible Colorcoat			
- Volume of coating sprayed, L/yr (gal/yr)			184,615 (32,510)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.55 (4.6)
- % solids by volume at gun			35.2 35.2
- Volume of VOC sprayed, l/yr (gal/yr)			119,609 (21,063)
- Volume of solids applied, l/yr (gal/yr)			27,302 (4,808)
• High-Bake Exterior Nonflexible Clearcoat			
- Volume of coating sprayed, L/yr (gal/yr)			92,307 (16,260)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.52 (4.3)
- % solids by volume at gun			39.4 39.4
- Volume of VOC sprayed, l/yr (gal/yr)			55,904 (9,848)
- Volume of solids applied, l/yr (gal/yr)			15,289 (2,693)

TABLE 2-9. LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant C-1	Plant C-2	Plant C-3
• Low-Bake Exterior Nonflexible Primer			
- Volume of coating sprayed, L/yr (gal/yr)			30,753 (8,125)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.72 (6.0)
- % solids by volume at gun			15.5 15.5
- Volume of VOC sprayed, l/yr (gal/yr)			25,989 (6,866)
- Volume of solids applied, l/yr (gal/yr)			2,001 (529)
• Low-Bake Exterior Nonflexible Colorcoat			
- Volume of coating sprayed, L/yr (gal/yr)			61,544 (16,260)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.68 (5.7)
- % solids by volume at gun			19.7 19.7
- Volume of VOC sprayed, l/yr (gal/yr)			49,408 (13,054)
- Volume of solids applied, l/yr (gal/yr)			5,097 (1,347)
• Low-Bake Exterior Nonflexible Clearcoat			
- Volume of coating sprayed, L/yr (gal/yr)			30,766 (8,128)

TABLE 2-9. LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant C-1	Plant C-2	Plant C-3
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating			0.50 (4.2)
- % solids by volume at gun			40.8 40.8
- Volume of VOC sprayed, l/yr (gal/yr)			18,199 (4,808)
- Volume of solids applied, l/yr (gal/yr)			5,278 (1,394)
Coating equipment			
Conveyorized lines	0	0	0
Booths per line	0	0	0
Off-line booths	3	3	3
Air Atomized spray guns (25% TE)			
• manual	3	3	3
• robotized	0	0	0
Electrostatic spray guns (50% TE)			
• manual	0	0	0
• robotized	0	0	0
High-volume low-pressure (HVLP) (50% TE)			
• manual	0	0	0
• robotized	0	0	0
Dry filter spray booths	3	3	3

TABLE 2-9. LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant C-1	Plant C-2	Plant C-3
Recirculating waterwash spray booths (side-draft for automated spray, down-draft for manual spray)	0	0	0
Spray booth ventilation rate (manual), m^3/s (acfm)	7.5 (16,000)	7.5 (16,000)	7.5 (16,000)
Spray booth ventilation rate (automated), m^3/s (acfm)	3.3 (7,000)	3.3 (7,000)	3.3 (7,000)
Gas-fired curing ovens	0	0	0
Coating Application			
Average transfer efficiency			
• primer, colorcoat, or clearcoat	42%	42%	42%
Average dry film thickness			
• primer	1 mil	1 mil	1 mil
• colorcoat	1.5 mil	1.5 mil	1.5 mil
• clearcoat	1.5 mil	1.5 mil	1.5 mil
• total film thickness applied	4.0 mil	4.0 mil	4.0 mil
Average flash-off period			
• primer	Variable	Variable	Variable
• colorcoat	Variable	Variable	Variable
• clearcoat	Variable	Variable	Variable
Curing temperature and time in bake-oven			
• primer	air dry	170	250
• colorcoat	air dry	250	250
• clearcoat	air dry	250	250

TABLE 2-9. LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONCLUDED)

Parameter	Plant C-1	Plant C-2	Plant C-3
Average conveyor speed, m/s (ft/min)	N/A N/A	N/A N/A	N/A N/A

TABLE 2-10. EXTRA LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR

Parameter	Plant D-1		Plant D-2		Plant D-3	
Production						
Total volume of coating used at capacity, L/yr (gal/yr)	1,135,624	(300,000)	1,135,624	(300,000)	1,135,624	(300,000)
Total solids sprayed, L/yr (gal/yr)	6,370,528	(1,682,915)	43,318,673	(9,084,790)	51,848,637	(9,930,066)
Total solids applied, L/yr (gal/yr)	2,739,327	(723,654)	18,627,029	(3,906,460)	22,294,914	(4,269,929)
Operating Parameters						
Period of Operation						
• hours/day		24		24		24
• days/week		5		5		5
• weeks/year		50		50		50
Process Parameters						
Interior Parts						
• Air Dry Interior Primer						
- Volume of coating sprayed, L/yr (gal/yr)	269,711	(71,250)				
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating*	0.72	(6.0)				
- % solids by volume at gun*	4.2	4.2				

TABLE 2-10. EXTRA LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant D-1		Plant D-2	Plant D-3
- Volume of VOC sprayed, l/yr (gal/yr)	258,383	(68,258)		
- Volume of solids applied, l/yr (gal/yr)	4,871	(1,287)		
• Air Dry Interior Colorcoat				
- Volume of coating sprayed, L/yr (gal/yr)	809,132	(213,750)		
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating*	0.72	(6.0)		
- % solids by volume at gun*	4.2	4.2		
- Volume of VOC sprayed, l/yr (gal/yr)	775,148	(204,773)		
- Volume of solids applied, l/yr (gal/yr)	14,613	(3,860)		
• High-Bake Interior Primer				
- Volume of coating sprayed, L/yr (gal/yr)	14,195	(3,750)		
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating*	0.65	(5.4)		

TABLE 2-10. EXTRA LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant D-1		Plant D-2		Plant D-3
- % solids by volume at gun*	23.9	23.9			
- Volume of VOC sprayed, l/yr (gal/yr)	10,796	(2,852)			
- Volume of solids applied, l/yr (gal/yr)	1,462	(386)			
• High-Bake Interior Colorcoat					
- Volume of coating sprayed, L/yr (gal/yr)	42,586	(11,250)			
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating*	0.55	(4.6)			
- % solids by volume at gun*	35.2	35.2			
- Volume of VOC sprayed, l/yr (gal/yr)	27,591	(7,289)			
- Volume of solids applied, l/yr (gal/yr)	6,448	(1,703)			
Exterior Parts					
• High-Bake Exterior Flexible Primer					
- Volume of coating sprayed, L/yr (gal/yr)			283,906	(50,010)	

TABLE 2-10. EXTRA LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant D-1	Plant D-2	Plant D-3
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating*		0.65 (5.4)	
- % solids by volume at gun*		23.9 23.9	
- Volume of VOC sprayed, l/yr (gal/yr)		215,928 (38,036)	
- Volume of solids applied, l/yr (gal/yr)		29,230 (5,149)	
• High-Bake Exterior Flexible Colorcoat			
- Volume of coating sprayed, L/yr (gal/yr)		567,812 (99,990)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating*		0.55 (4.6)	
- % solids by volume at gun*		35.2 35.2	
- Volume of VOC sprayed, l/yr (gal/yr)		367,878 (64,782)	
- Volume of solids applied, l/yr (gal/yr)		85,972 (15,139)	

TABLE 2-10. EXTRA LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant D-1	Plant D-2	Plant D-3
• High-Bake Exterior Flexible Clearcoat			
- Volume of coating sprayed, L/yr (gal/yr)		189,288 (50,010)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating*		0.52 (4.3)	
- % solids by volume at gun*		39.4 39.4	
- Volume of VOC sprayed, l/yr (gal/yr)		114,639 (30,288)	
- Volume of solids applied, l/yr (gal/yr)		32,099 (8,481)	
• Low-Bake Exterior Flexible Primer			
- Volume of coating sprayed, L/yr (gal/yr)		94,587 (24,990)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating*		0.72 (6.0)	
- % solids by volume at gun*		15.5 15.5	
- Volume of VOC volume sprayed, l/yr (gal/yr)		79,933 (21,118)	

TABLE 2-10. EXTRA LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant D-1	Plant D-2		Plant D-3
- Volume of solids applied, l/yr (gal/yr)		6,301	(1,665)	
• Low-Bake Exterior Flexible Colorcoat				
- Volume of coating sprayed, L/yr (gal/yr)		189,288	(50,010)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating*		0.68	(5.7)	
- % solids by volume at gun*		19.7	19.7	
- Volume of VOC sprayed, l/yr (gal/yr)		151,963	(40,149)	
- Volume of solids applied, l/yr (gal/yr)		16,049	(4,240)	
• Low-Bake Exterior Flexible Clearcoat				
- Volume of coating sprayed, L/yr (gal/yr)		94,621	(24,999)	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating*		0.50	(4.2)	
- % solids by volume at gun*		40.8	40.8	

TABLE 2-10. EXTRA LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant D-1	Plant D-2	Plant D-3
- Volume of VOC sprayed, l/yr (gal/yr)		55,973 (14,788)	
- Volume of solids applied, l/yr (gal/yr)		16,619 (4,391)	
• High-Bake Exterior Nonflexible Primer			
- Volume of coating sprayed, L/yr (gal/yr)			283,906 (50,010)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating*			0.50 (4.2)
- % solids by volume at gun*			40.8 40.8
- Volume of VOC sprayed, l/yr (gal/yr)			167,944 (29,583)
- Volume of solids applied, l/yr (gal/yr)			49,863 (8,783)
• High-Bake Exterior Nonflexible Colorcoat			
- Volume of coating sprayed, L/yr (gal/yr)			567,812 (99,990)

TABLE 2-10. EXTRA LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant D-1	Plant D-2	Plant D-3	
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating*			0.55	(4.6)
- % solids by volume at gun*			35.2	35.2
- Volume of VOC sprayed, l/yr (gal/yr)			367,878	(64,782)
- Volume of solids applied, l/yr (gal/yr)			85,972	(15,139)
• High-Bake Exterior Nonflexible Clearcoat				
- Volume of coating sprayed, L/yr (gal/yr)			283,906	(50,010)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating*			0.52	(4.3)
- % solids by volume at gun*			39.4	39.4
- Volume of VOC sprayed, l/yr (gal/yr)			171,943	(30,288)
- Volume of solids applied, l/yr (gal/yr)			48,144	(8,481)

TABLE 2-10. EXTRA LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIV ,TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant D-1	Plant D-2	Plant D-3
• Low-Bake Exterior Nonflexible Primer			
- Volume of coating sprayed, L/yr (gal/yr)			94,587 (24,990)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating*			0.72 (6.0)
- % solids by volume at gun*			15.5 15.5
- Volume of VOC sprayed, 1/yr (gal/yr)			79,933 (21,118)
- Volume of solids applied, 1/yr (gal/yr)			6,301 (1,665)
• Low-Bake Exterior Nonflexible Colorcoat			
- Volume of coating sprayed, L/yr (gal/yr)			189,288 (50,010)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating*			0.68 (5.7)
- % solids by volume at gun*			19.7 19.7
- Volume of VOC sprayed, 1/yr (gal/yr)			151,963 (40,149)

TABLE 2-10. EXTRA LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant D-1	Plant D-2	Plant D-3	
- Volume of solids applies, l/yr (gal/yr)			16,049	(4,240)
• Low-Bake Exterior Nonflexible Clearcoat				
- Volume of coating sprayed, L/yr (gal/yr)			94,625	(25,000)
- VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating*			0.50	(4.2)
- % solids by volume a gun*			40.8	40.8
- Volume of VOC sprayed, l/yr (gal/yr)			55,975	(14,789)
- Volume of solids applies, l/yr (gal/yr)			16,619	(4,391)
Coating Equipment				
• Conveyorized lines	0	0	0	
• Booths per line	0	0	0	
• Off-line booths	3	3	3	
• Air Atomized spray guns (25% TE)				
- manual	3	3	3	
- robotized	0	0	0	

TABLE 2-10. EXTRA LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant D-1	Plant D-2	Plant D-3
• Electrostatic spray guns (50% TE)			
- manual	0	0	0
- robotized	0	0	0
• High volume low pressure (HVLP) (50% TE)			
- manual	0	0	0
- robotized	0	0	0
• Dry filter spray booths	3	3	3
• Recirculating waterwash spray booths (Side-draft for automated spray, Down-draft for manual spray)	0	0	0
• Spray booth ventilation rate (manual), m^3/s (acfm)	7.5 (16,000)	7.5 (16,000)	7.5 (16,000)
Spray booth ventilation rate (automated), m^3/s (acfm)	3.3 (7,000)	3.3 (7,000)	3.3 (7,000)
• Gas-fired curing ovens	0	0	0

TABLE 2-10. EXTRA LARGE MODEL PLANT PARAMETERS FOR AUTOMOTIVE/TRANSPORTATION SECTOR (CONTINUED)

Parameter	Plant D-1	Plant D-2	Plant D-3
Coating Application			
• Average transfer efficiency			
– prime, colorcoat, or clearcoat	43%	43%	43%
• Average dry film thickness			
– primer	1 mil	1 mil	1 mil
– colorcoat	1.5 mil	1.5 mil	1.5 mil
– clearcoat	1.5 mil	1.5 mil	1.5 mil
– total film thickness applied	4.0 mil	4.0 mil	4.0 mil
• Average flash-off period			
– primer	Variable	Variable	Variable
– colorcoat	Variable	Variable	Variable
– clearcoat	Variable	Variable	Variable
• Curing temperature and time in bake - oven			
– primer	air dry	170	250
– colorcoat	air dry	250	250
– clearcoat	air dry	250	250
• Average conveyor speed,	N/A	N/A	N/A
m/s (ft/min)	N/A	N/A	N/A

scenarios for each size of model plant were explored. Therefore, the model plants for the automotive/transportation industry were developed assuming that only one type of plastic is coated. By differentiating the model plants by the type of plastic coated, a facility coating two or three different types of plastics would be able to compare processes with the model plants of the appropriate size and processes.

The coatings used in the plastic parts industry have different VOC and solids contents depending on their application (i.e., primer, colorcoat, clearcoat, low-bake, and high-bake). Therefore, each type of coating was evaluated separately for each of the plastic types coated.

Because of the very low usage of specialty coatings, their effect on emissions estimates is expected to be negligible. Therefore, specialty coatings are not included in the model plant scenarios.

The following sections describe the model plant coating consumption, operating parameters, and baseline VOC emissions.

2.7.1.1 Coating Consumption. Annual coating consumption data were selected as the basis for establishing the four sizes of model plants. These data were obtained from permitting information, which is more readily available than data pertaining to the total surface area of parts coated per year. The total amount of solids sprayed is a function of the coating formulation (which varies with each coating category) and annual coating consumption.

The annual coating consumption data used to establish the model plants were taken from permitting data supplied by the Ohio EPA. The data indicated that the industry could be categorized by four size ranges. These sizes coincided with those reported in the response to the EPA's investigation.[29] The annual coating consumption of the facilities that fell into each of the four size ranges was averaged to determine each of the four representative model plant sizes.

Transfer efficiency plays a key role in determining the annual coating consumption of a spray coating facility. The lower the transfer efficiency, the more coating that is needed to coat a given part. For the model plants, the volume of solids deposited at baseline is based on an estimated transfer efficiency of 25 percent if sprayed using a conventional air atomized spray gun or 50 percent if sprayed using either an electrostatic or an HVLP spray gun. These transfer efficiencies are based on average values reported in the literature and by industries using the equipment, and from responses to inquiries by the EPA.

Because each model plant uses a combination of spray gun types, a weighted transfer efficiency was estimated for each model plant based on the type and number of guns assumed, the expected transfer efficiency of the gun, and the assumption that an equal volume of coating passes through each gun.

2.7.1.2 Process Parameters. Interior plastic parts are usually coated with a primer and a nonflexible colorcoat. Exterior parts require three different types of coating. A primer coat is needed to ensure that the additional coating layers will adhere to the part. If the exterior part is flexible (such as a RIM fascia), the coating of choice would be a flexible coating. Flexible coatings can better survive impact and are less prone to cracking. A flexible colorcoat would be applied to the exterior part following application of the primer. Finally, an exterior flexible clearcoat would be applied. If the exterior part is not flexible, such as an SMC body panel, then a flexible coating is not necessary; however, three coating layers would still be needed: primer, colorcoat, clearcoat.

The type of primer, colorcoat, and clearcoat selected also varies depending upon the substrate being painted. Both high-bake and low-bake coatings are used to some extent in all applications described above. The proportion of high-bake and low-bake coatings used in the model plants was determined based on national usage data for high-bake versus low-bake coatings. Interior parts coatings are primarily low-bake, while exterior coatings are primarily high-bake. Table 2-11 shows the amount of high- and low-bake coating used at the three small model plants. The ratios of high-bake to low-bake coating usage for the medium, large, and extra large model plants are the same as those for the small model plants. The baseline coatings used in the model facilities were selected based on information obtained from coating facilities, coating manufacturers, the National Paint and Coatings Assocation (NPCA), and previous regulatory investigations.[2,27,30] The corresponding amount of solids sprayed for each coating type was calculated from this information, assuming an average density of 7.1 pounds VOC per gallon (lb VOC/gal) coating for the coating thinner added by the coater before spraying.[30]

Conveyorized lines require a large capital investment that can only be recovered by facilities with high production rates. For this reason, only the three largest model plants have conveyors included in their coating operations. Likewise, robotized and electrostatic spray systems require extensive capital investment. For this reason, only the two largest model plants have robotized, electrostatic spray equipment. In addition, waterwash spray booths are found in use only at the larger, higher-production facilities because this type of spray booth also requires extensive capital investment.

2.7.1.3 Baseline Volatile Organic Compound Emissions. Baseline VOC emissions were determined based on the assumption that all VOC's in coatings are emitted and that baseline should reflect coating technologies currently in use. The baseline VOC content levels were determined for each type of coating by considering available coating consumption and VOC content data along with existing State regulations--in particular, Michigan's Rule 632 and the South Coast Air Quality Management District's 1987 limits. A database was developed with information on the VOC content of each coating identified in this study.

TABLE 2-11. AUTOMOTIVE/TRANSPORTATION MODEL PLANT COATINGS

Model Plant	Coating Type	Usage (gal/yr)
1	Interior	
	Low-bake primer	2,850
	High-bake primer	150
	Low-bake colorcoat	8,550
	High-bake colorcoat	450
2	Exterior Flexible	
	High-bake primer	2,880
	Low-bake primer	120
	High-bake clearcoat	2,330
	Low-bake clearcoat	670
	High-bake colorcoat	3,400
	Low-bake colorcoat	2,600
3	Exterior Nonflexible	
	High-bake primer	2,750
	Low-bake primer	250
	High-bake clearcoat	2,330
	Low-bake clearcoat	670
	High-bake colorcoat	3,400
	Low-bake colorcoat	2,600

Information on VOC content was gathered from responses to questionnaires sent to coating users, from material safety data sheets (MSDS's) obtained during site visits and from one coating formulator, and from background information obtained from Michigan's regulatory development processes. In addition, significant data on coating usage and VOC content were supplied by the NPCA.[30] These data reflect a nationwide survey of plastic parts coatings used for automotive and transportation applications.

Table 2-12 shows the baseline VOC content for each coating category used in the automotive/transportation model plants. The weighted average VOC content was calculated from 1988 national usage data for each coating and was used as a guideline for determining the baseline level. These weighted averages were compared to the ranges of VOC contents in the coating database and adjusted as necessary to reflect current reported usage.[31]

2.7.2 Model Plants in the Business Machine Sector

Three model plants were developed to represent the major equipment and techniques currently being used to surface coat plastic parts for business machines (including office, medical, stereo, and telecommunications equipment). These model plants represent the range of facility types in this segment, from facilities that perform coating services exclusively up to large contractors with fully automated facilities that perform both molding and coating of plastic parts. The three model plants developed for the business machine segment were selected based on information collected during the data gathering phase of this project and during development of the New Source Performance Standard (NSPS) for Plastic Parts for Business Machines.[7,32] The three model plants represent small (Plant A), medium (Plant B), and large (Plant C) facilities. The model plant in each size category is expected to apply all four types of coatings: primer,

TABLE 2-12. BASELINE VOC LEVELS FOR AUTOMOTIVE/TRANSPORTATION SECTOR

Coating Category	Baseline (lb VOC/gal)
Auto Interiors	
High-Bake Colorcoat	4.6
High-Bake Primer	5.4
Low-Bake	6.0
Low-Bake	6.0
Auto Exteriors	
Flexible	
High-Bake Colorcoat	4.6
High-Bake Clearcoat	4.3
High-Bake Primer	5.4
Low-Bake Primer	6.0
Low-Bake Colorcoat	5.7
Low-Bake Clearcoat	4.2
Nonflexible	
High-Bake Colorcoat	4.6
High-Bake Clearcoat	4.3
High-Bake Primer	4.2
Low-Bake Primer	6.0
Low-Bake Colorcoat	5.7
Low-Bake Clearcoat	4.2

colorcoat, color/texture coat, and EMI/RFI shielding. The model plant parameters developed for business machines are presented in Table 2-13.

2.7.2.1 Production. The baseline coating utilization estimates presented in Table 2-13 are based on data used in the development of the NSPS for Plastic Parts for Business Machines as well as information collected during this study. Because plant sizes used in developing the business machines NSPS were felt to be representative of the industry, they were retained for this analysis. Model plant transfer efficiency was estimated in the same way as described in Section 2.7.1.1.

2.7.2.2 Process Parameters. The baseline coatings used in each of the business machine applications were selected based on information in the coating database. The most commonly used baseline colorcoats and color/texture coats are solvent-based polyurethanes, and contain 13 to 80.6 percent solids by volume at the gun. The most commonly used primers are also organic solvent-based polyurethanes containing 14 to 41 percent solids by volume at the gun.

All three model plants have the capability to perform EMI/RFI shielding, although not all plastic parts require it. A typical EMI/RFI shielding would be either a nickel- or copper-filled coating with an organic solvent base containing 27 percent solids by volume at the gun.[33]

As discussed for the automotive/transportation segment, conveyorized lines, robotized and electrostatic spray systems, and waterwash booths are found only in the larger facilities because these types of equipment require a large capital investment.

2.7.2.3 Baseline Volatile Organic Compound Emissions. Baseline VOC levels selected for the model plants representing the business machine segment are presented in Table 2-14. The baseline coatings used in each type of business machine coating application were selected based on information

TABLE 2-13. MODEL PLANT PARAMETERS FOR BUSINESS MACHINES

Parameter	Plant A		Plant B		Plant C	
I. Production						
A. Total volume of coating used at capacity, L/yr (gal/yr)	19,408	(5,127)	155,202	(41,000)	388,031	(102,507)
B. Total solids sprayed, L/yr (gal/yr)	4,192	(954)	33,524	(7,626)	83,815	(19,066)
C. Total solids applied, L/yr (gal/yr)	1,048	(238)	11,733	(2,669)	32,595	(7,415)
II. Operating Parameters						
A. Period of Operation						
1. hours/day		16		16		16
2. days/week		5		5		5
3. weeks/year		50		50		50
III. Process Parameters						
A. Computer Cabinet						
1. Solvent-borne primer						
a. Volume of coating sprayed, L/yr (gal/yr)	4,852	(513)	38,800	(4,100)	97,008	(10,251)
b. VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating	0.68	(5.7)	0.68	(5.7)	0.68	(5.7)
c. % solids by volume at gun	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%
d. Volume of VOC sprayed, L/yr (gal/yr)	3,982	(410)	31,040	(3.280)	77,606	(8,201)
e. Volume of solids applied, L/yr (gal/yr)	243	(26)	2,716	(287)	7,545	(797)
2. Colorcoat - Solvent based						
a. Volume of coating sprayed, L/yr (gal/yr)	5,822	(1,538)	46,561	(12,300)	116,409	(30,752)
b. VOC content of baseline coating kg VOC/L (lb VOC/gal) coating	0.74	(6.2)	0.74	(6.2)	0.74	(6.2)
c. % solids by volume at gun	13.0%	13.0%	13.0%	13.0%	13.0%	13.0%
d. Volume of VOC sprayed, L/yr (gal/yr)	5,065	(1,338)	40,508	(10,701)	101,276	(26,754)
e. Volume of solids applied, L/yr (gal/yr)	189	(50)	2,119	(560)	5,885	(1,555)
3. Colorcoat/Texture coat - solvent-based						
a. Volume of coating sprayed, L/yr (gal/yr)	4,852	(1,282)	38,800	(10,250)	97,008	(25,627)
b. VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating	0.74	(6.2)	0.74	(6.2)	0.74	(6.2)
c. % solids by volume at gun	13.0%	13.0%	13.0%	13.0%	13.0%	13.0%
d. Volume of VOC sprayed, L/yr (gal/yr)	4,221	(1,115)	33,756	(8,918)	84,397	(22,295)
e. Volume of solids applied, L/yr (gal/yr)	158	(42)	1,765	(466)	4,904	(1,296)

TABLE 2-13 MODEL PLANT PARAMETERS FOR BUSINESS MACHINES (CONTINUED)

Parameter	Plant A		Plant B		Plant C	
4. EMI/RFI Solvent-borne nickel- or copper-filled acrylic for EMI/RFI Sheilding						
a. Volume of coating sprayed, L/yr (gal/yr)	6,793	(1,794)	54,321	(14,350)	135,811	(35,877)
b. VOC content of baseline coating, kg VOC/L (lb VOC/gal) coating	0.66	(5.5)	0.66	(5.5)	0.66	(5.5)
c. % solids by volume at gun	27.0%	27.0%	27.0%	27.0%	27.0%	27.0%
d. Volume of VOC sprayed, L/yr (gal/yr)	4,959	(1.310)	39,654	(10,476)	99,142	(26,191)
e. Volume of solids applied, L/yr (gal/yr)	459	(191)	5,113	(1,356)	14,260	(3,767)
B. Coating equipment						
1. Conveyorized lines	0		1		2	
2. Booths per line	0		3		3	
3. Off-line booths	2		2		3	
4. Air atomized spray guns (25% TE)						
a. Manual	2		3		4	
b. Robotized	0		0		0	
5. Electrostatic spray guns (50% TE)						
a. Manual	0		0		0	
b. Robotized	0		0		0	
6. High volume low pressure (HVLP) (50% TE)						
a. Manual	0		2		5	
b. Robotized	0		0		0	
7. Dry filter spray booths	2		5		6	
8. Recirculating waterwash spray booths (Side draft for automated spray, down draft for manual spray)	r		0		0	
9. Spray booth ventil. rate (man.), m3/s (acfm)	4.7 (10,000)		4.7 (10,000)		4.7 (10,000)	
10. Spray booth ventil. rate (auto.), m3/s (acfm)	N/A N/A		N/A N/A		14.1 (30,000)	
11. Gas-fired curing ovens	1		2		2	
C. Coating application						
1. Average transfer efficiency						
a. primer, colorcoat, or clearcoat	25%		35%		39%	
2. Average film thickness						
a. primer	2 mil		2 mil		2 mil	
b. colorcoat	1 mil		1 mil		1 mil	
c. clearcoat	3 mil		3 mil		3 mil	
d. total film thickness applied	6 mil		6 mil		6 mil	

TABLE 2-13 MODEL PLANT PARAMETERS FOR BUSINESS MACHINES (CONTINUED)

Parameter	Plant A	Plant B		Plant C	
3. Average flash-off period					
a. primer	Variable	12 min		12 min	
b. colorcoat	Variable	12 min		12 min	
c. clearcoat	Variable	12 min		12 min	
4. Curing temperature and time in bake oven (°C/min)					
a. primer	air dry	140	30 min	140	30 min
b. colorcoat	air dry	140	30 min	140	30 min
c. clearcoat	air dry	140	30 min	140	30 min
5. Average conveyor speed, m/s (ft/min)	N/A	0.04 (8)		0.04 (8)	

TABLE 2-14. BASELINE COATINGS FOR THE BUSINESS MACHINE SECTOR

Type of Coating	VOC Content lb/gal of coating less water
Primer	4.5
Colorcoat	4.8
Colorcoat/texture coat	4.8
EMI/RFI Shielding	4.9

presented in the memorandum summarizing information from the coating database.[29] For colorcoats and color/texture coats, a baseline of 4.8 lb/gal, less water was chosen. All color/texture coats and the majority of colorcoats reported also can achieve this level. In addition, all State regulations in effect as of 1991 are at least this stringent.

For primers, the baseline was selected as 4.5 lb VOC/gal coating, less water; for EMI/RFI shielding, a baseline level of 4.9 lb VOC/gal coating, less water, was selected.

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3.0 EMISSION CONTROL TECHNIQUES

3.1 INTRODUCTION

Volatile organic compound emissions occur when organic solvents evaporate from coatings during coating and curing processes. This chapter describes techniques that are available to control VOC emissions from the surface coating of plastic parts. The control techniques discussed are the use of lower-VOC coatings, process modifications, and add-on controls. Section 3.2 presents a discussion of potential coating reformulation options, including waterborne coatings and higher-solids coatings. Section 3.3 discusses potential process modifications that could reduce VOC emissions before they are generated and Section 3.4 presents potential add-on control options to reduce the amount of VOC's that escape to the atmosphere.

3.2 USE OF COATINGS WITH LOWER VOLATILE ORGANIC COMPOUND CONTENT

One method to reduce the amount of VOC's emitted to the atmosphere during the plastic parts surface coating process is through the use of lower-VOC coatings. The two principle types of lower-VOC coatings are waterborne and higher-solids coatings. Although additional lower-VOC coating systems exist, waterborne and higher-solids coatings have been identified as the only technologies that are suitable to a wide variety of applications. They are, consequently, the two lower-VOC technologies that are focused on in this document, and are discussed in Sections 2.3.1 and 3.2.2, respectively. For the sake of completeness, Section 3.2.3 describes some other less widely applicable coatings.

In waterborne coatings, organic solvent is replaced with water (producing either a waterborne or water-reducible coating). Higher-solids coatings increase the volume percent of solids in the coating, thereby reducing the amount of solvent and the amount of coating required to apply a given amount of solids.

The coatings discussed in this chapter were identified in the data-gathering effort to support development of this CTG. Information was obtained from questionnaires, site visits, and from data gathered from States in support of their rulemaking efforts. This information was compiled in a coatings database. The development and use of the database is discussed in separate memoranda.[1,2] All coating contents provided in the database are "as sprayed," and follow recommended dilution instructions.

3.2.1 Waterborne Coatings

Waterborne coatings are those that contain water as the major solvent or disbursent. A generally accepted definition of a waterborne coating is "a coating containing more than 5 weight percent water in its volatile fraction."[3] Waterborne coatings can contain 5 to 40 percent organic co-solvent to aid in wetting, viscosity control, and pigment dispersion, resulting in a much lower VOC content than that of traditional coatings. Waterborne coatings can be applied with the normal application methods found in the painting industry, although airless and electrostatic techniques are less common for waterborne coatings. In addition, all fittings on spray equipment must be made of stainless steel to prevent corrosion.[4,5] The major advantages of waterborne coatings are that they reduce VOC emissions, reduce fire hazard, tend to lower toxicity, and use basically the same application equipment as solvent-borne paints. Color, impact resistance, gloss, weatherability, corrosion resistance, and repairability characteristics are similar to those of conventional coatings. Primary limitations of waterborne formulations include:

- Stainless steel or plastic pipe fittings are often recommended for the coating equipment;
- Some formulations must be protected from freezing (once waterborne coatings have frozen, they cannot be recovered);[6]
- Better control of booth temperature and humidity may be required;
- Longer flash-off time may be needed; and
- Some plastics may be difficult to coat and may have poor adhesion.

The performance of waterborne coatings compared to organic-solvent-based coatings is debated by coaters and coating manufacturers. Many coaters feel that the adhesion, durability, and gloss of waterborne coatings are inferior to those achieved with solvent-based coatings.[7,8] However, some coaters feel the quality of the finish obtained with waterborne coatings is acceptable.[9,10] One of the coaters said that a waterborne EMI/RFI shielding coating outperformed its solvent-based counterparts.[9]

3.2.1.1 Waterborne Coatings for the Automotive/ Transportation Sector. There is limited information on the use of waterborne coatings in the automotive industry. Waterborne coatings are primarily used in interior coatings because of the more stringent durability and gloss requirements for exterior coatings. Automotive industry groups have raised several issues concerning waterborne coatings: (1) color matching with solvent-borne coatings is difficult; (2) waterborne coatings require increased drying time and/or the use of plastics that can withstand drying oven temperatures; (3) stainless steel piping and spray equipment are required; and (4) waterborne coatings have not been developed to meet many coating performance specifications.[11,12] The only waterborne coatings in the current database for the automotive segment are five automotive interior colorcoats, ranging in VOC content from 2.5 to 3.2 lb VOC/gal coating, less water.[2]

3.2.1.2 Waterborne Coatings for the Business Machines Sector. Waterborne exterior decorative/ protective coatings that can be cured at low temperatures are presently used on some plastic business machine parts, although they are not as commonly used as organic-solvent-based coatings. Waterborne coatings are being used to coat structural foam parts that require substantial coating films and to coat straight-injection-molded parts with molded-in color and texture that require films of 0.5 mil or less. Several large business machine manufacturers have approved waterborne coatings for use on their products.

The current plastic parts surface coating database contains 12 waterborne coatings. Each is discussed in the appropriate section below.

3.2.1.2.1 Primers. One waterborne primer, manufactured by Lilly, is available for use on business machines. This coating is reported to have a VOC content of 1.19 lb VOC/gal coating, less water.[13]

3.2.1.2.2 Colorcoats. Eight waterborne colorcoats or color/texture coatings are included in the current database. These coatings are manufactured or distributed by Armitage, Lilly, Komac, and Sherwin Williams and range in VOC content from 1.06 to 2.25 lb VOC/gal coating, less water.[9,11]

3.2.1.2.3 Clearcoats. Information was obtained on one waterborne clearcoat manufactured by Lilly. This coating has a VOC content of 2.5 lb VOC/gal coating, less water.[11]

3.2.1.2.4 Electromagnetic interference and radio frequency interference shieldings. Information was obtained on one waterborne shielding: a waterborne nickel shielding coating with a VOC content of 2.5 lb VOC/gal, less water.[9]

3.2.2 Higher-Solids Coatings

Higher-solids coatings are typically solvent based and contain greater than normal amounts of pigment and binder. Higher-solids paints can reach the 50- to 65-percent solids range, or higher. Higher-solids coatings reduce VOC emissions by allowing less coating to accomplish the same coating job.

For example, a coater using a coating that has 0.25 gallon of solids per gallon of coating will need to use 4 gallons of coatings to apply 1 gallon of solids (at a 100 percent transfer efficiency). Assuming that the remaining coating is VOC, 3 gallons of VOC will be emitted. If the coater switches to a coating containing 0.5 gallon solids per gallon of coating, only 2 gallons of the new coating will need to be used to apply 1 gallon of solids, emitting only 1 gallon of VOC. As the transfer efficiency decreases from 100 percent, the differences become even more pronounced.

Higher-solids coatings have the following additional advantages:

- Less solvent is emitted into the atmosphere;
- Less coating must be shipped, stored, pumped, and sprayed;
- Lower oven air volumes are required;
- Spray booths may sometimes be smaller;
- Formulations may be less expensive to produce on a solids basis; and
- Less energy is needed for solvent evaporation.

Operating cost savings of 20 to 30 percent are common when a coating process switches from higher-solvent coatings to higher-solids coatings.[14]

The limitations of higher-solids coatings include:

- High-viscosity coatings must often be heated to around 93°C (200°F) to achieve sprayability;
- They may exhibit poor performance in dip tanks and flow coaters because of excessive viscosity;
- Films may be much thicker at the bottom of the parts than at the top;
- Difficulty in pumping and atomizing may be experienced, especially when cold;
- The cleaning quality of the coating may be more important than for conventional paints because there is less solvent present to "clean as it coats;"

- Overspray is difficult to clean up because it remains in the uncured state and is sticky; and

- The added viscosity may preclude the use of some spray systems, which could lead to additional capital expenditures for new equipment.

3.2.3 Non-Volatile-Organic-Compound-Emitting Coatings

This section describes lower-VOC coating technologies other than waterborne and higher-solids technologies. Most of these alternatives are applicable to specialized uses.

3.2.3.1 Electromagnetic Interference and Radio Frequency Interference Shieldings. Alternative coatings that provide EMI/RFI shielding but usually do not emit VOC's include zinc-arc spraying, electroless plating, and vacuum-metallizing or sputtering. Considerations other than VOC emissions greatly influence the EMI/RFI shielding techniques used. Two important considerations are shielding effectiveness and the cost of a given technique. Cost factors are discussed in Chapter 5.0. Simple comparisons of EMI/RFI shielding effectiveness cannot be made among the different shielding techniques. Shielding effectiveness depends on the type of material used for shielding, coating thickness, coating uniformity, and the frequency of the EMI/RFI signals.

The three methods of non-VOC EMI/RFI coatings are briefly discussed below. Techniques that provide EMI/RFI shielding without application of any surface coating are discussed in Section 3.3.2.2.

3.2.3.1.1 Zinc-arc spraying. Zinc-arc spraying is a two-step process in which the plastic surface is roughened by sanding or grit-blasting, and a coating of molten zinc is sprayed onto the roughened surface. Advantages of zinc-arc spraying include high shielding effectiveness over a wide range of frequencies and the fact that it is a widely demonstrated EMI/RFI shielding technique. Disadvantages include the need for special equipment such as a zinc-arc spray gun, a spray gun air supply, a face shield and breathing air supply or respirator for the operator, hearing protection, and a waterwash spray booth or baghouse dust collector.[15]

3.2.3.1.2 Electroless plating. Electroless plating is a dip process in which a film of metal is deposited from aqueous solution onto all exposed surfaces of the part. The plastic parts are prepared for electroless plating by oxidizing their surfaces with aqueous chromic and sulfuric acids or with gaseous sulfur trioxide. Following the oxidizing step, a metal film (usually copper, nickel, or chrome) is electrolessly plated onto the plastic part.

Advantages of electroless plating include the ability to coat the plated parts electrostatically, low materials and labor costs, and good shielding effectiveness. One disadvantage is the incompatibility of electroless plating with molded-in color unless masking is used. Another disadvantage is the potential for VOC emissions if coatings that emit VOC's are applied prior to the plating step so that only selected areas of the parts are plated.[16]

3.2.3.1.3 Vacuum-metallizing or sputtering. Vacuum-metallizing and sputtering are two similar techniques in which a thin film of metal is deposited onto the plastic substrate from the vapor phase. Although no VOC emissions occur during the actual metallizing process, solvent-based prime coats and topcoats are often sprayed onto parts to promote adhesion and prevent degradation of the metal film. The VOC emissions reduction potential of these techniques depends on the extent to which VOC-containing prime coats and topcoats are used, and the VOC content of the coatings used. A disadvantage of these techniques is the need to purchase additional equipment.

3.2.3.2 Other Coatings. Other coating technologies that emit little or no VOC's are powder coatings, UV or electronic-beam cure coatings, and vapor-cure coatings. These coating technologies are currently more limited in their use on plastic parts than are waterborne and higher-solids coatings, but are growing in popularity for some coating applications. A description of the three systems follows.

3.2.3.2.1 Powder coatings. Powder coating is a coating that is applied in the form of a finely ground dry powder. The powder weakly adheres to a substrate by means of electrical attraction. After application, parts are heated to melt the powder, which is then cooled to form a solid film. The major advantages of powder coating are:

- No solvent emissions and/or related costs;
- Less fire hazard;
- Less toxicity;
- No water pollution;
- No liquid mixing or pumping required;
- Less make-up air required;
- No flash-off time needed;
- Less tendency to trap air-borne dirt; and
- Less shrinkage stress developed during curing.

The most serious limitations of the powder coating process are:

- Limited use on plastics because of the high cure temperature requirement;
- High-quality appearance often difficult;
- Powder must remain dry at all times prior to spraying; and
- Color change is a problem because overspray must be collected for reuse, and each color must be kept separate from the others.

Because of the limitations of powder coatings, they are not used to a significant degree in the plastic coating industry, mainly because many plastics cannot be heated to the temperatures necessary to melt the coating.[15]

3.2.3.2.2 Ultra-violet and electron beam coatings. Ultraviolet cure coatings involve the absorption of light energy by an uncured coating material, resulting in a chemical reaction that cures and hardens the coating. The entire process may take less than one second. The advantages of UV-curable technology is the high-solids nature of the coating (80 to 100 percent solids) and the low temperatures at which the process operates. Disadvantages include the need for specialized equipment for the curing process and the safety hazards associated with this equipment.[17]

In the electron beam coating process, high-energy electrons are produced from an electron beam radiation source. These high-energy electrons cure specially formulated coatings. Like UV-cured coatings, electron beam coatings typically contain low volumes of VOC's, if any. In addition, both UV and electron beam products have lower energy requirements than a typical thermal cure line, and the rapid cure time of these products allows for a high production rate.

Disadvantages of this method includes its ability to cure only what is in the "line-of-sight," higher material costs, possible product hazards, and some problems with adhesion. However, ongoing research is addressing each of these concerns, and the increased emphasis on developing low-VOC coatings is leading to the growth of both UV and electronic beam coatings.[18]

The plastic parts surface coating category accounted for approximately 36 percent of the $110 million radiation-cured (including both UV and electronic beam) coatings market in 1989. The primary use of these coatings is in the coating of parts such as plastic cosmetic caps, containers, ready-to-assemble furniture, speaker enclosures, and headlight bezels for automobiles. One industrial source projects a 12-percent annual growth for radiation-cured products.[17]

3.2.3.2.3 Vapor-cure coatings. Vapor cure coatings are urethane coatings that are cured primarily by exposure to an amine vapor. The coated parts are exposed to the vapor either in a separate curing chamber, or the air to the paint spray device is enriched with the amine vapor. In the latter case, the curing process is initiated as the paint-air mixture leaves the spray gun. Advantages of this coating system include the ability to cure at or near ambient temperatures, short processing cycles, and compatibility with many plastic substrates. The major limitation of this coating system is the fact that it is new, with only a limited number of coatings currently available.[2,5]

3.3 PROCESS MODIFICATIONS

Process modifications can also be employed to reduce the amount of VOC's that are emitted into the atmosphere. The two major types of process modifications are changes in spray equipment and process changes that allow finishing to be completed without the use of solvent-laden coatings. These two modifications are discussed below.

3.3.1 Spray Equipment

Changes in spray equipment can reduce VOC emissions by increasing the transfer efficiency of the process. As discussed in Chapter 2.0, transfer efficiency is defined as the ratio of the amount of coating solids that adheres to the surface of the coated part to the amount of coating solids used (typically, sprayed). Transfer efficiency is dependent on many factors, including part configuration, spray equipment, coating characteristics, and operating parameters (such as distance from nozzle to part and spray booth ventilation rate).

Because equipment type is only one variable in determining transfer efficiency, it is impossible to accurately assign values to the transfer efficiency of specific spray equipment. A discussion of the various spray systems is included in Chapter 2.0. Although actual transfer efficiency values are controversial, there is anecdotal evidence that HVLP systems can reduce coating usage by 20 to 60 percent, with both turbine and non-turbine HVLP guns regularly achieving 20 percent reduction.[19]

3.3.2 Process Changes

Another method of reducing the emissions of VOC is to eliminate the coating process. Several methods for accomplishing this are discussed below.

3.3.2.1 Molded-in Color and Texture. The major non-VOC-emitting technique employed to provide an attractive finish on plastic parts is the use of molded-in color and texture. This method is used primarily on business machines, office equipment, and on the internal components of some machines where color matching and finish are not of primary concern.[6] This method relies on the use of straight injection molding techniques in which pigment is added to the resin before or during the injection molding step to provide the desired color. Molded-in texture requires that the mold itself be tooled in such a way as to provide the desired raised texture pattern on the molded parts. Parts with molded-in color and texture cannot be produced using structural foam injection molding.

The use of molded-in color and texture has been the method of choice for some producers of plastic parts for business machines and miscellaneous equipment.[6,16] Some coaters feel that the technology of molded-in color and texture does not provide satisfactory color reproductibility and color stability, and does not protect the plastic parts from environmental stress. Some coaters report that plastic parts with molded-in color and texture still require some surface coating. If too much coating is applied, however, the molded-in texture may be masked.[6,16]

Cost considerations also influence the use of molded-in color and texture. The mold used for straight injection molding is more expensive than the mold used for structural foam injection molding. The reduction in finishing costs realized by using molded-in color and texture (a straight injection molding process) must, therefore, offset the higher cost of the mold. The cost considerations affecting this choice are complex and depend on many factors, including the size of the part, the complexity of the shape of the part, and the number of parts produced from the mold.

3.3.2.2 Electromagnetic Interference/Radio Frequency Interference Shieldings. There are two types of EMI/RFI shielding techniques that eliminate or reduce the need for surface coating of plastic business machine components: conductive plastics and metal inserts. These are discussed below.

3.3.2.2.1 Conductive plastics. Conductive plastics, which are mixtures of resins and conductive fillers, are not widely used for EMI/RFI shielding at the present time. However, these materials are being studied extensively for their usefulness in business machine applications, and some conductive plastics are already being used to make business machine enclosures. Available resin types include ABS, polycarbonate blends, PPO, nylon 6/6, PVC, and PBT. Conductive fillers include aluminum, steel, metallized glass, and carbon.

Advantages of using conductive plastics include elimination of the EMI/RFI shielding finishing step and improved resistance to warping. Disadvantages include high materials cost; less effective EMI/RFI shielding, especially when structural foam molding is used; and the addition of a cosmetic finishing step to improve the surface appearance.

3.3.2.2.2 Metal inserts. The use of metal inserts to house electronic components within a plastic housing is a demonstrated EMI/RFI shielding technique. The metal insert can be a metal box within a plastic housing, metal foil laminated between layers of compression-molded plastic, metal foil glued inside the housing, or metal screens or fibers placed within a plastic housing. Shielding effectiveness is comparable to that obtained with metal housings. Many equipment manufacturers are switching to metal inserts instead of coatings. The inserts are less expensive and provide a consistent, known shielding ability.[6]

3.4 ADD-ON CONTROL EQUIPMENT

Add-on control equipment such as carbon adsorbers, incinerators, and condensers are presently being used to control VOC emissions at many surface coating facilities, including magnetic tape coaters, fabric coaters, and automobile coaters. Some facilities using add-on control devices have been identified in the plastic parts surface coating industry, including some automotive plastic part coaters who use afterburners on some curing ovens.[20,21] Most of the solvent-laden air in these facilities comes from the application/flash-off area. The concentration of VOC's in this air is very low because it is diluted to protect workers from exposure to harmful levels of organic solvents and overspray. One plastic business machine parts coater uses an adsorption/incineration system to control VOC emissions from the spray booths, flash-off areas, and curing oven.

The amount of VOC's in the air exhausted from the curing ovens is low because the majority of the solvent evaporates before the coated parts enter the oven. Therefore, only a small percent of the total emissions can be reduced by ducting oven emissions to a control device.

The solvent-laden air from the application/flash-off area can be captured and ducted to a control device, but the high volume of air and the low concentration of VOC's make this a costly method of control. Volatile organic compound concentrations in the solvent-laden air would typically range from 10 to 100 ppmv. The actual concentration in the exhaust stream sent to the control device would be affected by variables such as VOC content of the coatings and flow rate of the booth exhaust, a function of blower capacity.

In some cases, such as with automated spray systems, it may be feasible to recirculate the booth exhaust to concentrate the VOC's. This would reduce operating costs of the control device. However, consideration must be given to product quality and safety, thus limiting the applicability of recirculation.

The general principles behind carbon adsorption, incineration, and condensation are discussed in the following sections.

3.4.1 Carbon Adsorption

Carbon adsorption uses a bed of activated carbon to remove organic vapors from an incoming airstream. The mechanism of VOC removal is complex, but the removal efficiency is enhanced by specific characteristics of the carbon. Its high surface-to-volume ratio and its affinity for organics make activated carbon an effective adsorbent of VOC's.

The VOC adsorption efficiency across a carbon bed can be at least 95 percent if the bed is properly maintained and if inlet VOC concentration levels are sufficiently high.[14] Because plastic parts coatings often contain ketones (e.g., methyl ethyl ketone and methyl isobutyl ketone) in their formulations, they pose significant operation concerns for carbon adsorption equipment because of the potential for ketones to cause fires on the carbon bed. Safety precautions, in the form of nitrogen blanketing, restrict the chance for such occurrences but require a more elaborate equipment configuration.

After a carbon bed has adsorbed a certain amount of VOC's, a breakthrough is reached beyond which VOC removal efficiency decreases rapidly. The bed must be regenerated before the breakthrough is reached; otherwise, saturation will occur and removal efficiency will approach zero. Typically, a carbon bed is regenerated by passing steam through the carbon, countercurrent to the regular air flow, to strip the solvent from the carbon. The effluent is either condensed and then separated from the residual water by decantation or it is incinerated. The solvent collected by condensation may be reused, sold, or disposed of as hazardous waste.

Figure 3-1 shows a typical carbon adsorption system. The two-bed configuration allows for continuous operation of the coating facility because one adsorber can be regenerated while the other is on line.

3.4.2 Absorption (Scrubbing)

Absorption involves the scrubbing of soluble organic gas components by a relatively non-volatile liquid. The absorption step is only the collection step. After the gas is dissolved, it must be recovered or reacted to an innocuous form and then reclaimed or disposed of. Common adsorbents for organic vapors are water, non-volatile organics, and aqueous solutions.

This control method is not demonstrated to adequately remove organic solvents from an air stream. Scrubbing towers must be quite large to provide sufficient contact time to solubilize, react, or condense small quantities of organic compounds. Because solubility is generally a function of pollutant concentrations, large volumes of liquid may be required, and this liquid ultimately requires treatment. Because of the expense and limited efficiency of this control method, it is normally not considered a viable control method for reducing coating operation emissions.[16]

3.4.3 Incineration

The incineration process converts incoming VOC to carbon dioxide and water vapor. The two main types of incinerators are thermal incinerators and catalytic incinerators. Heat recovery may be used on both types of incinerators to reduce operating costs. However, capital costs increase as the extent of heat recovery increases.

3.4.3.1 Thermal Incineration. A schematic diagram of a thermal incinerator is shown in Figure 3-2. In this particular design, the solvent-laden air is preheated by primary heat exchange with waste heat from the combustion chamber. A burner is supplied with additional fuel that ignites the preheated air stream.

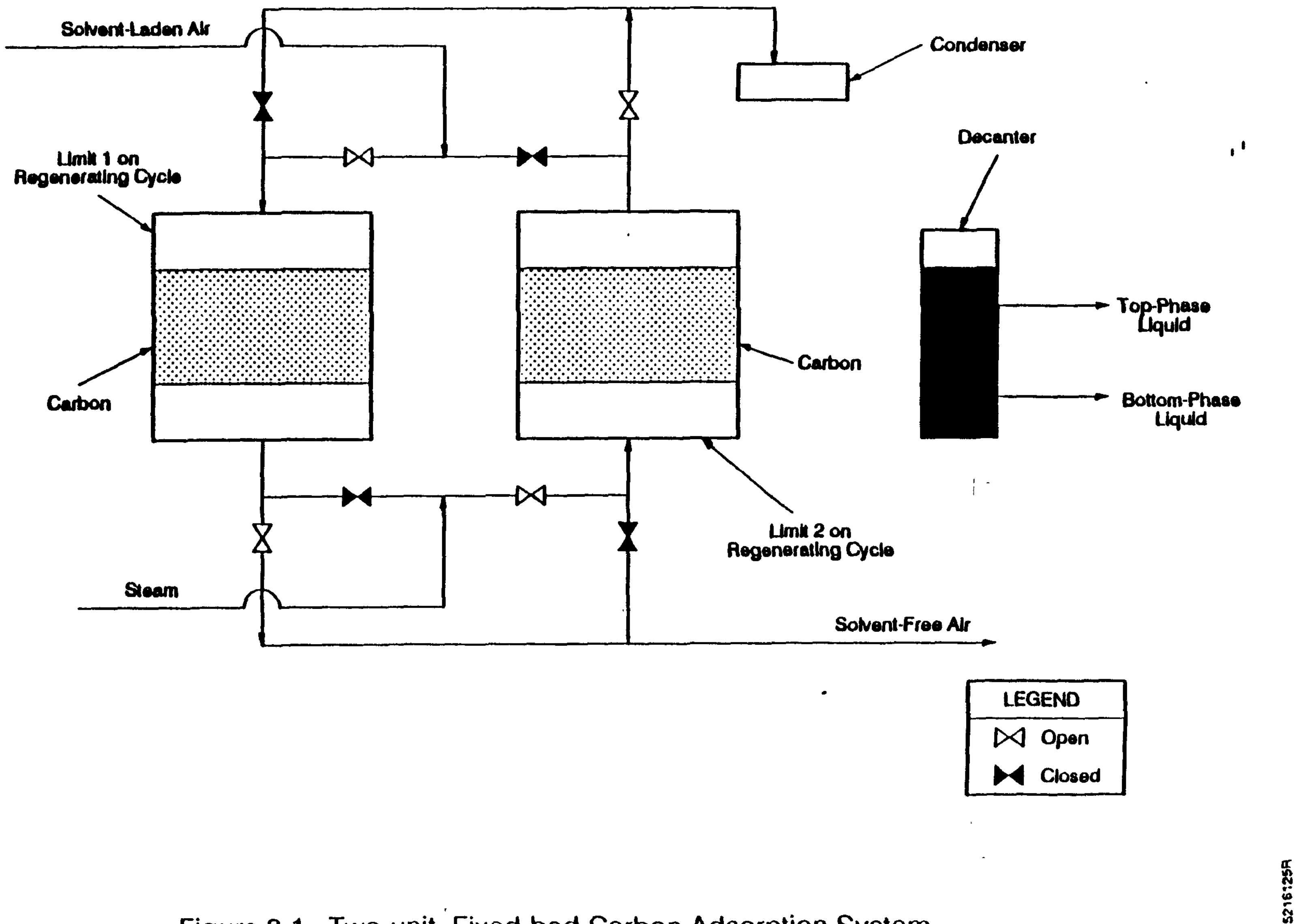

Figure 3-1. Two-unit, Fixed-bed Carbon Adsorption System

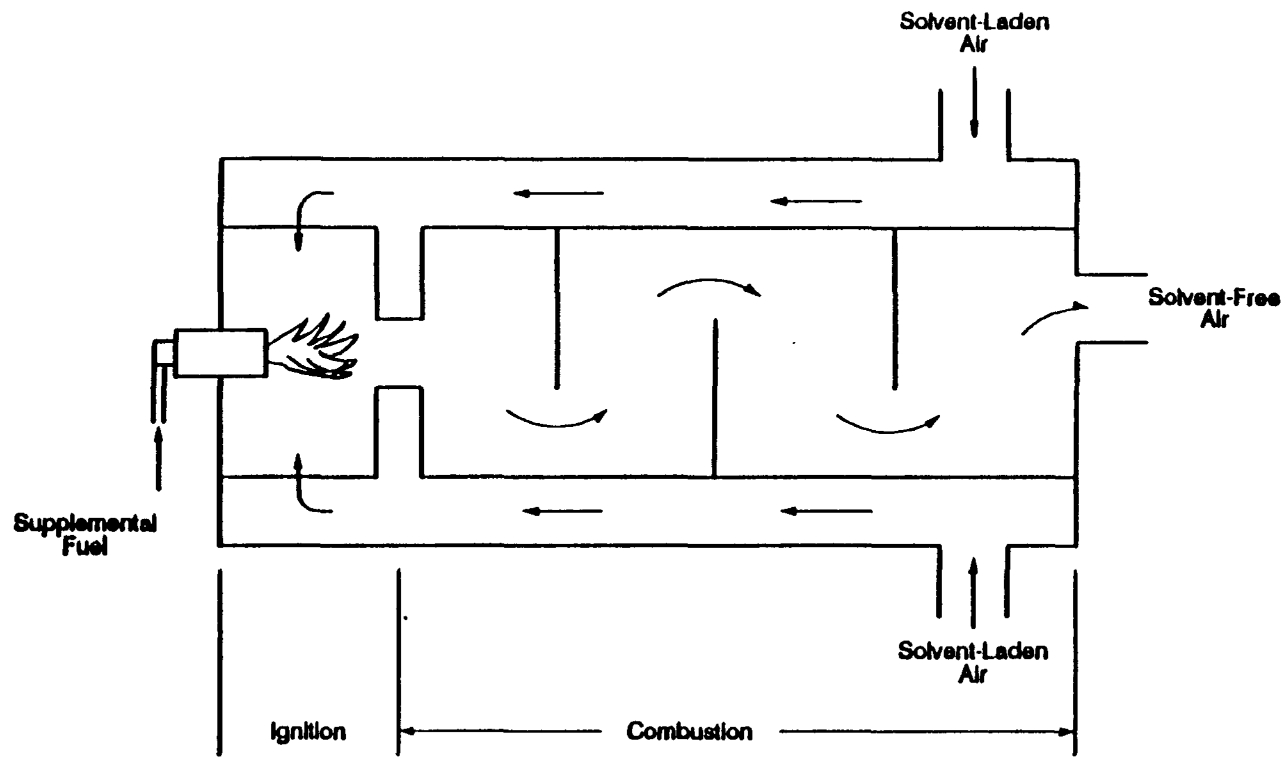

Figure 3-2. Diagram of Thermal Incinerator

Three important design considerations of the combustion chamber are time, temperature, and turbulence. The residence time, which must be sufficient to permit complete combustion of the VOC's, is typically 0.2 to 0.8 seconds. The necessary temperature range for combustion of VOC's using thermal incineration is generally 760°C to 870°C (1400°F to 1600°F). Turbulence facilitates the mechanical mixing of oxygen, heat, and VOC's necessary for maximum destruction efficiency. A properly designed incinerator can achieve destruction efficiencies of 98 percent if VOC concentration levels are sufficiently high.[22]

3.4.3.2 Catalytic Incineration. Figure 3-3 shows a typical catalytic incinerator. The solvent-laden air enters the device from the oven or application area. It is preheated to 260°C to 460°C (500°F to 860°F) and blown across a catalyst site, where oxidation occurs. About 98 percent of the incoming VOC's can be removed in this manner.[20]

The catalyst accelerates the rate of oxidation without undergoing a chemical change itself. Typical materials used are noble metals such as platinum or palladium, dispersed on an alumina support. Combustion temperatures are lower for catalytic incinerators than for thermal incinerators.

3.4.4 Combination of Carbon Adsorption and Incineration

This system is designed to concentrate dilute solvent-laden emissions using carbon adsorption prior to final treatment by solvent recovery or catalytic/thermal incineration. The key component of the system is a rotor that consists of a honeycomb structure element made of activated carbon fiber paper in a corrugated form. The rotor is divided into two sectors (one for adsorption and one for desorption) and rotates continuously at slow speed.

The VOC-laden process exhaust flows through tubular paths in the honeycomb. Hydrocarbons in the process exhaust are adsorbed in the activated carbon filter in the adsorption sector of the rotor. A small air stream is used to desorb the VOC's from the carbon filter. The desorbed air stream is only

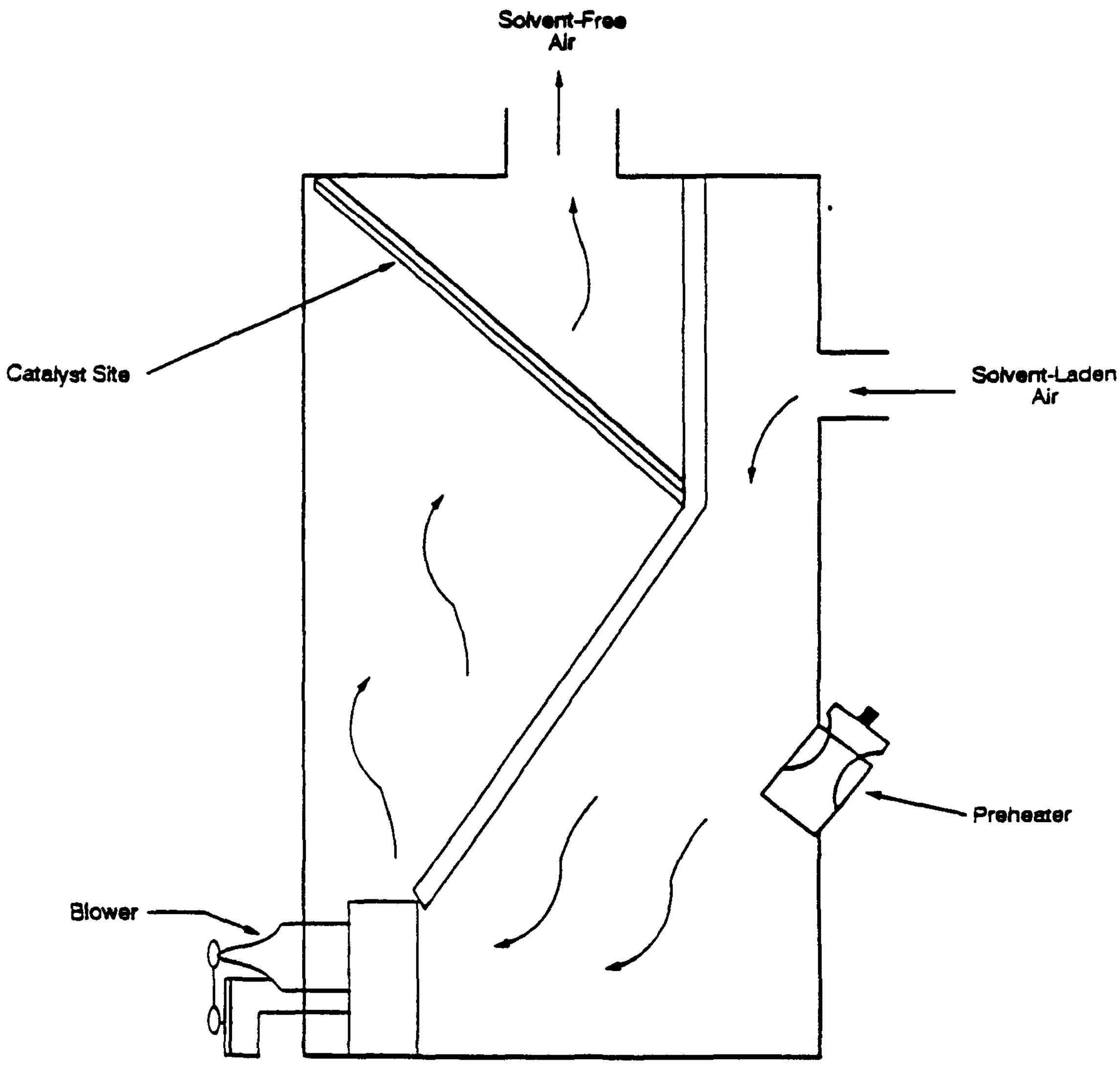

Figure 3-3. Catalytic Incinerator

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one-fifth to one-fifteenth the volume of the original solvent-laden air stream entering the adsorber and, as a result, the solvent concentration 5 to 15 times greater. Therefore, the costs to incinerate this desorbed air stream are lower than those associated with the original solvent-laden stream. Heat from the incinerator is recovered and used to heat the air used in the desorption process of the carbon adsorber--another cost-saving feature of the system.

3.4.5 Condensation

Condensation is a method of controlling VOC emissions by cooling solvent-laden gases to the dew point of the solvent and collecting the liquid droplets. Liquid nitrogen and air are typical coolants used in the shell and tube surface condenser shown in Figure 3-4. Heat is extracted from the incoming air stream as it passes through the cooled metal tubes. When the vapor condenses, it is collected and either reused or discarded, depending on its purity.

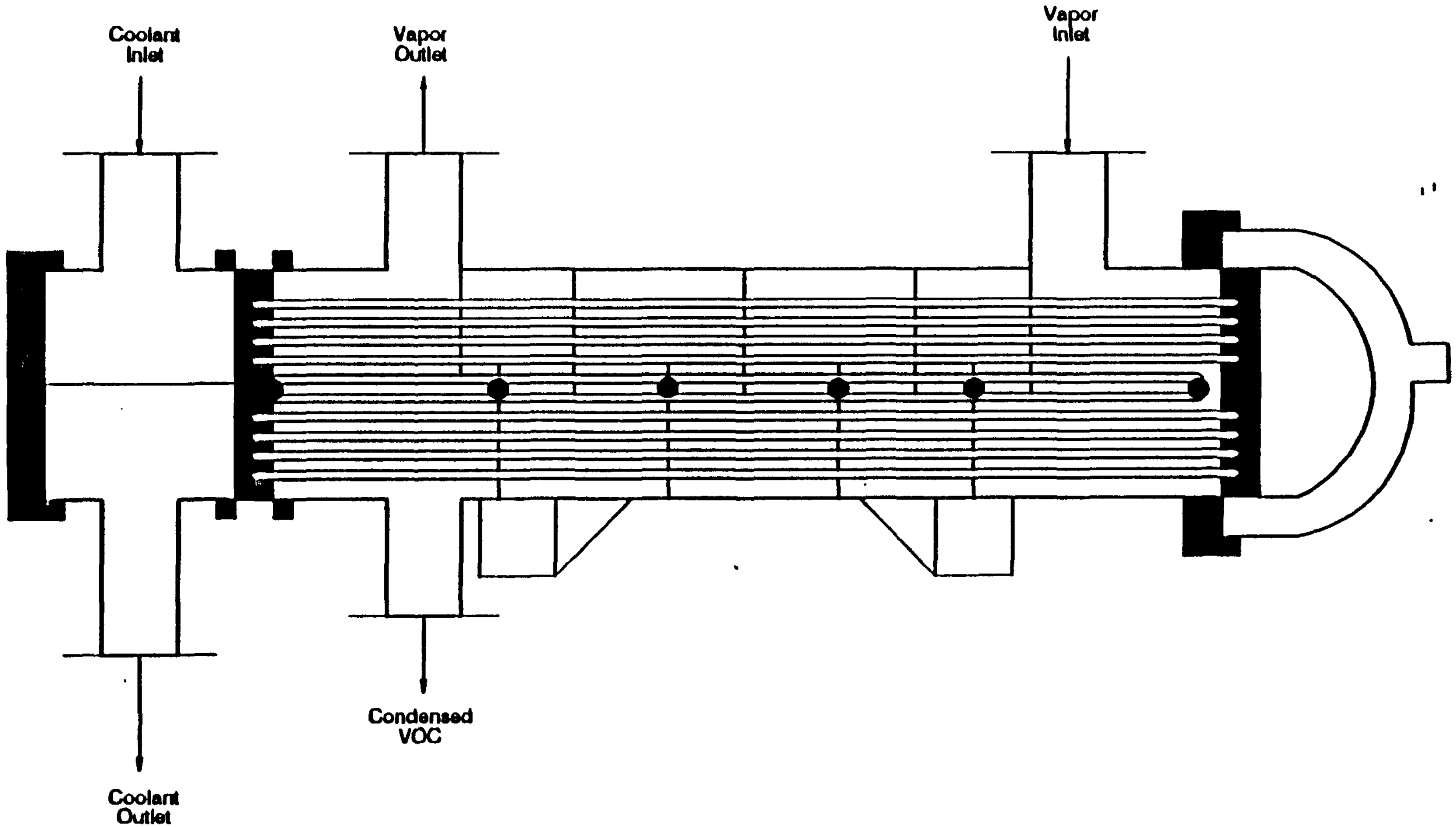

Figure 3-4. Shell and Tube Surface Condenser

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4.0 ENVIRONMENTAL IMPACT

This chapter presents a discussion of the environmental impacts associated with the control of VOC emissions from plastic parts surface coating operations. An analysis of VOC emissions impacts was performed using the model plants presented in Chapter 3.0 and three different VOC control levels representing two control technologies--coating reformulation and thermal incineration. The VOC emissions reductions achieved by each control level at each model plant were calculated. Other environmental impacts were evaluated qualitatively. Section 4.1 presents the three control levels. Sections 4.2, 4.3, and 4.4 cover air emissions, water quality, and solid waste impacts, respectively. Section 4.5 discusses energy consumption. Health and safety impacts are addressed in Section 4.6 and other environmental concerns are discussed in Seciton 4.7.

4.1 CONTROL LEVELS

Three control levels were developed to estimate potential VOC emissions reductions. Two of the levels, Level 1 and Level 2, are based on reformulation (i.e., use of waterborne or higher-solids coatings); the third control level, Level 3, is based on thermal incineration. These technologies were selected for analysis because of their availability and feasibility for the range of coating applications covered by this ACT. A detailed discussion of these control levels and how they were chosen are presented in a separate memorandum.[1]

4.1.1 Reformulation

Table 4-1 presents a summary of the coating reformulation control levels for automotive and business machines plastic parts, as well as baseline VOC levels. Both reformulation options represent VOC levels for types of coatings that would achieve significant VOC emissions reductions and that are currently available. **For more information on exterior automotive coatings see Section 6.1. For more information on business machine coatings see Section 6.2.**

The technology is not now available to formulate specialty coatings with reduced VOC content. Since these coatings are generally used in such small quantities, reformulation may not be cost effective. The recommended control options for specialty coatings are therefore equal to the baseline levels. The baseline levels are based on data obtained from trade associations, industry, and EPA's coating data base.[2,3,4,5]

One important exception is adhesion primers (adhesion promoters) which are used in large quantities at some automotive bumper painting facilites. In the past year several automobile manufacturers have approved waterborne adhesion promoters for use by their suppliers. These waterborne coatings have been used in production by some coaters, but there are still concerns about how coating performance may vary with variations in the resin used to mold the plastic parts.

4.1.2 Thermal Incineration

Control Level 3 is the use of thermal incineration for destruction of VOC's from surface coating operations. As described in Section 3.4, VOC concentrations in coating operation exhaust streams are typically low--about 10 to 100 ppmv. Auxiliary fuel is therefore required for incineration. For the purposes of impact analysis, 80 percent capture efficiency and 98 percent destruction efficiency were assumed for thermal incineration.

TABLE 4-1. REFORMULATION CONTROL LEVEL (LOW-VOC COATINGS)

Coating category	Baseline (lb VOC/gal)	Control level 1 (lb VOC/gal)	Control level 2 (lb VOC/gal)
Auto interiors			
High-bake colorcoat	4.5	4.3	4.1
High-bake primer	5.4	4.3	3.8
Low-bake colorcoat	6.0	5.0	3.2
Low-bake primer	6.0	3.5	3.5
Auto exteriors[1]			
Flexible			
High-bake colorcoat	4.6	4.3	4.1
High-bake clearcoat	4.3	3.8	3.5
High-bake primer	5.4	5.0	4.5
Low-bake colorcoat	5.7	5.4	5.1
Low-bake clearcoat	4.2	4.0	3.7
Low-bake primer	6.0	5.5	5.5
Nonflexible			
High-bake colorcoat	4.6	4.3	4.1
High-bake clearcoat	4.3	3.8	3.5
High-bake primer	4.2	4.0	3.0
Low-bake colorcoat	5.7	5.4	5.1
Low-bake clearcoat	4.2	4.0	3.7
Low-bake primer	6.0	5.5	5.5

[1] For additional information on exterior automobile coatings see Section 6.1.

TABLE 4-1. REFORMULATION CONTROL LEVEL (LOW-VOC COATINGS) (CONTINUED)

Coating category	Baseline (lb VOC/gal)	Control level 1 (lb VOC/gal)	Control level 2 (lb VOC/gal)
Auto Specialty			
Group A coatings: Black and reflective argent Air bag cover coatings Soft coatings Vacuum metalizing basecoats Texture basecoats	5.5	5.5	5.5
Group B coatings: Gloss reducers Vacuum metalizing topcoats Texture topcoats	6.4	6.4	6.4
Group C coatings: Stencil Adhesion primers Ink pad Electrostatic prep Resist	6.8	6.8	6.8
Headlamp lens coatings	7.4	7.4	7.4

TABLE 4-1. REFORMULATION CONTROL LEVEL (LOW-VOC COATINGS) (CONTINUED)

Coating category	Baseline (lb VOC/gal)	Control level 1 (lb VOC/gal)	Control level 2 (lb VOC/gal)
Business Machines[2]			
Colorcoat	4.8	3.5	2.3
Colorcoat/texture coat	4.8	3.5	2.3
Primer	4.5	2.9	1.2
EMI/RFI shielding	4.9	4.0	4.0
Business Specialty			
Soft coatings	4.3	4.3	4.3
Plating resist	5.9	5.9	5.9
Plating sensitizers	7.1	7.1	7.1

[2] For additional information on business machine coatings see Section 6.2

4.2 AIR EMISSIONS IMPACTS

The air impacts of each control option are presented in Section 4.2.1 in terms of VOC emissions. Consideration to other air emissions occurring during the coating process is given in Section 4.2.2.

4.2.1 Volatile Organic Compound Emissions

Volatile organic compound emissions can occur at several points during the plastic parts coating process: in the spray booth, in the flash-off area, and in the curing oven (as described in Chapter 2.0, some operations do not include a curing oven). The percent of total emissions occurring at each of these points depends on a number of factors, including the transfer efficiency of the operation and the amount of time the parts spend in the flash-off area before entering the oven. However, in all cases, the majority of the emissions occur in the spray booth.

The percentage of emissions occurring at the spray booth depends on the transfer efficiency because only the coating that actually adheres to the part has the potential to dry (and thus release VOC's) outside the confines of the spray booth. For example, if an average transfer efficiency for a coating operation is 25 percent, at least 75 percent of the coating remains in the spray booth or the overspray filter. Therefore, at least 75 percent of the emissions occur in the spray booth.

It is reasonable to assume that an additional percentage of emissions occurs in the spray booth as the coatings adhering to the part begin to dry. Furthermore, coatings applied to plastic parts must dry at lower temperatures than metal parts coatings, so they often contain solvents with lower boiling points. The rapid evaporation of these lower-boiling-point solvents in the spray booth and flash-off area means that only a small portion of the VOC's are emitted in the curing oven (if a curing oven is used). According to some estimates, 80 to 90 percent of VOC emissions occur in the spray booth.[6,7,8]

Emissions reductions are calculated from the difference between the emission level at a model plant using baseline coatings and the emission level at a model plant using coatings that meet a given option. Table 4-1 shows a summary of the VOC content for two potential control levels for which emissions reductions are calculated. The emissions reduction over baseline and the percent emissions reduction achieved by each option at each model plant are shown in Table 4-2. Reductions range from a low of 21 percent for Level 1 controls for automotive/transportation model plants applying exterior coatings to a high of 86 percent calculated for each interior automotive/transportation model plant using the Level 2 control option.

Among the control options requiring coatings with reduced VOC content (Levels 1 and 2), the highest reduction is achieved using Level 2 controls for automotive interior coatings. All four sizes of model plants (A through D) show VOC emissions reductions greater than 80 percent for automotive interior coatings at Level 2. Percent reductions are greatest for automotive interior coatings because this category includes coatings with some of the highest baseline VOC content coatings. Percent reductions are smallest for exterior flexible coatings. Emissions reductions from business machine/miscellaneous coatings are equivalent at all sizes of model plants, with Level 2 achieving the greatest percent reductions for lower-VOC-content coatings.

Emissions reductions would be even greater for the model plants by replacing conventional sprayers with more efficient sprayers (e.g. HVLP) in addition to reduced-VOC-content coatings. By increasing transfer efficiency, HVLP sprayers decrease overspray as well as the total amount of coating used.

As described in Chapter 3.0, coaters can achieve lower VOC content by using waterborne or higher-solids coatings. In addition to containing a lower percentage of VOC's, fewer gallons of a higher-solids coating are required to apply a given amount of solids.

4.2.2 Other Air Emissions

Other air emissions that occur during coating operations include nickel particles from spraying nickel-filled EMI/RFI shielding coatings, aluminum oxide particles from grit

TABLE 4-2. VOLATILE ORGANIC COMPOUND EMISSIONS REDUCTIONS FOR CONTROL OPTIONS

	Automotive Transportation											
Control level	Consumption (gal coating/yr)	Emissions (lb VOC/yr)	Emissions reduction (lb VOC/yr)	(%)	Consumption (gal coating/yr)	Emissions (lb VOC/yr)	Emissions reduction (lb VOC/yr)	(%)	Consumption (gal coating/yr)	Emissions (lb VOC/yr)	Emissions reduction (lb VOC/yr)	(%)
	Plant A-1: Small, Interior				A-2: Small, Exterior, Flexible				A-2: Small, Exterior, Non-Flexible			
Baseline	12,000	71,300	--	--	12,000	59,600	--	--	12,000	56,000	--	--
1	6,000	28,000	44,000	62%	10,200	46,000	12,000	20%	11,000	46,000	10,000	18%
2	4,000	12,000	58,000	81%	9,000	40,000	22,000	37%	10,000	40,000	16,000	29%
3	12,000	71,300	69,874	98%	12,000	59,600	58,408	98%	12,000	56,000	54,880	98%
	Plant B-1: Medium, Interior				B-2: Medium, Exterior, Flexible				B-3: Medium, Exterior, Non-Flexible			
Baseline	27,250	162,000	--	--	27,250	135,200	--	--	27,250	128,000	--	--
1	13,000	62,0000	100,000	62%	23,100	106,200	29,000	21%	24,000	104,000	24,000	19%
2	8,000	28,000	134,000	83%	20,400	87,000	48,200	36%	22,000	90,000	38,000	30%
3	27,250	162,000	158,760	98%	27,250	135,200	132,496	98%	27,250	128,000	125,440	98%
	Plant C-1: Large, Interior				C-2: Large, Exterior, Flexible				C-3: Large, Exterior, Non-Flexible			
Baseline	97,540	580,000	--	--	97,540	484,200	--	--	97,540	458,000	--	--
1	47,000	224,000	356,000	61%	82,900	380,000	104,200	22%	86,000	372,000	86,000	19%
2	30,000	102,000	478,000	82%	73,200	311,200	173,000	36%	78,000	320,000	138,000	30%
3	97,540	580,000	568,400	98%	97,540	484,200	474,516	98%	97,540	458,000	448,840	98%
	Plant D-1: Very Large, Interior				D-2: Very Large, Exterior, Flexible				D-3: Very Large, Exterior, Non-Flexible			
Baseline	300,000	1,782,000	--	--	300,000	1,489,000	--	--	300,000	1,408,000	--	--
1	144,000	680,000	1,102,000	62%	254,900	1,168,600	320,400	22%	263,000	1,146,000	262,000	19%
2	91,000	304,000	1,478,000	83%	225,100	957,000	532,000	36%	241,000	988,000	420,000	37%
3	300,000	1,782,000	1,746,360	98%	300,000	1,489,000	1,459,220	98%	300,000	1,408,000	1,379,840	98%
	Business Machines											
	Plant A-Small				Plant B-Medium				Plant C-Large			
Baseline	5,130	24,600	--	--	41,000	197,000	--	--	102,500	492,000	--	--
1	3,330	11,860	12,740	52%	26,600	94,800	102,200	52%	66,600	238,000	254,000	52%
2	2,370	5,080	19,520	79%	19,000	40,600	156,400	79%	47,400	101,600	390,400	79%
3	5,130	480	24,120	98%	41,000	3,940	193,060	98%	102,500	10,000	482,000	98%

blasting prior to zinc-arc spraying, and zinc oxide fumes from zinc-arc spraying operations. Paint solids from powder coatings are also emitted during spray application. Although free of solvent, the powder can be abrasive.[9] Dry filters and water walls in spray booths often have particulate removal efficiencies in excess of 99 percent; therefore, emissions of the above substances are expected to be minor.[10]

Amine vapors are emitted during the curing of vapor-cure coatings; however, special equipment and separate curing chambers control and minimize emissions from vapor-cure operations.

Certain proprietary compounds are often used in conductive coatings, but their emissions are not known. The conductive coatings are often composed of alcohol, water, organic salt, and proprietary compounds that may produce air emissions during the baking stage. However, these emissions do not appear to be significant. Conductive coatings are applied to the substrates by conventional spray. Electrostatic spray technology may increase the transfer efficiency of conductive coating application.

Cleaning spray booths and spray guns with solvents also produces VOC emissions. Guns can be cleaned by soaking them in vats of solvent.[11] Manual guns can also be cleaned by spraying solvent through the gun.[12] Automatic spray systems can be cleaned with internal solvent circulation systems. Only the tips of the automatic guns or bells require manual solvent cleaning, thus reducing air emissions.[5] Another method of reducing emissions is to reclaim the solvent used for booth and spray gun cleaning through distillation. Distillation can be performed on site or off site, with recoveries of roughly 80 percent.[5]

The following hazardous air pollutants (HAP's) are typically contained in some combination in plastic parts coatings and are emitted during the coating processes: formaldehyde, methanol, methyl ethyl ketone, ethyl benzene, ethylene glycol, methyl isobutyl ketone, toluene, xylene, and glycol ethers. All of these HAP's are VOC's and would be controlled to some extent by each of the alternatives.

Incineration may produce negligible amounts of nitrogen oxides and carbon monoxide from the high temperatures and incomplete combustion of hydrocarbons.

4.3 WATER IMPACTS

Plastic parts surface coating facilities may use water in waterwash spray booths, gun cleaning systems, and dip tanks for electroless plating. Waterwash spray booths are equipped with a water curtain that removes overspray particles from the spray booth exhaust. Water pollution results from the entrainment of coating solids and from the dissolution of soluble overspray components into the water. Water pollution also results from gun-cleaning solvents in waterwash systems. Some systems allow the captured paint and water (oil/water emulsion) to be routed to large vats, where chemicals are added to deactivate the paint, forming a flocculent that can be skimmed off through filtering.[5]

Plastic parts may undergo multi-stage washing cycles that require water in order to prepare the substrates for coatings.[5,13,14] Water is also used in pressurized systems to clean paint build-up from grating and carriers.[5] In addition, metal conveyor rods are often dipped into salt water baths to remove dried paint.[5]

The types of water pollutants likely to result from spray coating operations include organic solvents, resins, pigments such as lead chromates and titanium dioxide, nickel particles from EMI/RFI shielding coatings, and zinc from zinc-arc spraying.[15]

Water pollution from electroless plating processes for EMI/RFI shielding results from dragout, which is defined as the volume of solution carried over the edge of a process tank by an emerging piece of work. This solution usually ends up in the water used to clean the application area or in process drains. Examples of water pollutants emitted from plating processes are sulfuric acid and nickel and chromium compounds.[11]

Only Wisconsin has specific water pollution regulations for the electroplating industry. The Wisconsin Administrative Code, Chapter NR 260, establishes effluent limitations, standards of performance, and pretreatment standards for discharging by electroplaters. Federal water pollution regulations for the electroplating and other industries are governed by the Water Pollution Control Act.[11] This Act specifies several levels of control: (1) for existing plants, best practical control technology currently available and best practical treatment (BPCTCA/BPT) by 1977; (2) for existing plants, best available technology economically achievable and best available treatment (BATEA/BAT) by 1983. The Act allows States to establish more stringent control levels than Federal standards if desired.

Methods currently employed by the coating industry to handle wastewater and sludge include discharging to a sanitary sewer, recycling, incineration, and hauling to a licensed disposal site. Facilities can reduce water pollution by improving transfer efficiency and by using dry filter spray booths and in-plant controls. Use of dry filter spray booths instead of waterwash spray booths will reduce the amount of wastewater, but increase the amount of solid waste generated by a plant. Examples of in-plant controls include separating process and non-process water and reusing and recycling water.

The regulatory alternative of using higher-solids coatings would not appreciably affect water usage or contamination in waterwash spray booths. Regulatory alternatives such as HVLP and electrostatic spray methods reduce overspray and, thus, can decrease the volume of contamination in the wastewater from waterwash spray booths. However, if a scrubber is used as part of an emissions control system, water may need to be discharged into a sewer system.

4.4 SOLID WASTE DISPOSAL IMPACTS

The majority of solid waste generated by the surface coating process is the coating overspray collected by dry filter and waterwash spray booths. Solid waste is usually in the form of dirty filters from dry filter spray booths and sludge from waterwash spray booths. Paint also accumulates on metal carriers, grates, and booths.

Reducing overspray by using HVLP and electrostatic spray techniques can decrease the amount of solid waste generated by coating operations. Paint recirculation systems that constantly agitate and move the paint can also minimize the amount of paint wasted.[5]

Another means of reducing solid waste is a paint recovery system. In one type of system, paint overspray collects onto baffles. The paint solids then drop from the baffles into a barrel, where they are recovered, reduced, and reused.[5] Using only zinc-arc spray for EMI/RFI shielding also reduces solid waste production, if the zinc overspray is recovered and sold by coaters.

Using the reformulations control options, solid waste from coating operations could be significantly reduced where higher-solids coatings are used. Fewer gallons of higher-solids coating are needed to apply the same amount of solids than are needed for conventional coatings. Consequently, less coating is sprayed, and fewer coating containers are disposed of. The use of HVLP's significantly decreases the amount of overspray and, hence, the amount of dry filter and sludge waste.

4.5 ENERGY IMPACTS

Because coatings for plastic parts must cure at a low temperature to avoid damaging the plastic, the energy consumption for this process is lower than for similar metal coating processes. Many of the organic-solvent-based coatings used on plastic parts can be cured at room temperature, but most manufacturers recommend a baking schedule to achieve optimum finish quality.

Waterborne coatings generally require a low-temperature oven cure. Most coaters use low-temperature ovens to speed up production regardless of the types of coatings used. Some coaters feel that increased oven air flows, and even intermediate baking between coats, are necessary to produce an acceptable finish with waterborne coatings.[5] Regulatory alternatives that require the exclusive use of waterborne exterior coatings or waterborne EMI/RFI shielding coatings might increase energy consumption at some surface coating plants because of the higher air flow rates or longer curing times. However, waterborne coatings are cured at temperatures in the range of 50°C to 60°C (125°F to 149°F), similar to those used for organic-solvent-based coatings. Therefore, the energy impact of the regulatory alternatives specifying waterborne coatings is expected to be negligible.

Regulatory alternatives such as emission control equipment and application equipment with better transfer efficiency (e.g., HVLP and electrostatic spray devices) could require additional energy in the form of electricity or fuel consumption.

4.6 HEALTH AND SAFETY IMPACTS

Some of the regulatory alternatives intended to reduce VOC emissions may affect the health and safety standards for workers at surface coating plants. Worker exposure to some of the materials used in the surface coating process must be controlled through the use of respirators and proper ventilation. For example, vapor cure and powder coatings can reduce VOC emissions, but worker exposure to the fumes and particles must be considered. Electrostatic spray devices can also reduce emissions by improving transfer efficiency. However, these applicators have greater potential fire and shock hazards than conventional air spray. Examples of regulated materials that might be affected by the regulatory alternatives are listed in Table 4-3.

TABLE 4-3. SURFACE COATING PROCESS SUBSTANCES OF HEALTH AND SAFETY CONCERN

Substance	Associated process	Exposure limits TLV[a] (mg/m³)	Exposure limits PEL[b] (mg/m³)	Comments
Organic solvents (VOC)	Use of organic-solvent-based coatings	Varies[c]	Varies[c]	
Toluene-2, 4-diisocyanate	Use of some two-component catalyzed urethanes	0.04	0.04	
Aluminum	Grit blasting prior to zinc-arc spray	10	15 (5)[d]	
Zinc oxide fume	Zinc-arc spray	5	5	
Nickel metal	Use of nickel-filled EMI/RFI shielding coatings	1	1	Suspected carcinogen
Soluble nickel compounds	Electroless plating for EMI/RFI shielding	0.1	0.1	Suspected carcinogen

[a]Threshold Limit Value. An 8-hour time-weighted average. (Source: Threshold limit values for chemical substances and physical agents; ACGIH; 1990)

[b]Permissable Exposure Limit. An 8-hour time-weighted average. (Source: Federal Register) January 19, 1989.

[c]Exposure limits vary depending on the specific compounds.

[d]Exposure limit for respirable dust.

Regulatory alternatives that promote the use of waterborne coatings could reduce worker exposure to organic solvents and isocyanates. Fire hazards could also be reduced by use of waterborne coatings.

Regulatory alternatives that promote the use of non-VOC-emitting EMI/RFI shielding methods could reduce worker exposure to the organic solvents and nickel particles present in nickel-filled EMI/RFI shielding coatings; however, other occupational hazards are associated with non-VOC-emitting EMI/RFI shielding methods. Zinc-arc spray operators must be protected from zinc oxide fumes and noise. Electroless plating techniques employ acids and soluble nickel and chromium compounds that are toxic. The EMI/RFI shielding options presented in the regulatory alternative have different types of health risks associated with them, each of which should be evaluated accordingly.

Guidance regarding fire and electrical hazards can be obtained from the National Fire Protection Association. The Occupational Safety and Health Administration, the National Institute of Occupational Safety and Health, among other government agencies, provide specific guidance on worker safety and health.

4.7 OTHER ENVIRONMENTAL CONCERNS

4.7.1 Irreversible and Irretrievable Commitment of Resources

For many of the regulatory alternatives, such as the use of HVLP's and add-on control devices, additional equipment would be required. Manufacturing such equipment would consume steel and other raw materials. However, compared to current coating industry use of these resources, the increase in consumption would be insignificant.

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5.0 CONTROL COSTS ANALYSES

This chapter presents the costs associated with the VOC emissions control options described in Chapter 4.0 for the plastic parts surface coating industry. Section 5.1 explains cost derivations for add-on thermal incineration systems and for substituting currently used coatings with coatings having lower VOC and/or higher solids content for the automotive/ transportation sector. Section 5.2 presents the same type of information for the business machine/miscellaneous sector. All costs are provided in first-quarter 1990 dollars. When necessary, equipment and materials costs were updated using chemical engineering cost indices. Labor rates and utility prices were obtained from recent publications by the U. S. Department of Labor and the U. S. Department of Energy. (See Appendix C for sample calculations of cost analysis.)

5.1 AUTOMOTIVE/TRANSPORTATION SECTOR

5.1.1 Add-on Thermal Incineration Systems

As discussed in Chapter 3.0, the use of add-on thermal incineration systems is an effective strategy for controlling VOC emissions at surface coating facilities. Thermal incineration is the predominant type of add-on control used in this industry. Incinerator system costs were developed using the methodology in Chapters 2.0 and 3.0 of the Office of Air Quality Planning and Standards (OAQPS) Control Cost Manual.[1] Scrubbers were neither required nor costed because the VOC's in the coatings are not halogenated.

Table 5-1 presents the operating parameters used for thermal incineration design and cost estimations for the automotive/transportation model plants described in

TABLE 5-1. THERMAL INCINERATION SYSTEM PARAMETERS FOR THE AUTOMOTIVE/TRANSPORTATION SECTOR

Model plant[a]	Stream inlet flow rate (scfm)[a]	Inlet VOC loading (lbVOC/hr)[a]	Natural gas flow rate (scfm)[b,c]	Total ductwork length (ft)[c]	Number of incinerators required[c]	Total outlet flow rate (scfm)[c]	Outlet VOC loading (lb VOC/hr)[c]	Outlet VOC concentration (ppmv)[c]
ATA1	30,000	4.36	401	400	1	34,000	0.087	0.181
ATA2	30,000	11.3	401	400	1	34,000	0.227	0.471
ATA3	30,000	11.1	401	400	1	34,000	0.222	0.461
ATB1	50,000	11.1	668	750	2	57,000	0.222	0.277
ATB2	50,000	29.0	668	750	2	57,000	0.579	0.722
ATB3	50,000	28.4	668	750	2	57,000	0.567	0.706
ATC1	126,000	39.9	1,670	1,200	3	128,000	0.798	0.443
ATC2	126,000	103.	1,650	1,200	3	128,000	2.07	1.15
ATC3	126,000	102.	1,650	1,200	3	128,000	2.03	1.13
ATD1	266,000	305.	3,460	2,400	6	269,000	6.10	1.61
ATD2	266,000	236.	3,460	2,400	6	269,000	4.72	1.24
ATD3	266,000	231.	3,460	2,400	6	269,000	4.62	1.22

[a]Input to costing algorithm.

[b]Based on 70% heat recovery, 98% destruction efficiency, and 1600°F operating temperature.

[c]Output from costing algorithm.

Chapter 2.0. Other information used as input to the costing program included an operating temperature of 1,600°F and a destruction/removal efficiency of 98 percent, as discussed in Chapter 4.0. The inlet stream heat value ranged from 0.044 to 0.344 British thermal units per standard cubic foot (Btu/scf), as determined from the heat value of the dilute VOC's in the booth exhaust.

The cost-effectiveness of a system using recirculation to concentrate the VOC level (and thus the heat content) in the stream was also investigated. For automated lines, recirculation may be a cost-effective alternative. However, recirculation is not feasible on nonautomated coating lines because worker exposure levels would be unacceptable; therefore, on a plant-by-plant basis, it was not cost-effective.[2]

Annual operating hours of 6,000 hours per year for automotive/transportation model plants D-1, D-2, and D-3 and 4,000 hours per year for all other model plants were used to calculate the emission rates as well as operational costs such as labor and utilities.

Capital costs, annual costs, and cost-effectiveness are discussed below.

5.1.1.1 Capital Costs. The cost analysis followed the methodology outlined in the OAQPS Control Cost Manual.[1] Equipment cost correlations were based on data provided by various vendors. Each correlation is valid for flow rates in the 500 to 50,000 standard cubic feet per minute (scfm) range. For flow rates above 50,000 scfm, additional incinerators were costed.

Equipment costs for thermal incinerators are a function of total volumetric throughput (Q_{tot}), expressed in scfm. Four different heat recovery scenarios were evaluated in the cost estimation procedures. The cost algorithm includes systems with heat recoveries of 0, 35, 50, and 70 percent. The equipment costs for each model plant size were calculated by using the following equations:

Heat Recovery (%)	Equipment Cost ($)
0	$10,294 \times (Q_{tot})^{0.2355}$
35	$13,149 \times (Q_{tot})^{0.2609}$
50	$17,056 \times (Q_{tot})^{0.2502}$
70	$21,342 \times (Q_{tot})^{0.2500}$

where Q_{tot} is the sum of all streams fed to the incinerator: vent stream, auxiliary fuel, combustion air, and dilution air.

The amount of heat exchange that occurs is decided by an economic optimization routine, with the least-cost system being selected as the logical choice for a control device. Total capital and annual costs are based on the most cost-effective configuration. The trade-off between the capital cost of the equipment and the operating cost of fuel for the system determines the optimum level of energy recovery. For each of the model plants, 70-percent heat recovery was selected as the optimum level.

The cost of the ductwork and fans required to carry the vent stream from the spray booth to the incinerator are not included in the above equations. The costs for this auxiliary equipment were based on the assumption of 1/8-inch carbon steel ducting, 2 feet in diameter, with two elbows per 100 feet of ducting.[3] The fans were assumed to be 24-inch diameter and able to produce the pressure increase necessary to move the vent stream. The equations for these costs are as follows:

$$\text{Duct Cost} = [(210 \times d^{0.839}) + (e \times 4.52 \times d^{1.43})] \times 1 \times (355.6/352.4)$$

where:

d = diameter (in inches),

e	=	number of elbows per 100 feet,
1	=	length of duct work (in hundreds of feet), and
355.6/352.4	=	cost conversion from February 1989 dollars to 1st-quarter 1990 dollars.
Fan Cost	=	$N \times (96.96418 \times Q_v^{0.547}) \times (355.6/342.5)$.

where:

N	=	number of incinerators required,
Q^v	=	Vent stream flow rate (scfm), and
(355.6/342.5)	=	cost conversion from 1988 (avg.) dollars to 1st-quarter 1990 dollars.

The sum of the incinerator, ductwork, and fan costs is the equipment cost. Table 5-2 presents factors used to calculate purchased equipment cost. The total direct cost is then calculated as a function of the purchased equipment cost, as is the total indirect cost. Total capital cost is the sum of purchased equipment costs, direct costs, and indirect costs, or 1.61 times purchased equipment cost, as shown in Table 5-2. Table 5-3 presents a summary of total capital costs for the 12 automotive/transportation model plants

5.1.1.2 Annual Costs. Total annual costs for the thermal incinerator system include annualized capital costs, as well as operating and maintenance costs. The assumptions used for determining annual costs are presented in Table 5-4. Table 5-3 presents a summary of the annual costs of control.

5.1.1.3 Cost-Effectiveness. Cost-effectiveness is defined as the total annualized cost per megagram of VOC emissions reduction. The information required to calculate cost-effectiveness for thermal incineration is summarized in Table 5-5. The costs per emission reduction were determined by applying the costing methodologies described in previous sections to the individual model plant emissions reductions of VOC. The method for determining model plant emissions reductions of VOC was described in Chapter 2.0.

TABLE 5-2. CAPITAL COST FACTORS FOR THERMAL INCINERATORS

Direct Costs	
Equipment Costs (EC):	
Incinerator + Auxiliary Equipment[a]	EC
Instrumentation	0.10 EC
Sales Taxes	0.03 EC
Freight	0.05 EC
Purchased equipment cost (PEC)	PEC = 1.18 EC
Direct Installation Costs	
Foundation and Supports	0.08 PEC
Handling and Erection	0.14 PEC
Electrical	0.04 PEC
Piping	0.02 PEC
Insulation for Ductwork	0.01 PEC
Painting	0.01 PEC
Total Direct Cost (DC)	0.30 PEC
Indirect Costs (Installation)	
Engineering	0.10 PEC
Construction and Field Expenses	0.05 PEC
Contractor Fees	0.10 PEC
Start-up	0.02 PEC
Performance Test	0.01 PEC
Contingencies	0.03 PEC
Total Indirect Cost (IC)	0.31 PEC
Total Capital Cost (TCC)	
TCC = PEC + DC + IC = PEC + 0.30PEC + 0.31PEC = 1.61PEC	

[a]Ductwork and fan(s).

TABLE 5-3. SUMMARY OF COSTS OF CONTROL BY THERMAL INCINERATION FOR AUTOMOTIVE/TRANSPORTATION

Model plant	ID	Capital cost[a] ($)	Capital recovery cost[b] ($/yr)	Natural gas cost[c] ($/yr)	Electricity cost[c] ($/yr)	Other annual cost[d] ($/yr)	Total annual cost ($/yr)
Small	ATA1	636,000	103,000	312,000	62,000	46,000	524,000
	ATA2	636,000	103,000	314,000	62,000	46,000	527,000
	ATA3	636,000	103,000	314,000	62,000	46,000	527,000
Medium	ATB1	1,260,000	204,000	519,000	94,000	92,000	910,000
	ATB2	1,260,000	204,000	519,000	94,000	92,000	910,000
	ATB3	1,260,000	204,000	519,000	94,000	92,000	910,000
Large	ATC1	2,330,000	379,000	1,460,000	391,000	156,000	2,390,000
	ATC2	2,330,000	379,000	1,460,000	391,000	156,000	2,390,000
	ATC3	2,330,000	379,000	1,470,000	391,000	164,000	2,400,000
Very Large	ATD1	4,900,000	798,000	4,110,000	1,050,000	385,000	6,340,000
	ATD2	4,900,000	798,000	4,110,000	1,050,000	385,000	6,340,000
	ATD3	4,900,000	798,000	4,110,000	1,050,000	385,000	6,340,000

[a]Calculated by method given in Section 5.1.1.1.

[b]Based on Capital Recovery Factor in Table 5-4.

[c]Output from computerized costing algorithm.

[d]Includes labor, materials overhead, tax, insurance, and administration.

TABLE 5-4. ASSUMPTIONS FOR CALCULATING ANNUAL COSTS OF THERMAL INCINERATION

Annual Operating Hours (hrs)	
• Automotive/Transportation Model Plants D-1, D-2, D-3	6,000
• All Other Model Plants	4,000
Operating Labor Rate ($/hr)	15.64
Operating Labor Required (hrs/8-hour shift)	0.5
Supervisor Cost (% of Operating Labor)	15
Maintenance Labor Rate ($/hr)	17.21
Maintenance Labor Required (hrs/8-hour shift)	0.5
Annual Maintenance Material	100% of Maintenance Labor
Utilities	
• Electricity ($/1000 KW-hr)	61.0
• Natural Gas ($/$10^6$ Btu)	3.30
Overhead (% of Operation and Maintenance)	60
Administrative Charges	2% TCC
Property Taxes	1% TCC
Insurance	1% TCC
Capital Recovery Factor (10% interest, 10-year lifetime)	0.16275

TCC = Total capital cost.

TABLE 5-5. SUMMARY OF COST-EFFECTIVENESS FOR APPLYING THERMAL INCINERATION TO MODEL PLANTS IN THE AUTOMOTIVE/TRANSPORTATION SECTOR

Model plant	Total annual cost ($/yr)	Total VOC emission reduction [Mg/yr	(tons/yr)]	Overall cost-effectiveness [$/Mg	($/ton)]
A1[a]	524,000	31.7	(34.9)	16,600	(15,000)
A2[a]	524,000	26.4	(29.0)	19,900	(18,100)
A3[a]	524,000	25.0	(27.5)	21,000	(19,100)
B1[b]	910,000	71.9	(79.1)	12,700	(11,500)
B2[b]	910,000	60.1	(66.1)	15,200	(13,800)
B3[b]	910,000	56.8	(62.5)	16,000	(14,600)
C1[c]	2,390,000	257	(283)	9,281	(7,600)
C2[c]	2,390,000	215	(236)	11,107	(9,000)
C3[c]	2,390,000	203	(224)	11,807	(9,600)
D1[d]	6,340,000	791	(870)	8,000	(7,300)
D2[d]	6,340,000	661	(727)	9,600	(8,700)
D3[d]	6,340,000	625	(688)	10,100	(9,200)

[a]Small model plants.

[b]Medium model plants.

[c]Large model plants.

[d]Very large model plants.

These analyses show that, in general, VOC reduction from dilute streams (e.g., the exhausts from each of the model plants) requires significant investment of capital. In addition, large quantities of auxiliary fuel are needed, which significantly increases annual operating costs. Combining these conditions with the emissions reductions achieved produces high cost-effectiveness values, ranging from \$8,000/Mg (\$7,300/ton) removed for the largest model plants up to \$21,000/Mg (\$19,100/ton) removed for the smallest model plants.

5.1.2 Substituting Lower-Volatile-Organic-Compound Coatings

Using coatings with lower VOC and/or higher solids content was discussed in Chapter 3.0 as an effective emissions control strategy. To develop control costs for this strategy, the baseline and optional VOC levels were first selected as described in Chapter 4.0. Equations for estimating the cost of coatings with varying levels of VOC's, were developed and used to calculate the cost impact and cost-effectiveness at both option levels for each type of coating used by the model plants.

5.1.2.1 Capital Costs. No capital costs were estimated for the reformulation control options. This is based on the assumption that a facility's existing equipment can apply the reformulated coatings without a capital expense.

5.1.2.2 Annual Costs. Total annual costs for reformulated coating application is calculated from the difference in annual coating cost between the given option level and the baseline level. The equations used to calculate coating cost are as follows:

$$\text{Colorcoat Cost (\$/gal)} = -14.43 \times C_{VOC} + 99.76$$
$$\text{Clearcoat Cost (\$/gal)} = -12.98 \times C_{VOC} + 89.79$$
$$\text{Primer Cost (\$/gal)} = -7.21 \times C_{VOC} + 49.88$$

where C_{VOC} is the amount (lb/gal) of VOC in the coating.

The estimated cost associated with each coating was based on information provided by the NPCA and coating formulators.[4] All costs are provided in first-quarter 1990 dollars. Representative cost estimates for each coating corresponding to its level of VOC content are presented in Table 5-6. Table 5-6 shows the VOC level and cost of each coating for the baseline and both control options. The total annual coating cost over baseline is estimated by the following equation:

$$TAC = \sum_{i=1}^{n} \left[U_C \times VOC_C\right] - \sum_{i=1}^{n} \left[U_B \times VOC_B\right]$$

where:

- Uc = Usage of control level coating in gal/yr.
- Ub = Usage of baseline coating in gal/yr.
- VOC_C = VOC content of control level coating in lb/gal.
- VOC_B = VOC content of baseline coating in lb/gal.

The coating use for an option was estimated based on the assumption that the total amount of solids applied remains constant when substituting the lower-VOC coating for the baseline coating.

5.1.2.3 Cost-Effectiveness. The cost-effectiveness was calculated for each option on a model plant basis and on an overall basis. The equation for cost-effectiveness is:

$$CE\ (\$/ton) = \frac{TAC\ (\$/yr)}{[\text{Emissions reduction (lb/hr)}/2000\text{(lb/ton)}]}$$

Emission reductions for each model plant are calculated as in Chapter 4.

TABLE 5-6. ESTIMATED COSTS AND VOLATILE ORGANIC COMPOUND CONTENTS OF COATINGS IN THE AUTOMOTIVE/TRANSPORTATION SECTOR

	Baseline		Level 1		Level 2	
Automotive exterior	VOC[a]	Cost[b]	VOC[a]	Cost[b]	VOC[a]	Cost[b]
Low-bake color	6.0	13.18	5.0	27.61	3.2	53.58
Low-bake primer	6.0	6.62	3.5	24.65	3.5	24.65
High-bake colorcoat	4.6	33.38	4.3	37.71	4.1	40.60
High-bake primer	5.4	10.95	4.3	18.88	3.8	22.48
Automotive Exterior						
				21.48		
Flexible	5.7	17.51	5.4	37.87	5.1	26.17
Low-bake colorcoat	4.2	35.27	4.0	10.23	3.7	41.76
Low-bake clearcoat	6.0	6.62	5.5		5.5	10.23
Low-bake primer						
				37.71		
High-bake colorcoat	4.6	33.38	4.3	40.47	4.1	40.60
High-bake clearcoat	4.3	33.98	3.8	13.83	3.5	44.36
High-bake primer	5.4	10.95	5.0		4.5	17.44
NonFlexible				21.48		
Low-bake colorcoat	5.7	17.51	5.4	37.87	5.1	26.17
Low-bake clearcoat	4.2	35.27	4.0	10.23	3.7	41.76
Low-bake primer	6.0	6.62	5.5		5.5	10.23
				37.71		
High-bake colorcoat	4.6	33.38	4.3	40.47	4.1	40.60
High-bake clearcoat	4.3	33.98	3.8	21.04	3.5	44.36
High-bake primer	4.2	19.60	4.0		3.8	22.48

a lb VOC/gal coating, less water.
b $/gallon as purchased.

The results of the cost-effectiveness calculations are shown in Table 5-7. The cost-effectiveness for each type of model plant (interior, exterior flexible, and exterior non-flexible) was constant, regardless of size. Table 5-7 also shows the incremental cost-effectiveness, i.e., the cost-effectiveness of the emissions reductions achieved by moving from control Level 1 to control Level 2.

5.2 BUSINESS MACHINE SECTOR

5.2.1 Add-on Thermal Incineration System

As with the automotive/transportation sector, capital costs, annual costs, and cost-effectiveness were calculated using the methodology given in the OAQPS Control Cost Manual.[1] Table 5-8 presents system parameters for adding thermal incineration to the model plants for the business machine sector described in Chapter 2.0.

5.2.1.1 Capital Costs. The costing equations and relationships used to calculate total capital costs are shown in Section 5.1.1.1. The capital costs for applying thermal incineration to the business machines model plants are presented in Table 5-9, and range from $590,000 for the small model plant to $1,870,000 for the large model plant.

5.2.1.2 Annual Costs. The costing equations and relationships used to calculate total annual costs are shown in Section 5.1.1.2. The annual costs for applying thermal incineration to the business machines model plants are presented in Table 5-9, and range from $373,000/yr for the small model plant to $1,490,000/yr for the large model plant.

5.2.1.3 Cost-Effectiveness. The costing equations and relationships used to calculate cost-effectiveness are shown in Section 5.1.1.3. The cost-effectiveness values for applying thermal incineration to the business machines model plants are presented in Table 5-10. These cost-effectiveness values range from $7,560/Mg removed ($6,860/ton removed) for the largest model plants up to $37,900/Mg removed ($34,500/ton removed) for the smallest model plant.

TABLE 5-7. COST-EFFECTIVENESS OF APPLYING REFORMULATION CONTROL LEVELS TO AUTOMOTIVE/TRANSPORTATION MODEL PLANTS $/Mg($/ton)

Model plant ID[a]	Level 1	Level 2	Incremental
Interior coatings	694 (630)	729 (662)	832 (756)
Exterior flexible coatings	674 (612)	666 (605)	655 (595)
Exterior nonflexible coatings	735 (667)	736 (668)	737 (669)

[a]Refers to model plants described in more detail in Chapter 3.0.

TABLE 5-8. THERMAL INCINERATION SYSTEM PARAMETERS FOR THE AUTOMOTIVE/TRANSPORTATION SECTOR[a]

Model plant ID[b]	Stream inlet flow rate (scfm)[b]	Inlet VOC loading (lb/hr)[b]	Natural gas flow rate (scfm)[c]	Total ductwork length (feet)[b]	Number of incinerators required[c]	Total outlet flow rate (scfm)[c]	Outlet VOC loading (lb/hr)[c]	Outlet VOC concentration (ppm)[c]
(A) Small	20,000	5.54	267	350	1	22,800	0.111	0.345
(B) Medium	50,000	44.3	668	750	2	57,000	0.887	1.10
(C) Large	90,000	111	1200	1200	3	103,000	2.22	1.53

a A control efficiency of 98 percent and an operating temperature of 1600°F were used for this analysis.

b Input to costing algorithm.

c Output from costing algorithm.

TABLE 5-9. SUMMARY OF COST OF CONTROL BY THERMAL INCINERATION FOR BUSINESS MACHINES

Model plant ID	Capital cost[a] ($)	Capital recovery[b] cost ($/yr)	Natural gas cost[c] ($/yr)	Electricity cost[c] ($/yr)	Other annual costs[d] ($/yr)	Total annual cost ($/yr)
(A) Small	590,000	96,100	211,000	22,000	44,000	373,000
(B) Medium	1,210,000	196,000	529,000	52,000	90,000	867,000
(C) Large	1,870,000	305,000	952,000	93,000	138,000	1,490,000

[a]Calculated by method given in Section 5.1.1.1.

[b]Based on Capital Recovery Factor in Table 5-4.

[c]Output from computerized costing algorithm.

[d]Includes labor, materials overhead, tax, insurance, and administration.

TABLE 5-10. COST-EFFECTIVENESS OF APPLYING THERMAL INCINERATION TO THE BUSINESS MACHINE MODEL PLANTS

Model plant ID[a]	Total annual costs ($/yr)	Total VOC emissions reduction	Cost-effectiveness $/Mg ($/ton)
(A) Small	373,000	11.9 (10.8)	38,000 (34,500)
(B) Medium	867,000	95.4 (86.7)	11,000 (10,000)
(C) Large	1,490,000	238 (217)	7,600 (6,900)

[a]Refers to model plants described in more detail in Chapter 3.0.

5.2.2 Substituting Lower-Volatile-Organic-Compound Coatings

As discussed in Chapter 2.0 and Section 5.1.2, substituting lower-VOC- and/or higher-solids-content coatings is a cost-effective control strategy. The costs, emissions reductions, and cost-effectiveness calculations parallel those shown in sections 5.1.2.1, 5.1.2.2, and 5.1.2.3.

5.2.2.1 Capital Costs. No capital costs were estimated for the reformulation control options. This is based on the assumption that a facility's existing equipment can be used to apply the reformulated coatings without a capital expense.

5.2.2.2 Annual Costs. The annual costs of implementing coatings specified by an option were calculated as detailed in Section 5.1.2.2. The following equations were used to estimate coating cost ($/gal):

Colorcoat, colorcoat/texture coat, Clearcoat, and primer	$= -9.04 \times C_{VOC} + 62.57$
Solventborne EMI/RFI	$= -35.07 \times C_{VOC} + 247.20$
Waterborne EMI/RFI	$= -36.09 \times C_{VOC} + 249.85$

where C_{VOC} is the coating VOC content in lb/gal. Cost curves were developed based on coating costs reported in the business machine surface coating New Source Performance Standards.[5]

Table 5-11 shows the VOC level and calculated cost per gallon of each coating at the baseline and both option levels.

TABLE 5-11. ESTIMATED COSTS AND VOLATILE ORGANIC COMPOUND CONTENTS OF COATINGS IN THE BUSINESS MACHINE SECTOR

	Baseline			Level 1			Level 2		
	VOC[a]	% Solids[b]	Cost[c]	VOC[a]	% Solids[b]	Cost[c]	VOC[a]	% Solids[b]	Cost[c]
- Colorcoat	4.8	32	19.18	3.5	51	30.93	2.3	68	41.78
- Texturecoat	4.8	32	19.18	3.5	51	30.93	2.3	68	41.78
- Primer	4.5	37	21.89	2.9	59	36.35	1.2	83	51.72
- EMI/RFI Shielding	4.9	31	45.70	4.0	44	53.84	2.5	65	95.48

[a]lb VOC/gal coating, less water.

[b]Percent solids, by volume.

[c]$/gal coating as purchased.

5.2.2.3 Cost-Effectiveness. The cost-effectiveness of each option may be calculated in exactly the same manner as presented in Section 5.1.2.3. Table 5-12 shows the results these calculations.

TABLE 5-12. COST-EFFECTIVENESS OF APPLYING REFORMULATION CONTROL LEVELS TO BUSINESS MACHINE MODEL PLANTS $/Mg ($/ton)

Model plant	Level 1	Level 2	Incremental
(A) Small	517 (470)	529 (480)	1,199 (1,088)
(B) Medium	517 (470)	522 (474)	520 (481)
(C) Large	517 (470)	517 (470)	518 (470)

5.3 REFERENCES

1. U. S. Environmental Protection Agency, OAQPS Control Cost Manual. OAQPS/EPA. Research Triangle Park, NC. EPA-450/3-90-006. January 1990.

2. Memoradum from Ferrero, B., Radian Corporation, to David Salman, U. S. Environmental Protection Agency, Chemicals and Petroleum Branch. Recirculation of Spray Booth Ventilation Stream. February 24, 1992.

3. Vatavuk, William. Pricing Equipment for Air-Pollution Control. Chemical Engineering. May 1990. pp. 126-130.

4. Memorandum form Fortier, G., Radian Corporation to Salman, D., U. S. Environmental Protection Agency, Chemicals and Petroleum Branch. Sensitivity Analysis Performed on Coating Cost Assumptions. May 1, 1991.

5. Business Machine NSPS.

6.0 ADDITIONAL TECHNICAL INFORMATION

This chapter presents additional technical information to supplement the information on low VOC content coatings presented in Chapters 3, 4 and 5. Section 6.1 presents additional information on exterior coatings for automotive/transportation parts. Section 6.2 presents additional information on coatings for business machine parts.

6.1 EXTERIOR AUTOMOTIVE COATINGS

The development of lower VOC content exterior coatings for the automotive/transportation industry is a complicated process involving product development such as new or modified substrates, coating performance (weatherability, durability, etc.), and assessment of changing customer demands. As described in Chapter 2 and Table 2-4, the industry has reduced exterior coating VOC content and emissions over the past decade by developing many new lower VOC content materials.

Improvements in exterior coating performance in some cases has required higher VOC loadings than the lower VOC content coatings in control levels 1 and 2 in Chapters 4 and 5. Recent information presented by the industry indicate that some of the lower VOC exterior coatings in control levels 1 and 2 were based on out-of-date or incorrect data. Table 6-1 presents a new exterior coating option (control level 4) for exterior automotive coatings. The reasons for changes from the options presented in Chapters 4 and 5 are:

- Red and black colorcoats require higher VOC content than other colors to achieve the same performance due to pigment particle size (see discussion in Section 2.3);

- Flexible primers require higher VOC content than the initial lower VOC formulations to avoid masking problems for multiple color systems;

- Non-flexible primers require higher VOC content than the initial lower VOC formulations to provide smooth finishes to match other body parts;

- Primers with the initial lower VOC levels had poor weatherability. Higher VOC levels are needed to achieve acceptable performance;

- Clearcoats with the initial lower VOC levels did not provide adequate acid etch resistance. Recent clearcoats with slightly higher VOC content provide adequate acid etch resistance;

- The original colorcoat database did not span the full range of colors used in the industry; and

- The low-bake clearcoat data originally reported by the coating manufacturers did not reflect correct as-applied VOC levels.

Tables 6-2 and 6-3 compare control level 4 with the control levels presented in Chapters 4 and 5 for exterior low-bake and high-bake coatings. Emission reductions and cost-effectiveness of control level 4 were determined as discussed in Chapters 4 and 5 for control levels 1 and 2. Table 6-4 compares the national impacts of control levels 1, 2 and 4. Other environmental impacts of control level 4 are equivalent to those for levels 1 and 2, as discussed in Chapter 4.

6.2 BUSINESS MACHINE COATINGS

The appropriateness of particular lower VOC content coatings for business machine parts may be influenced by the conditions in which the final product will be used. Many machines are used in a home or office setting, while others are used in a more hostile factory or field environment. The coatings used on parts destined for factory or field use must be able to withstand the conditions present in those environments. This may preclude the use of some of the lower VOC content materials suitable for parts destined for home or office use on parts destined for factory or field use.

TABLE 6-1. AUTOMOTIVE/TRANSPORTATION NEW EXTERIOR COATING OPTION (CONTROL LEVEL 4)

Low-Bake Flexible and Nonflexible Coatings Coating Type	VOC Content (lb/gal)[a]
Primers	5.5
Colorcoats	
Red and Black	5.6
All other colors	5.1
Clearcoats	4.5

High-Bake Coatings

Coating Type	VOC Content (lb/gal)[a]
Primers	
Flexible	5.0
Nonflexible	4.5
Colorcoats	4.6
Clearcoats	4.3

[a] All VOC contents are measured as pounds of VOC per gallon of coating less water.

APPENDIX A

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APPENDIX B

EMISSIONS CALCULATION

1. BASELINE

A. Automotive

Baseline VOC levels were determined for each coating category for each model plant based on information reported by NPCA. The volume of each coating used at each model plant was multiplied by the estimated baseline VOC level, to get an estimate of model plant baseline VOC emissions (see Example B-1).

Example B-1: VOC Emissions Calculation (Model Plant ATA1)

Coating	Usage (gal/yr)		VOC Content (lb VOC/gal)		Emissions (lb VOC/yr)
Highbake Colorcoat	450	x	4.6	=	2,070
Highbake Primer	150	x	5.4	=	810
Lowbake Colorcoat	8,550	x	6.0	=	51,300
Lowbake Primer	2,850	x	6.0	=	17,100
Total	12,000 gal/yr				71,280 lb VOC/yr

(71,280 lb VOC/yr)(1 ton/2,000 lb) = 35.6 tons VOC/yr - 36 tons VOC/yr

It was assumed that 100 percent of coating VOC content was emitted. Tables B-1, B-2, B-3, and B-4 present the model plant usage, VOC level, and emissions for each category at baseline and each option. Options 1 and 2 are reformulation options, and Option 3 applies incineration as an add-on control. Note that as VOC content is lowered due to reformulation, total usage is

TABLE B-1. AUTOMOTIVE/TRANSPORTATION SECTOR SMALL MODEL PLANT EMISSIONS

Coating Category	Total Annual Use (1000 gal)	Baseline VOC content (lbs/gal)	Baseline emissions (tons/yr)	Control Level 1 annual usage (1000 gal)	Control Level 1 VOC content (lbs/gal)	Level 1 emissions (tons/yr)	Control Level 2 annual usage (1000 gal)	Control Level 2 VOC content (lbs/gal)	Level 2 emissions (tons/yr)	Control Level 3 annual usage (1000 gal)	Level 3 emissions (tons/yr)
I. Auto Interiors											
1) Highbake Colorcoat	0.45	4.6	1.0	0.4	4.3	0.9	0.4	4.1	0.8	0.45	0.02
2) Highbake Primer	0.15	5.4	0.4	0.1	4.3	0.2	0.1	3.8	0.2	0.15	0.01
3) Lowbake Colorcoat	8.55	6.0	25.6	4.5	5.0	11.2	2.4	3.2	3.9	8.55	0.51
4) Lowbake Primer	2.85	6.0	8.6	0.9	3.5	1.5	0.9	3.5	1.5	2.85	0.17
TOTALS =	12		36	6		14	4		6	12	0.71
II. Auto Exteriors (Flexible)											
1) Highbake Colorcoat	3.40	4.6	7.8	3.0	4.3	6.5	2.8	4.1	5.8	3.40	0.16
2) Highbake Clearcoat	2.33	4.3	5.0	2.0	3.8	3.8	1.8	3.5	3.2	2.33	0.10
3) Highbake Primer	2.88	5.4	7.8	2.3	5.0	5.8	1.9	4.5	4.2	2.88	0.16
4) Lowbake Primer	0.12	6.0	0.4	0.1	5.5	0.2	0.1	5.5	0.2	0.12	0.01
5) Lowbake Colorcoat	2.60	5.7	7.4	2.1	5.4	5.8	1.8	5.1	4.6	2.60	0.15
6) Lowbake Clearcoat	0.67	4.2	1.4	0.6	4.0	1.3	0.6	3.7	1.1	0.67	0.03
TOTALS =	12		30	10		23	9		19	12	0.61
III. Auto Exteriors (Nonflexible)											
1) Highbake Colorcoat	3.40	4.6	7.8	3.0	4.3	6.5	2.8	4.1	5.8	3.40	0.16
2) Highbake Clearcoat	2.33	4.3	5.0	2.0	3.8	3.8	1.8	3.5	3.2	2.33	0.10
3) Highbake Primer	2.75	4.2	5.8	2.6	4.0	5.1	2.4	3.8	4.6	2.75	0.12
4) Lowbake Primer	0.25	6.0	0.8	0.2	5.5	0.5	0.2	5.5	0.5	0.25	0.02
5) Lowbake Colorcoat	2.60	5.7	7.4	2.1	5.4	5.8	1.8	5.1	4.6	2.60	0.15
6) Lowbake Clearcoat	0.67	4.2	1.4	0.6	4.0	1.3	0.6	3.7	1.1	0.67	0.03
TOTALS =	12		28	11		23	10		20	12	0.58

TABLE B-2. AUTOMOTIVE/TRANSPORTATION SECTOR MEDIUM MODEL PLANT EMISSIONS

Coating Category	Total Annual Use (1000 gal)	Baseline VOC content (lbs/gal)	Baseline emissions (tons/yr)	Control Level 1 annual usage (1000 gal)	Control Level 1 VOC content (lbs/gal)	Level 1 emissions (tons/yr)	Control Level 2 annual usage (1000 gal)	Control Level 2 VOC content (lbs/gal)	Level 2 emissions (tons/yr)	Control Level 3 annual usage (1000 gal)	Level 3 emissions (tons/yr)
I. Auto Interiors											
1) Highbake Colorcoat	1.02	4.6	2.4	0.91	4.3	2.0	0.85	4.1	1.8	1.02	0.05
2) Highbake Primer	0.34	5.4	0.9	0.21	4.3	0.4	0.18	3.8	0.3	0.34	0.02
3) Lowbake Colorcoat	19.42	6.0	58.2	10.17	5.0	25.4	5.48	3.2	8.8	19.42	1.16
4) Lowbake Primer	6.47	6.0	19.4	1.98	3.5	3.5	1.98	3.5	3.5	6.47	0.39
TOTALS =	27.25		81	13		31	8		14	27.25	1.6
II. Auto Exteriors (Flexible)											
1) Highbake Colorcoat	7.72	4.6	18	7	4.3	15	6.4	4.1	13	7.72	0.36
2) Highbake Clearcoat	5.29	4.3	11	4	3.8	9	4.1	3.5	7	5.29	0.23
3) Highbake Primer	6.54	5.4	18	5	5.0	13	4.3	4.5	10	6.54	0.35
4) Lowbake Primer	0.27	6.0	1	0.3	5.5	1	0.2	5.5	0.5	0.27	0.02
5) Lowbake Colorcoat	5.90	5.7	17	5	5.4	13	4.1	5.1	10	5.90	0.34
6) Lowbake Clearcoat	1.52	4.2	3	1	4.0	3	1.3	3.7	2	1.52	0.06
TOTALS =	27.25		68	23		53	20		43	27.25	1.4
III. Auto Exteriors (Nonflexible)											
1) Highbake Colorcoat	7.72	4.6	18	7	4.3	15	6	4.1	13	7.72	0.36
2) Highbake Clearcoat	5.29	4.3	11	4	3.8	9	4	3.5	7.2	5.29	0.23
3) Highbake Primer	6.25	4.2	13	6	4.0	12	5	3.8	10	6.25	0.26
4) Lowbake Primer	0.57	6.0	2	0.4	5.5	1	0.4	5.5	1.1	0.57	0.03
5) Lowbake Colorcoat	5.90	5.7	17	5	5.4	13	4	5.1	11	5.90	0.34
6) Lowbake Clearcoat	1.52	4.2	3	1.4	4.0	3	1.3	3.7	2.4	1.52	0.06
TOTALS =	27.25		64	24		52	22		45	27.25	1.5

TABLE B-3. AUTOMOTIVE/TRANSPORTATION SECTOR LARGE MODEL PLANT EMISSIONS

Coating Category	Total Annual Use (1000 gal)	Baseline VOC content (lbs/gal)	Baseline emissions (tons/yr)	Control Level 1 annual usage (1000 gal)	Control Level 1 VOC content (lbs/gal)	Level 1 emissions (tons/yr)	Control Level 2 annual usage (1000 gal)	Control Level 2 VOC content (lbs/gal)	Level 2 emissions (tons/yr)	Control Level 3 annual usage (1000 gal)	Level 3 emissions (tons/yr)
I. Auto Interiors											
1) Highbake Colorcoat	3.66	4.6	8.4	3.3	4.3	7	3.0	4.1	6	3.66	0.17
2) Highbake Primer	1.22	5.4	3.3	0.7	4.3	1.6	0.63	3.8	1	1.22	0.07
3) Lowbake Colorcoat	69.50	6.0	208	36	5.0	91	20	3.2	31	69.50	4.17
4) Lowbake Primer	23.17	6.0	70	7.1	3.5	12	7.1	3.5	12	23.17	1.39
TOTALS =	97.54		290	47		112	30		50	98.54	6
II. Auto Exteriors (Flexible)											
1) Highbake Colorcoat	27.63	4.6	64	25	4.3	53	23	4.1	47	37.63	1.27
2) Highbake Clearcoat	18.94	4.3	41	16	3.8	31	15	3.5	26	18.94	0.81
3) Highbake Primer	23.41	5.4	63	19	5.0	47	15	4.5	34	23.41	1.26
4) Lowbake Primer	0.98	6.0	3	1	5.5	2	1	5.5	2	0.98	0.06
5) Lowbake Colorcoat	21.13	5.7	60	17	5.4	47	15	5.1	38	21.13	1.20
6) Lowbake Clearcoat	5.45	4.2	11	5	4.0	10	5	3.7	9	5.45	0.23
TOTALS =	97.54		242	83		190	74		156	97.54	5
III. Auto Exteriors (Nonflexible)											
1) Highbake Colorcoat	27.63	4.6	64	25	4.3	53	23	4.1	47	27.63	1.27
2) Highbake Clearcoat	18.94	4.3	41	16	3.8	31	15	3.5	26	18.94	0.81
3) Highbake Primer	22.36	4.2	47	21	4.0	42	20	3.8	37	22.36	0.94
4) Lowbake Primer	2.03	6.0	6	1	5.5	4	1	5.5	4	2.03	0.12
5) Lowbake Colorcoat	21.13	5.7	60	17	5.4	47	15	5.1	38	21.13	1.20
6) Lowbake Clearcoat	5.45	4.2	11	5	4.0	10	5	3.7	9	5.45	0.23
TOTALS =	97.54		229	85		187	79		161	98.54	4

TABLE B-4. AUTOMOTIVE/TRANSPORTATION SECTOR EXTRA LARGE MODEL PLANT EMISSIONS

Coating Category	Total Annual Use (1000 gal)	Baseline VOC content (lbs/gal)	Baseline emissions (tons/yr)	Control Level 1 annual usage (1000 gal)	Control Level 1 VOC content (lbs/gal)	Level 1 emissions (tons/yr)	Control Level 2 annual usage (1000 gal)	Control Level 2 VOC content (lbs/gal)	Level 2 emissions (tons/yr)	Control Level 3 annual usage (1000 gal)	Level 3 emissions (tons/yr)
I. Auto Interiors											
1) Highbake Colorcoat	11.25	4.6	26	10	4.3	22	9	4.1	19	11.25	0.52
2) Highbake Primer	3.75	5.4	10	2	4.3	5	2	3.8	4	3.75	0.20
3) Lowbake Colorcoat	213.75	6.0	641	112	5.0	280	60	3.2	96	213.75	12.83
4) Lowbake Primer	71.25	6.0	214	22	3.5	38	22	3.5	38	71.25	4.27
TOTALS =	300.00		891	146		345	93		157	300.00	18
II. Auto Exteriors (Flexible)											
1) Highbake Colorcoat	84.99	4.6	195	76	4.3	163	71	4.1	145	84.99	3.91
2) Highbake Clearcoat	58.25	4.3	125	49	3.8	94	45	3.5	79	58.25	2.50
3) Highbake Primer	72.00	5.4	194	58	5.0	146	47	4.5	106	72.00	3.89
4) Lowbake Primer	3.00	6.0	9	2	5.5	6	2	5.5	6	3.00	0.18
5) Lowbake Colorcoat	65.00	5.7	185	54	5.4	145	46	5.1	116	65.00	3.71
6) Lowbake Clearcoat	16.75	4.2	35	16	4.0	31	14	3.7	26	16.75	0.71
TOTALS =	300.00		743	255		585	225		478	300.00	15
III. Auto Exteriors (Nonflexible)											
1) Highbake Colorcoat	84.99	4.6	195	76	4.3	163	71	4.1	145	84.99	3.91
2) Highbake Clearcoat	58.26	4.3	125	49	3.8	94	45	3.5	79	58.26	2.50
3) Highbake Primer	68.76	4.2	144	64	4.0	129	60	3.8	115	38.76	2.89
4) Lowbake Primer	6.25	6.0	19	4	5.5	12	4	5.5	12	6.25	0.38
5) Lowbake Colorcoat	65.00	5.7	185	54	5.4	145	46	5.1	116	65.00	3.71
6) Lowbake Clearcoat	16.75	4.2	35	16	4.0	31	14	3.7	26	16.75	0.70
TOTALS =	300.00		703	263		574	240		493	300.00	14

reduced. This is based on the assumption that the total amount of solids required remains constant across the options (Example B-2).

Example B-2: Reformulated Coating Usage (Highbake Colorcoat, Model Plant ATA1)

$$\text{Reformulated Usage} = \text{Usage at Baseline} \times \frac{\left(1-\frac{C_{voc}}{7.1}\right)_{\text{baseline}}}{\left(1-\frac{C_{voc}}{7.1}\right)_{\text{option level}}}$$

$$\text{Usage at Level 1} = 450 \text{ gal/yr} \times \frac{\left(1-\frac{4.6}{7.1}\right)_{\text{baseline}}}{\left(1-\frac{4.3}{7.1}\right)_{\text{level 1}}} = 402 \text{ gal/yr}$$

The emissions from the add-on control option (Option 3) were calculated from the assumption of 98 percent destruction efficiency by thermal incineration. Emissions are therefore 2 percent of baseline emissions (Example B-3).

Example B-3: Emissions After Control (Model Plant ATA1)

Emissions from Example B-1= 36 tons

Option 3 emissions = Baseline Emission * 0.02

= 36 tons/yr (0.02) = 0.7 tons/yr

B. <u>Business Machines</u>

Coating usage and VOC levels were determined for each coating type for each model plant size based on information collected from the industry as explained in Chapter 2. VOC emissions from each model plant were then calculated by multiplying gallons used by VOC content per gallon as in Example B-1. Table B-5 shows model plant coating usage, VOC level, and calculated emissions for each coating at each option for all three business machine model plant sizes.

As in the automotive sector, add-on control was incineration with a destruction efficiency of 98 percent. Thus, emissions were estimated to be 2 percent of baseline emissions (see Example B-3).

2. EMISSION REDUCTIONS

Emission reductions are calculated as the difference between baseline emissions and the emissions at a given control option for every case. Table B-6 shows the emissions reduction for each control option for both the automotive and the business machine sectors. Example B-4 shows the emissions reduction calculation for ATA1.

<u>Example B-4</u>: Emission Reduction Calculation
(Model Plant ATA1, Option 2)

Emissions at Baseline = 36 tons/yr

Emissions at Option 2 = 6 tons/yr (from Table 1)

Emissions Reduction = 36 tons/yr - 6 tons/yr = 30 tons/yr

TABLE B-5. BUSINESS MACHINE/MISCELLANEOUS SECTOR MODEL PLANT EMISSIONS

Coating Category	Total Annual Use (1000 gal)	Baseline VOC content (lbs/gal)	Baseline emissions (tons/yr)	Control Level 1 annual usage (1000 gal)	Control Level 1 VOC content (lbs/gal)	Level 1 emissions (tons/yr)	Control Level 2 annual usage (1000 gal)	Control Level 2 VOC content (lbs/gal)	Level 2 emissions (tons/yr)	Control Level 3 annual usage (1000 gal)	Level 3 emissions (tons/yr)
Model Plant Size: Small											
1) Primer	0.51	4.5	1.15	10.37	3.5	0.65	0.28	2.3	0.32	0.51	0.02
2) Colorcoat	1.54	4.8	3.69	0.98	3.5	1.72	0.74	2.3	0.85	1.54	0.07
3) Colorcoat/Texture Coat	1.28	4.8	3.08	0.71	2.9	1.02	0.50	1.2	0.30	1.28	0.06
4) EMI/RFI Shielding	1.79	4.9	4.40	1.27	4.0	2.55	0.86	2.5	1.07	1.79	0.09
TOTALS =	5.13		12.3	3.33		5.93	2.37		2.54	5.13	0.24
Model Plant Size: Medium											
1) Primer	4.10	4.5	9.23	2.96	3.5	5.18	2.22	2.3	2.55	4.10	0.18
2) Colorcoat	12.30	4.8	29.52	7.86	3.5	13.75	5.89	2.3	6.78	12.30	0.59
3) Colorcoat/Texture Coat	10.25	4.8	24.60	5.61	2.9	8.14	4.00	1.2	2.40	10.25	0.49
4) EMI/RFI Shielding	14.35	4.9	35.16	10.18	4.0	20.37	6.86	2.5	8.58	14.35	0.70
TOTALS =	41.00		98.5	26.6		47.4	19.0		20.3	41.0	1.97
Model Plant Size: Large											
1) Primer	10.25	4.5	23.06	7.40	3.5	12.96	5.55	2.3	6.39	10.25	0.46
2) Colorcoat	30.75	4.8	73.80	19.65	3.5	34.38	14.73	2.3	16.94	30.75	1.48
3) Colorcoat/Texture Coat	25.63	4.8	61.51	14.04	2.9	20.35	9.99	1.2	5.99	25.63	1.23
4) EMI/RFI Shielding	35.88	4.9	87.91	25.46	4.0	50.93	17.16	2.5	21.45	35.88	1.76
TOTALS =	102.51		246	66.6		119	47.4		50.8	102	4.93

TABLE B-6. EMISSIONS REDUCTION

Model Plant	BASELINE Emissions (tons/yr)	BASELINE Emissions Reduction (tons/yr)	BASELINE Incremental Reduction (tons/yr)	OPTION 1 Emissions (tons/yr)	OPTION 1 Emissions Reduction (tons/yr)	OPTION 1 Incremental Reduction (tons/yr)	OPTION 2 Emissions (tons/yr)	OPTION 2 Emissions Reduction (tons/yr)	OPTION 2 Incremental Reduction (tons/yr)	OPTION 3 Emissions (tons/yr)	OPTION 3 Emissions Reduction (tons/yr)	OPTION 3 Incremental Reduction (tons/yr)
ATA 1	36	—	—	14	22	22	6	30	8	0.7	35.3	5.3
ATA 2	30	—	—	23	7	7	19	11	4	0.6	29.4	17
ATA 3	28	—	—	23	5	5	20	8	3	0.6	27.4	19
ATB 1	81	—	—	31	50	50	14	67	17	1.6	79	12
ATB 2	68	—	—	53	15	15	44	24	9	1.4	67	43
ATB 3	64	—	—	52	12	12	45	19	7	1.5	62	43
ATC 1	290	—	—	112	178	178	51	239	61	5.8	284	45
ATC 2	240	—	—	190	50	50	156	84	34	4.8	235	171
ATC 3	230	—	—	186	44	44	160	70	16	4.6	225	155
ATD 1	890	—	—	345	546	546	157	734	188	18	872	138
ATD 2	740	—	—	584	160	160	478	266	106	15	725	459
ATD 3	700	—	—	573	131	131	494	211	80	14	686	475
BMM A	12.3	—	—	5.9	6.4	6.4	2.5	9.8	3.4	0.2	12.1	2.3
BMM B	98.5	—	—	47.4	51.1	51.1	20.3	78.2	27.1	2.0	96.5	18.3
BMM C	246	—	—	119	128	128	50.8	196	68.0	5.0	241	45

APPENDIX C

COST CALCULATIONS

Costs of control for both the Automotive/Transportation and Business Machine/Miscellaneous sectors were developed in an identical manner; however, the approach differed between the reformulation options (1 and 2) and the add-on control option (3). Reformulation costs were developed from cost data supplied by manufacturers. The data was used to develop cost equations based on VOC content. To calculate the cost of a reformulation option, the cost of each of the individual coatings must first be calculated at both baseline and option levels. The cost equations are taken from Chapter 5. Example C-1 shows the required calculations for model plant ATA1.

Example C-1: Coating Cost Calculations

Baseline

Coating	VOC (lb/gal)	Cost Equation					Coating Cost ($/gal)
Highbake Colorcoat	4.6	-14.43*	(4.6)	+	99.76	=	33.38
Highbake Primer	5.4	-7.21*	(5.4)	+	49.88	=	10.95
Lowbake Colorcoat	6.0	-14.43*	(6.0)	+	99.76	=	13.18
Lowbake Primer	6.0	-7.21*	(6.0)	+	49.88	=	6.62

Option 1

Coating	VOC (lb/gal)	Cost Equation					Coating Cost ($/gal)
Highbake Colorcoat	4.3	-14.43*	(4.3)	+	99.76	=	37.71
Highbake Primer	4.3	-7.21*	(4.3)	+	49.88	=	18.88
Lowbake Colorcoat	5.0	-14.43*	(5.0)	+	99.76	=	27.61
Lowbake Primer	3.5	-7.21*	(3.5)	+	49.88	=	24.64

See Table 5-6 for the VOC content and calculated cost of each coating at baseline and both options.

The total cost of coating is found on a model plant basis by multiplying the total usage of each coating by its cost and summing each cost as shown in Example C-2.

Example C-2: Total Coating Cost for Model Plant ATA1

Baseline

Coating	Cost ($/gal)	Usage (gal/yr)	Total Cost ($/yr)
Highbake Colorcoat	33.88	450	15,000
Highbake Primer	10.95	150	1,600
Lowbake Colorcoat	13.18	8,550	112,700
Lowbake Primer	6.62	2,850	18,900
Totals		12,000	148,200

Option 1

Coating	Cost ($/gal)	Usage (gal/yr)	Total Cost ($/yr)
Highbake Colorcoat	37.71	400	15,100
Highbake Primer	18.88	90	1,700
Lowbake Colorcoat	27.61	4,480	123,700
Lowbake Primer	24.64	870	21,400
Totals		5,840	161,900

Table C-1 shows the total coating cost for each model plant at baseline and at both levels.

The cost of controlling a model plant at an option may then be calculated by finding the difference in total coating cost between the option cost and the baseline cost (Example C-3). Table C-1 presents the annual cost of control by reformulation for each model Plant at both control levels.

Example C-3: Annual Cost of Reformulation

Cost of Baseline (from Example C-2) = $148,200/yr

Cost of Option 1 (from Example C-2) = $161,900/yr

Cost of Control = $161,900/yr - $148,200/yr = $13,700/yr

The cost of controlling model plants with add-on incinerators was calculated by a computer program based on Chapter 3 of the OAQPS Control Cost Manual.[1] Table C-2 shows the input to the program, and Tables C-3 and C-4 show the costing output from the program.

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[1]U.S. Environmental Protection Agency. OAQPS Control Cost Manual. OAQPS/EPA. Research Triangle Park, North Carolina. EPA-450/3-90-006. January 1990

TABLE C-1. COST OF CONTROL BY REFORMULATION

	Baseline	Option 1		Option 2	
Model Plant	Coating Cost ($/yr)	Coating Cost ($/yr)	Control Cost ($/yr)	Coating Cost ($/yr)	Control Cost ($/yr)
ATA1	148,200	161,900	13,700	167,600	19,400
ATA2	294,100	298,100	4,000	300,600	6,500
ATA3	317,400	320,800	3,400	323,000	5,600
ATB1	336,600	367,800	31,200	380,700	44,100
ATB2	667,900	676,800	8,900	682,500	14,600
ATB3	720,600	728,500	7,900	733,300	13,700
ATC1	1,205,000	1,317,000	112,000	1,363,000	158,000
ATC2	2,391,000	2,423,000	32,000	2,443,000	52,000
ATC3	2,580,000	2,608,000	28,000	2,625,000	45,000
ATD1	3,705,000	4,050,000	345,000	4,191,000	486,000
ATD2	7,353,000	7,451,000	98,000	7,514,000	161,000
ATD3	7,934,000	8,022,000	88,000	8,075,000	141,000
BMM1	200,500	203,500	3,000	205,100	4,600
BMM2	1,604,000	1,628,000	24,000	1,640,000	36,000
BMM3	4,009,000	4,069,000	60,000	4,102,000	93,000

TABLE C-2. THERMAL INCINERATOR COSTING INPUT*

Stream #	Plant Size	Coating Type	Flow Rate (scfm)	VOC Loading (lb/hr)	Operating Hours (hr/yr)	VOC Conc (pmv)	Inlet Heat Value (BTU/scfm)
1	Small	Interior	30,000	17.820	4,000	42	0.2
2	Small	Exterior, Flexible	30,000	14.891	4,000	35	0.1
3	Small	Exterior, Nonflexible	30,000	14.086	4,000	33	0.1
4	Medium	Interior	50,000	40.468	4,000	57	0.2
5	Medium	Exterior, Flexible	50,000	33.814	4,000	48	0.2
6	Medium	Exterior, Nonflexible	50,000	31.986	4,000	45	0.2
7	Large	Interior	126,000	144.860	4,000	82	0.3
8	Large	Exterior, Flexible	126,000	121.039	4,000	68	0.3
9	Large	Exterior, Nonflexible	126,000	114.489	4,000	65	0.3
10	Extra Large	Interior	266,000	297.028	6,000	79	0.3
11	Extra Large	Exterior, Flexible	266,000	248.184	6,000	66	0.3
12	Extra Large	Exterior, Nonflexible	266,000	234.753	6,000	63	0.3
13	Small	Business Machine/Misc.	20,000	5.534	4,000	20	0.1
14	Medium	Business Machine/Misc.	50,000	44.326	4,000	63	0.3
15	Large	Business Machine/Misc.	90,000	110.823	4,000	87	0.4

*Other Input:
VOC is toluene (MW = 92)
Temperature is 77°F
Stream is 21% O_2 dry volume

TABLE C-3. EMISSIONS REDUCTION*

Record Number	Total Inlet Flow (scfm)	Inlet VOC Loading (lb/hr)	Inlet Heat Value (BTU/scf)	Natural Gas Flow (scfm)	Total Outlet Flow (scfm)	Outlet VOC Loading (lb/hr)	Total VOC Emission Reduction (Mg/yr)
1	30,000	17.820	0.2	393.56	30,394	0.356	31.7
2	30,000	14.891	0.1	397.05	30,397	0.298	26.4
3	30,000	14.086	0.1	397.05	30,397	0.282	25.0
4	50,000	40.468	0.2	655.93	50,656	0.809	71.9
5	50,000	33.814	0.2	655.93	50,656	0.676	60.1
6	50,000	31.986	0.2	655.93	50,656	0.640	56.8
7	126,000	144.860	0.3	1,638.29	127,638	2.897	257.3
8	126,000	121.039	0.3	1,638.29	127,638	2.421	215.0
9	126,000	114.489	0.3	1,638.29	127,638	2.290	203.4
10	266,000	297.028	0.3	3,458.62	269,459	5.941	791.4
11	266,000	248.184	0.3	3,458.38	269,459	4.964	661.2
12	266,000	234.753	0.3	3,458.62	269,459	4.695	625.4
13	20,000	5.534	0.1	264.70	20,265	0.111	9.8
14	50,000	44.326	0.3	650.12	50,650	0.887	78.7
15	90,000	110.823	0.4	1,159.74	91,160	2.216	196.8

*Assumption:
Incinerator Operates at 1600°F
70% Heat Recovery

TABLE C-4. CONTROL COSTS

Record Number	Source Description	Number of Incinerators	Incinerator Capital Cost ($)	Electrical Cost ($/yr)	Natural Gas Cost ($/yr)	Incinerator Annual Cost ($/yr)	VOC Cost Effectiveness (Mg/Removed)
1	Interior	1	635,907	62,357	311,698	523,948	16,554
2	Exterior, Flexible	1	635,923	62,360	314,462	526,718	19,914
3	Exterior, Nonflexible	1	635,923	62,360	314,462	526,718	21,052
4	Interior	2	1,256,690	94,209	519,497	910,425	12,666
5	Exterior, Flexible	2	1,256,690	94,209	519,497	910,425	15,159
6	Exterior, Nonflexible	2	1,256,690	94,209	519,497	910,425	16,025
7	Interior	3	2,247,899	320,668	1,297,528	2,136,844	8,305
8	Exterior, flexible	3	2,247,899	320,668	1,297,528	2,136,844	9,939
9	Exterior, nonflexible	3	2,247,899	320,668	1,297,528	2,136,844	10,508
10	Interior	6	4,903,670	1,051,642	4,108,838	6,343,361	8,016
11	Exterior, Flexible	6	4,903,670	1,051,642	4,108,838	6,343,361	9,593
12	Exterior, nonflexible	6	4,903,670	1,051,642	4,108,838	6,343,361	10,142
13	Business Machine/Misc.	1	571,240	33,798	209,641	380,221	38,682
14	Business Machine/Misc.	2	1,256,659	94,204	514,892	905,808	11,505
15	Business Machine/Misc.	2	1,480,004	239,536	918,516	150,047	7,621

APPENDIX D

CTG MODEL RULE FOR SURFACE COATING OF PLASTIC PARTS

D. 1 INTRODUCTION

This appendix outline a sample rule to limit volatile organic compound (VOC) emissions from the surface coating of plastic parts. The sample rule is for informational purposes only; it is intended to provide information concerning factors that need to be considered in writing a rule to ensure that it is enforceable.

This sample rule is general in nature; that is, the applicability of the rule, and thus the stringency, are determined when the emission limits are chosen by a State or local agency. As mentioned in Chapter 1, this document does not contain a recommendation on RACT; therefore, no emission limits are specified in the sample rule.

The remainder of this appendix contains the sample rule. Separate sections cover the following rule elements: applicability, definitions, emission standards, compliance demonstration, monitoring, recordkeeping and reporting.

D.2 APPLICABILITY

The provisions set forth in this sample rule apply to any facility that coats plastic components for the following uses:

> Automotive or other transportation equipment including interior and/or exterior parts for automobiles, trucks (light-, medium-, or heavy-duty), large and small farm machinery, motorcycles, construction equipment, vans, buses, and other mobile equipment; and
>
> Housings and exterior parts for business and commercial machines including, but not limited to, computers, copy machines, typewriters, medical equipment, and entertainment equipment.

This sample rule applies to in-house coating processes located at the original equipment manufacturer (OEM) site, as well as, to coating contractors specializing in molding and coating plastic parts, and job-shops performing coating only. This sample rule applies to coating operations including coating application, flash-off and drying/curing.

This sample rule does not apply to plastic parts coated on the main (body) paint line in automobile or light-duty truck assembly plants. This sample rule does not apply to the repair of plastic parts on fully assembled vehicles in automobile or light-duty truck assembly plants. These parts are covered under regulations for automobile and light-duty truck coating operations. This sample rule also does not apply to coating of interior and exterior parts for aircraft; coating of exterior of completely assembled marine vessels; refinishing of automobiles, trucks or other transportation equipment; and coating of internal electrical components of business and commercial machines.

The remainder of this appendix contains the sample rule. Separate sections cover the following rule elements: applicability, definitions, emission standards, emission standards testing, monitoring requirements, and reporting/ recordkeeping.

D.3 DEFINITIONS

Add-on control device. An air pollution control device such as a carbon adsorber or incinerator which reduces the pollution in an exhaust gas. The control device usually does not affect the process being controlled and thus is "add-on" technology as opposed to a scheme to control pollution through making some alteration to the basic process.

Adhesion promoter (primer). A coating applied to thermoplastic olefin (TPO) parts to promote adhesion of subsequent coatings.

Affected facility. Any apparatus, to which a standard is applicable, involved in the coating of plastic parts.

Aftermarket automobiles. Vehicles that have been purchased from the original equipment manufacturer.

Basecoat/clearcoat. A two-step topcoat system in which a highly pigmented, often metallic, basecoat is followed by a clearcoat, resulting in a finish with high-gloss characteristics. It is often used on automotive parts.

As applied. The condition of a coating at the time of application to the substrate, including any dilution solvents added before application of the coating.

Capture efficiency. The fraction of all organic vapors generated by a process that are directed to an abatement or recovery device.

Clearcoat. A transparent coating usually applied over a colored, opaque coat to improve gloss and provide protection to the colorcoat below.

Coating. A material applied onto or impregnated into a substrate for protective, decorative, or functional purposes. Such materials include, but are not limited to, paints, varnishes, sealants, adhesives, inks, maskants, and temporary protective coatings.

Coating unit [or line]. A series of one or more coating applicators and any associated preparation and drying areas and/or oven wherein a coating is applied, dried, and/or cured. A coating unit **[line]** ends at the point where the coating is dried or cured, or prior to any subsequent application of a different coating. However, a coating unit does not necessarily include an oven or a flash-off area, and may consist of any preparation and application areas.

Electromagnetic interference/radio frequency interference (EMI/RFI) coatings. Coatings used in plastic business machine housing to attenuate electromagnetic and radio frequency interference signals that would otherwise pass through the plastic housing.

Flash-off area. The area within a coating operation where solvents evaporate from a coating during the interval between coats or before the coated part enters a bake oven.

Flexible coating. A paint with the ability to withstand dimensional changes.

Gloss reducers. A low-gloss coating formulated to eliminate glare for safety purposes on interior surfaces of a vehicle, as specified under the U.S. Department of Transportation Motor Vehicle Safety Standards.

High bake coatings. Coatings designed to cure at temperatures above 194°F.

Higher-solids coating. Coating containing greater amounts of pigment and binder than conventional coatings. Solids are the non-solvent, non-water ingredients in the coating. Higher-solids coating usually contain more than 60 percent solids by volume.

Low bake coatings. Coatings designed to cure at lower temperatures (below 194°F).

Non-flexible coating. A paint without the ability to withstand dimensional changes.

OEM. Original equipment manufacturer.

Overspray. The solids portion of a coating which, when sprayed, fails to adhere to the part being coated. The applied solids plus overspray solids equal total coating solids delivered by the spray application system.

Plastic Part. A piece made from a substance that has been formed from resin through the application of pressure or heat or both.

Primer. Any coating applied prior to the application of a topcoat or color coat for the purpose of corrosion resistance, adhesion of the topcoat, and color uniformity.

Solids content. The non-solvent, non-water ingredients in the coating, consisting of pigment and binder, that do not evaporate and have the potential to form a cured (dry) film. The solids content can be expressed as volume percent or weight percent.

Specialty coatings. Coatings used for unusual job performance requirements. These products include adhesion primers, resist coatings, soft coatings, reflective coatings, electrostatic prep coatings, headlamp lens coatings, ink pad printing coatings, stencil coatings, coatings (automotive), vacuum metalizing coatings, and gloss reducers.

Topcoat. The final coat of paint applied to a substrate. Several layers of topcoat may be applied in some cases.

Transfer efficiency. The ratio of the amount of coating solids deposited onto the surface of the coated part to the total amount of coating solids used.

Two-component paint. A coating that is manufactured in two components that are mixed shortly before use. When mixed, the two liquids rapidly crosslink to form a solid composition.

Volatile organic compound (VOC) content. The amount of VOC in a coating as determined by Method 24. The VOC content can be expressed as pounds of VOC per gallon (or kg VOC/L) of coating, minus water and exempt compounds.

Waterborne coating. A coating that contains more than five weight percent water in its volatile fraction.

D.4 STANDARDS

(a) Automotive/Transportation Sector. The VOC content of any automotive/transportation plastic parts surface coating shall not exceed the applicable limitations as specified in Table 1.

(b) Business Machine Sector. The VOC content of any business machine plastic parts surface coating shall not exceed the applicable limitations as specified in Table 2.

(c) Daily Weighted Average Alternative. The daily weighted average VOC content of all coating used on a coating unit that are subject to a single limit in (a) or (b) above shall not exceed that limit.

(d) A facility may use a capture system and control device in lieu of complying coatings on any coating unit. The capture system and control device on a coating unit shall achieve an overall control efficiency which is greater than or equal to that needed to reduce the daily weighted average VOC content of the coatings used on that unit to the applicable emission limit on a solids basis.

D.5 COMPLIANCE DEMONSTRATION, MONITORING, RECORDKEEPING AND REPORTING

For information on possible compliance demonstration, monitoring, recordkeeping and reporting requirements, see Model Volatile Organic Compound Rules for Reasonably Available Control Technology, Planning for Ozone Nonattainment Pursuant to Title I of the Clean Air Act, Staff Working Document, June 1992.

TABLE 1. COATING CATEGORIES FOR AUTOMOTIVE/TRANSPORTATION COATINGS

Coating Category	Control Level (lb VOC/gal)[a]
I. Auto Interiors	
1) High Bake Colorcoat	
2) High Bake Primer	
3) Low Bake Colorcoat	
4) Low Bake Primer	
II. Auto Exteriors (Flexible and Nonflexible)	
1) High Bake	
a) Colorcoat	
b) Clearcoat	
c) Primer-Flexible	
d) Primer-Nonflexible	
2) Low Bake	
a) Primer	
b) Colorcoat Red and Black	
c) Colorcoat Others	
d) Clearcoat	
III. Auto Specialty	
1) Group (A)[b]	
2) Group (B)[c]	
3) Group (C)[d]	
4) Headlamp Lens	

[a]VOC content values are expressed in units of mass of VOC (kg, lb) per volume of coating (L, gal), excluding water and exempt compounds, as applied.

[b]Group A - Black and Reflective Argent Coatings, Soft Coatings, Air Bag Cover Coatings, Vacuum Metalizing Basecoat and Texture Coatings.

[c]Group B - Gloss Reducers, Vacuum Metalizing Topcoat, and Texture Topcoat.

[d]Group C - Stencil Coatings, Adhesion Primers, Ink Pad Printing Coatings, Electrostatic Prep Coats, and Resist Coatings.

TABLE 2. COATING CATEGORIES FOR BUSINESS MACHINE COATINGS

Coating Category	Control Level (lb VOC/gal)[a]
I. Primer	
II. Colorcoat	
III. Colorcoat/texture coat	
IV. EMI/RFI Shielding	
V. Specialty	
1) Soft Coatings	
2) Plating Resist	
3) Plating Sensitizer	

[a]VOC content values are expressed in units of mass of VOC (kg, lb) per volume of coating (L, gal), excluding water and exempt compounds, as applied.