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Planning and Standards
Research Triangle Park NC 27711

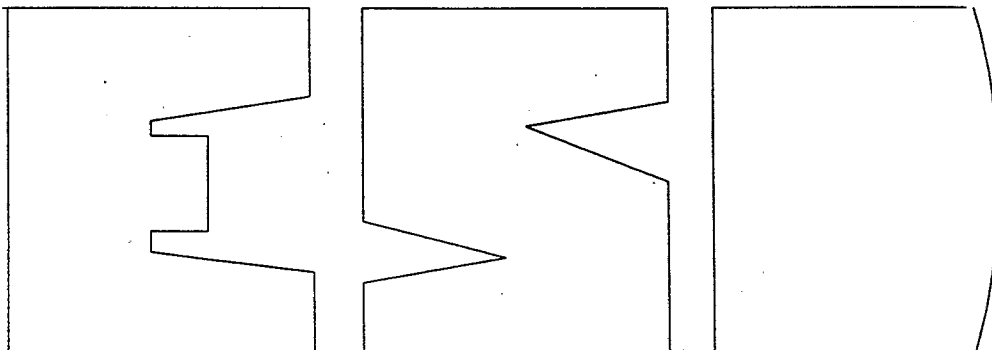
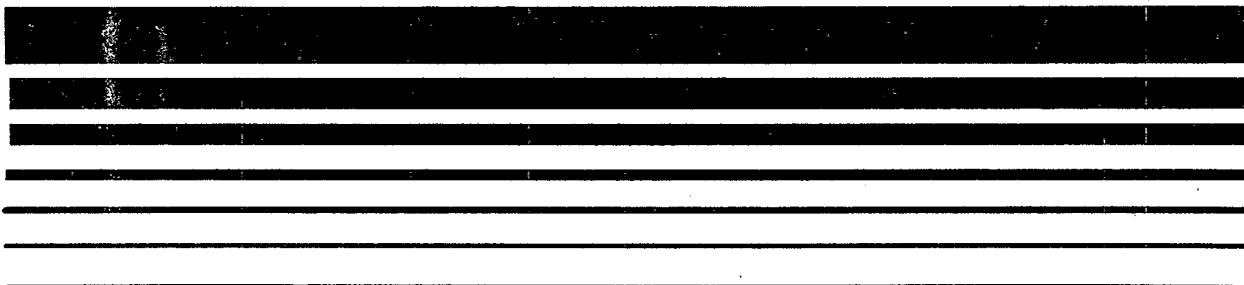
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Air



Volatile Organic Compound Emissions from Automobile Refinishing -- Background Information for Proposed Standards

Draft



**Volatile Organic Compound Emissions
from Automobile Refinishing --
Background Information for Proposed
Standards**

Emissions Standards Division

**U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711
August 1995**

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1.0 INTRODUCTION

National air quality monitoring data from 1989 through 1991 indicate that there are approximately 170 geographic areas that failed to attain the National Ambient Air Quality Standards (NAAQS) for ozone, with approximately 19 percent being classified as being serious or severe, and 22 percent being classified as being moderate or sub-marginal.¹ Ozone is a photochemical oxidant that is formed in the atmosphere through a series of chemical reactions between precursor emissions of volatile organic compounds (VOC's) and oxides of nitrogen (NO_x) in the presence of sunlight.

Although most large, stationary sources of VOC emissions are covered by existing regulations, an examination of emissions data completed in 1989 by the Congressional Office of Technology Assessment (OTA) indicates that individual small, dispersed sources of VOC's (area sources) contribute significantly to the continuing ozone nonattainment problem. According to the OTA report, "Catching Our Breath -- Next Steps for Reducing Urban Ozone," one area source of VOC emissions is the use of a wide range of consumer and commercial products.² This list of products includes automobile refinish coatings.

Almost all automobile refinish coatings contain VOC's. The volume used and VOC content are the primary factors that affect the total amount of VOC's emitted by this product category. The VOC emitted from automobile refinish coatings includes VOC that are part of a coating's original formulation, and VOC that are added during thinning or

reducing, and VOC's released as reaction byproducts while the coating dries and hardens. The total amount of VOC's emitted from automobile refinish coatings was estimated to be about 88,500 megagrams per year.

1.1 REFERENCES

1. Designation of Areas for Air Quality Planning Purposes, 40 CFR Part 81.
2. U. S. Congress, Office of Technology Assessment. Catching Our Breath: Next Steps for Reducing Urban Ozone. U. S. Government Printing Office. Washington, D.C. Publication No. OTA-0-412. July 1989. p. 16.

2.0 INDUSTRY DESCRIPTION

This chapter describes the automobile refinish industry. Section 2.1 provides an industry overview. Section 2.2 discusses the types of coatings used in refinishing. Section 2.3 describes the process steps and materials involved in refinishing. Preparation stations are discussed in Section 2.4, spray booths in Section 2.5, spray equipment in Section 2.6, and equipment cleaning in Section 2.7.

2.1 INDUSTRY OVERVIEW

As used in this document, "automobile" refers to passenger cars, vans, motorcycles, trucks, and all other mobile equipment that is capable of being driven or drawn upon a highway, such as farm machinery and construction equipment. "Refinishing" refers to any coating applications (to the interior or exterior bodies of automobiles) that occur subsequent to those at original equipment manufacturer (OEM) assembly plants, and includes dock repair of imported automobiles and dealer repair of transit damage before the sale of an automobile.

The automobile refinish industry consists of manufacturers that produce refinish coatings, distributors or "jobbers" that distribute coatings and other equipment, and body shops that repair and refinish automobiles.

2.1.1 COATING MANUFACTURERS

In 1989, sales of automobile refinish coatings in the United States totalled slightly over \$1 billion.¹ Five companies accounted for 95 percent of these sales: E.I. du Pont de Nemours & Company, Inc., PPG Industries, The Sherwin-Williams Company, BASF Chemicals, and Akzo Coatings.²

Approximately one dozen smaller manufacturers supply the remaining 5 percent.³ In the last few years, however, several other large foreign manufacturers have begun to enter the U.S. market, namely, ICI Autocolor, Spies Hecker, and Herberts Standox.

The five major manufacturers also produce components such as catalysts, solvents ("thinners" or "reducers"), and additives for use with their coatings. Approximately two dozen other U.S. manufacturers produce lower-cost coating components that are marketed for use with the coatings produced by the major manufacturers.⁴ However, the major manufacturers report that these lower-cost components may reduce the overall quality of their coatings and, consequently, will not honor their warranties if such components are added to their products.⁵

2.1.2 COATING DISTRIBUTORS

Distributors of refinish coatings also sell mixing components and other products used for refinishing, such as mixing stations, infrared heating lamps, sandpaper, and masking tape. Some distributors also sell equipment and products necessary to perform body repairs. Distributors provide body shops with valuable product support services such as training in new products and equipment, mixing of topcoat colors, troubleshooting advice, and general product information.

Although at least one coating manufacturer, The Sherwin-Williams Company, operates retail stores that distribute only Sherwin-Williams products,⁶ the large majority of the approximately 5,000 distributorships in the United States are not owned or operated by coating manufacturers. Another 10,000 body part distributors also sell refinish products.⁷ Both types of distributorships are known as paint, body supply, and equipment (PBE) specialists, and are commonly referred to as "jobbers" or "refinish jobbers."

2.1.3 BODY SHOPS

There are approximately 50,000 body shops of various sizes and technology levels in the U.S.,^{8,9,10} including small-size shops, medium-size shops, shops at new car dealerships, and large "production" shops. The work performed by most small- and medium-size body shops, which comprise most of the industry, is somewhat confined to repairing and refinishing small portions of an automobile (e.g., a panel, or a "spot" on a panel). About 90 percent of refinish work performed is spot repair.^{11,12} Sixty percent of new-car dealerships (approximately 13,500 facilities nationwide) reportedly operate body shops.¹³ New-car dealers refinish not only new cars damaged in shipment, but also cars that are brought in by customers for repair. Other types of shops specialize in repainting entire automobiles and are often referred to as "production" shops.

Although body shops in some areas of the United States must obtain permits or licenses to operate, painters are rarely required to be licensed.^{14,15} Painter training is often provided by coating manufacturers and distributors and by trade organizations, but no formal apprenticeship programs have been instituted by the industry.

In contrast, the refinish industry in several European countries is reportedly structured differently. For instance, in Germany, the refinish industry comprises large, sophisticated shops.¹⁶ In Holland, painters are required to be trained, pass a test, and obtain a license.¹⁷ In several European countries, painters usually participate in apprenticeship programs. These apprenticeships are not usually mandatory, but are part of the European culture.¹⁸

The refinish industry in the United States is a dynamic industry that has changed dramatically in the past decade.¹⁹ The industry is shifting away from a large number of small facilities toward fewer, larger shops, primarily because of worker health and safety issues and hazardous waste management concerns.²⁰ It is estimated that there were approximately

125,000 shops in operation in 1976, but by 1993 the number decreased to approximately 50,000.²¹

2.2 COATING TYPES AND PREPARATION

The main categories of coatings are primers and topcoats. The primer category consists of pretreatment wash primers, primers, primer surfacers, and primer sealers. Topcoats are applied over the primer coats and provide the final color to the refinished area.

Primers and topcoats can be classified as lacquer, enamel, or urethane coatings. These coatings differ in their chemistry, durability, and VOC content. Lacquer coatings cure by solvent evaporation only. Enamel and urethane coatings cure by solvent evaporation and chemical cross-linking reactions.²²

Lacquers and some types of enamel coatings consist mainly of pigment, resin, and solvent (thinner or reducer). The resin and pigment are collectively referred to as coating "solids" or "nonvolatiles" because they remain on the substrate to form the dry film. Solvents suspend the solids in solution and reduce the viscosity so that the coating flows into a uniform film on the substrate. The solvents evaporate, and only trace quantities remain in the film on the substrate. In addition to the coating components discussed above, urethanes and some enamel coatings use catalysts (or hardeners) to initiate the chemical cross-linking.

Urethane coatings typically have a much higher volume percent solids than lacquers and a slightly higher percentage than enamels. This is an important feature because, as mentioned above, the coating solids are the permanent part of the paint that remain on the surface as a film. The greater the solids content of a coating, the less coating required to obtain the desired film thickness.

The coatings applied by body shops differ from those applied by OEM's. OEM facilities use coatings that require temperatures up to 400 °F (204 °C) to cure the paint. This is possible because no temperature-sensitive materials have yet

been installed in the automobile. Body shops, on the other hand, must use coatings that cure at low temperatures (less than 150 °F [66 °C]) to avoid damaging the automobile's upholstery, glass, wiring, or plastic components.

2.2.1 Lacquer Coatings

Lacquers were one of the first types of coatings used on automobiles. Lacquers dry faster than most enamels or urethanes and, when dry, can be buffed to remove surface imperfections. These characteristics are attractive to body shops that do not have spray booths because the rapid drying helps minimize the opportunity for dirt to be trapped in the wet coating. One disadvantage of lacquers is that time and labor must be expended in buffing (compounding) lacquer finishes to achieve full luster.²³ Another disadvantage is that lacquer finishes are not as durable as enamel and urethane finishes.

2.2.2 Enamel Coatings

Enamel coatings, either alkyd or acrylic, have long been used in the automobile refinish industry. Alkyd enamel is a chemical combination of an alcohol, an acid, and an oil. Developed in 1929, alkyd enamels are less expensive than acrylic enamels but not as durable. Some acrylic enamels require hardeners to promote curing. Both types of enamels have a natural high gloss and do not require compounding to remove surface imperfections. Some enamel coatings can be polished, if necessary, to remove trapped dirt or dust.

2.2.3 Urethane Coatings

Urethane coatings are typically formed by a reaction between a hydroxyl-containing material and a polyisocyanate hardener. Their use is growing because of their superior gloss retention and durability. They are frequently used by the more technically sophisticated body shops for complete refinish jobs, such as refinishing of fleet vehicles.²⁴

Urethane coatings dry more slowly than lacquers and enamels, and spray booths may be necessary to reduce drying time and provide a clean, dust-free curing environment. The

possible presence of trace amounts of residual isocyanates requires painters to use an air-supplied respirator to reduce worker exposure. Isocyanate-free hardeners are available for use in some coating systems.²⁵

2.2.4 Waterborne Coatings

A waterborne coating contains more than 5 weight-percent water in its volatile fraction.^{26,27} Like enamel and urethane coatings, waterborne coatings dry relatively slowly. The use of a spray booth may be necessary to prevent contamination, and infrared heating equipment may be necessary to facilitate drying.

2.2.5 Additives and Specialty Coatings

Some additives and specialty coatings are necessary for unusual performance requirements, and are used in relatively small amounts to impart or improve desirable properties. Problems such as "fish eye" defects (a surface imperfection that can occur when the old finish contains silicone) can be prevented by the use of additives. Additives and specialty coatings include adhesion promoters, uniform finish blenders, elastomeric materials for flexible plastic parts, gloss flatteners, and anti-glare/safety coatings.

2.2.6 Coating Preparation

Most coatings are mixed with additional solvents (and sometimes catalysts) prior to application to ensure proper drying time, adhesion, appearance, and color-match. Topcoats in particular must be mixed exactly according to the manufacturer's instructions because even a slight deviation may result in unacceptable finish quality.

Many shops order topcoats to match the automobile being refinished from local automotive paint distributors. Others mix their own colors using mixing stations. A mixing station typically consists of a microfiche viewer or a computer that contains the coating manufacturer's mixing instructions, a digital scale, and a mixing machine. Shops that use mixing stations typically stock only a few primary colors, from which almost any OEM color can be produced.²⁸ According to an

industry survey, about one-half of all shops own mixing machines.²⁹ Almost all large volume or sophisticated shops own mixing stations, but few small shops (those employing only one or two painters) own them.³⁰

Shops that mix their own coatings strive to mix as little as possible to complete a job, but always with a slight excess to ensure that enough is available to complete the job. By minimizing the excess, the shop minimizes the cost of materials and the amount and cost of hazardous coating waste disposal.

2.2.7 Coating Systems

All of the major coating manufacturers market specific brands of primer and topcoat products as "systems." All of the coatings within a particular manufacturer's coating system are compatible and, according to the manufacturers, should be used exactly according to instructions and never interchanged with coatings from other systems.³¹ Problems with adhesion, durability, and recoatability are reportedly common if coating systems are not maintained.³²

2.3 PROCESS STEPS AND MATERIALS

The procedures for refinishing automobiles vary from shop to shop; however, some basic steps are followed, whether the job is to repair a spot, panel, or entire automobile. Generally, the surface is thoroughly cleaned to ensure proper adhesion of the coating, the metal surface is primed, a topcoat is applied, and the spray equipment is cleaned.

The following subsections describe the surface preparation and coating application processes. The spray equipment cleaning process is discussed in Section 2.6.

2.3.1 Surface Preparation

The first step in the refinish process is preparing the surface. The surface is normally washed with detergent and water and allowed to dry. It is then cleaned with either solvent or a solvent-based surface preparation product (solvent wipe) to ensure removal of all remaining wax, grease, and other contaminants.

Surface preparation products generally contain solvents (toluene, xylene, and petroleum distillates) and surfactants.³³ These products are wiped off after they have effectively dissolved the wax and grease from the surface. This step is important to avoid contamination and ensure proper adhesion of the coatings, and is necessary even if the existing paint does not have to be removed or if the parts to be coated are new. Some shops use waterborne, low-VOC surface preparation products instead of solventborne products.

If an existing primer/topcoat is in good condition (no chips or cracks), the new paint can be applied directly on top of it by merely "scuff-sanding" (or roughening) the surface to promote adhesion. If the existing finish has imperfections or the part has been damaged in an accident, the old finish should be completely removed down to bare metal.

Removal of old paint is by one of three methods: (1) by sanding (best for small areas), (2) with paint removers (which typically contain solvents such as methylene chloride, methanol, and ammonia, and are most efficient for large areas and complete panels), or (3) by sand blasting (best for complete automobiles or extremely large areas).^{34,35} The paint removal step is followed by a final solvent wipe.

2.3.2 Primer Application

Before any coatings are applied to bare metal, the surface should be treated with a metal conditioner to etch the surface and prevent flash rusting, which can occur from bare metal exposure to the atmosphere. Metal conditioning can be achieved using a hand-applied acidic conditioner, or by the application of a pretreatment wash ("self-etching") primer, that both etches and primes the surface. Pretreatment wash primers contain at least 0.5 percent acid by weight, and can be applied prior to the application of solventborne or waterborne coatings. If a pretreatment wash primer is not used, the conditioned surface should be primed to provide corrosion resistance and promote adhesion.³⁶

The term "precoat" has been used in several State automobile refinish rules to describe a bare metal coating category. A precoat is described as a coating that is applied to bare metal prior to the application of waterborne coatings. When pretreatment wash primers cannot be used (i.e., when they are incompatible with the substrate or other coatings), primers or primer sealers can be used to prepare the surface for subsequent waterborne coatings; therefore, a separate "precoat" category is not necessary.

2.3.3 Primer Surfacer Application

If imperfections remain in the surface after primer application, a primer surfacer is applied. Primer surfacers build film thickness in order to create a smooth surface after sanding, and provide adhesion and corrosion resistance.

2.3.4 Primer Sealer Application

If there are no surface imperfections, some shops apply only a primer sealer to provide more corrosion resistance, promote adhesion of subsequent coatings, and enhance the uniform appearance of the topcoat. Primer sealers prevent dulling of the topcoat caused by the penetration of topcoat solvents into the primer and primer surfacer coats.

2.3.5 Topcoat Application

The topcoat system, applied after the surface is prepared and free of defects, provides the final color and appearance. Topcoats may be single-stage, two-stage, or three-stage coating systems. Each stage of a two- or three-stage system directly impacts the durability of the topcoat system, and the ability to successfully match the old paint color.

Two-stage basecoat/clearcoat systems may have either a solid color or a metallic basecoat, covered by a transparent clearcoat for protection and gloss. The basecoat is approximately one-third and the clearcoat two-thirds of the total coating used.^{37,38,39} Two-stage systems are popular because of their deep, rich finish, which reportedly cannot be duplicated by a single-stage coating.

Metallic finishes contain small metal flakes, typically aluminum, which are suspended in a mixture of binders, solvent, and pigment. Light reflects off these metal flakes to produce the metallic effect. Color-matching these coatings is difficult and depends on the alignment of the metallic particles, which is influenced by the evaporation rate of the solvent. OEM's use metallic coatings on at least 50 percent of all new automobiles.⁴⁰

Three-stage systems consist of a basecoat, midcoat, and clearcoat. The basecoat and midcoat account for about one-half of the coating volume and the clearcoat for one-half.^{41,42} Three-stage refinish systems are often used to match three-stage OEM finishes.⁴³

Three-stage iridescent finishes are similar to metallic finishes; they contain flakes of mica in the midcoat that reflect light to produce an iridescent, or "pearl", effect.

As OEM topcoats have become more complex, the precise matching of original colors by painters has become more difficult. Annual changes in OEM color selections add a dimension of difficulty to achieving color-match. An automobile manufacturer typically will introduce over 10 new colors in a single year.⁴⁴ New car colors are developed by coating manufacturers, who preview them with automobile manufacturing stylists. The automobile manufacturer then determines from market research which colors to use.

Once a new color has been selected, the coating manufacturers develop coatings that achieve the desired appearance and performance specifications. Trial application by the automobile manufacturer may then take a number of months before the coating is approved for line application.

The typical automobile painter, however, lacks this period of "trial application" and is expected to meet color specifications and customer satisfaction for every job, regardless of previous experience with a particular color. Although refinish coating formulations are developed for each OEM color, there is often variability in the shade color,

which requires the painter to make adjustments to the formula. Because of the difficulty of matching certain colors, the painter must sometimes refinish more of the automobile rather than just the damaged portion. This, of course, increases coating usage.

2.4 PREPARATION STATIONS

Preparation of the surface for repainting and application of the primer usually are done in open areas of body shops; however, in some shops these steps are performed in preparation, or "prep", stations. Prep stations typically are ventilated and equipped with plastic curtains to control dust and coating overspray. Many shops are equipped with portable infrared heating units to facilitate drying of primers during cool and/or humid shop conditions. Figure 2-1 presents a diagram of a typical heating unit.

2.5 SPRAY BOOTHS

Spray booths are clean, well-lit, and well-ventilated enclosures for coating operations. Because of their longer drying times, enamel, water-based, and urethane coatings are best applied in a spray booth to minimize the possibility of dirt adhering to the wet coating. Air is drawn into a spray booth through filters to assure a flow of clean air past the automobile being painted. This air hastens drying and provides a safer work environment for the painter by removing solvent vapors from the booth. Filters in the discharge from the booth remove coating overspray (the portion of the coating solids that does not adhere to the surface being sprayed) from the exhaust air.

There are three types of spray booths used in the refinish industry: crossdraft, downdraft, and semi-downdraft (Figure 2-2). Traditionally, the air flow in refinish spray booths has been from one side of the booth to the other, or "crossdraft." In the crossdraft design, incoming air is pulled into the booth through filters located in the entrance door. The air travels along the length of the car and then passes through coating arrestor filters at the opposite end,

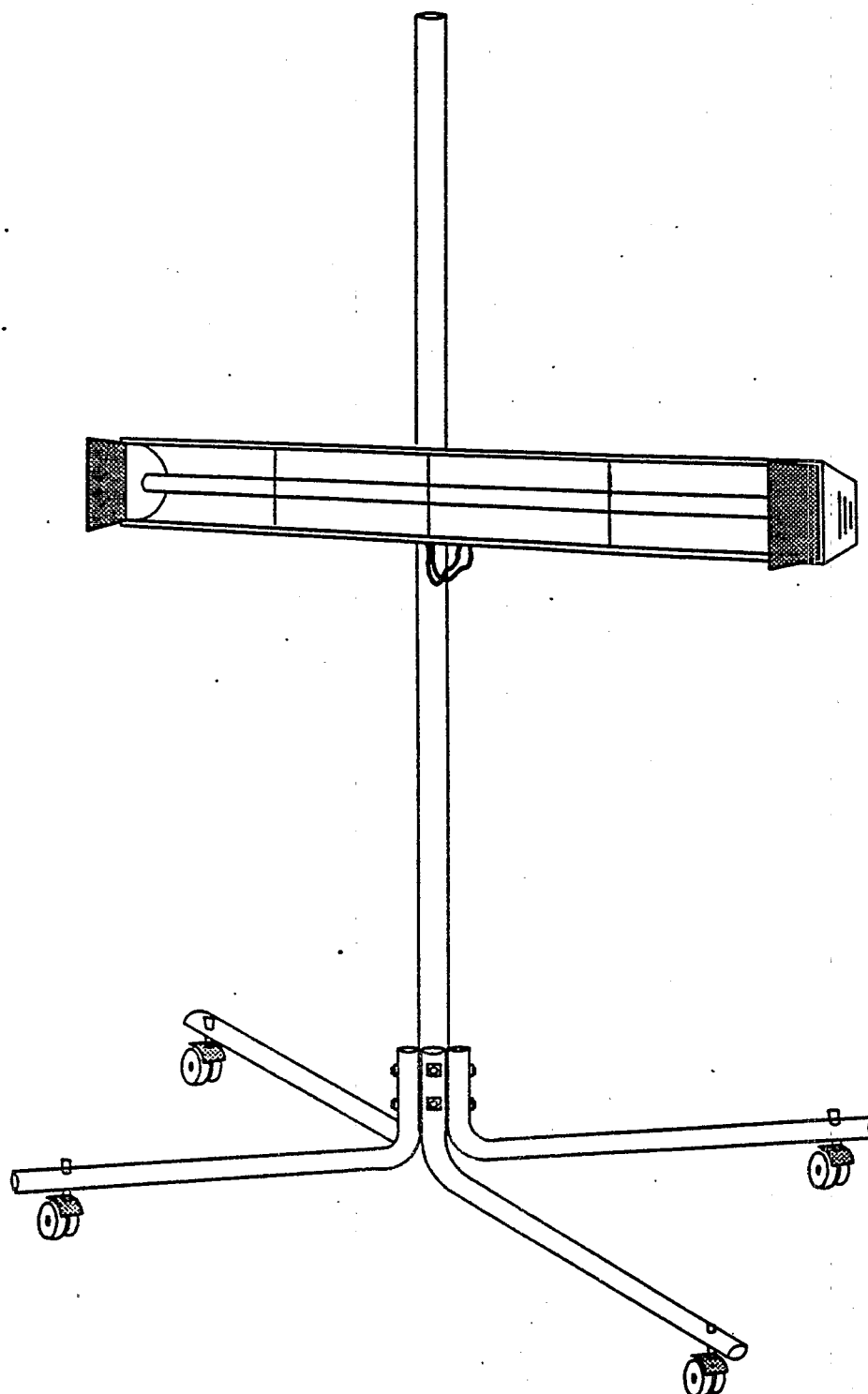
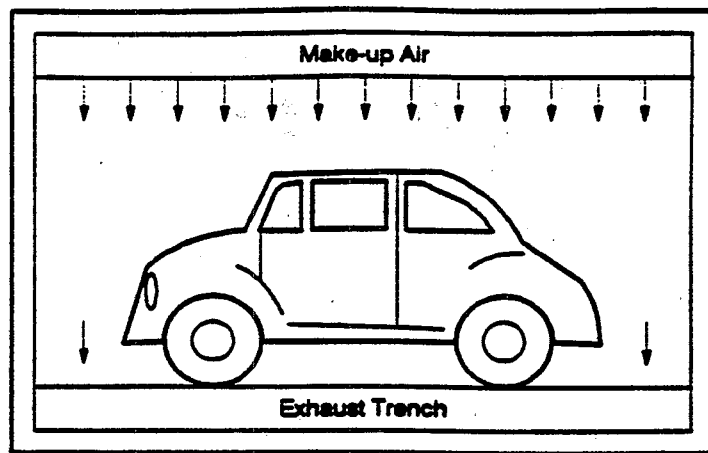
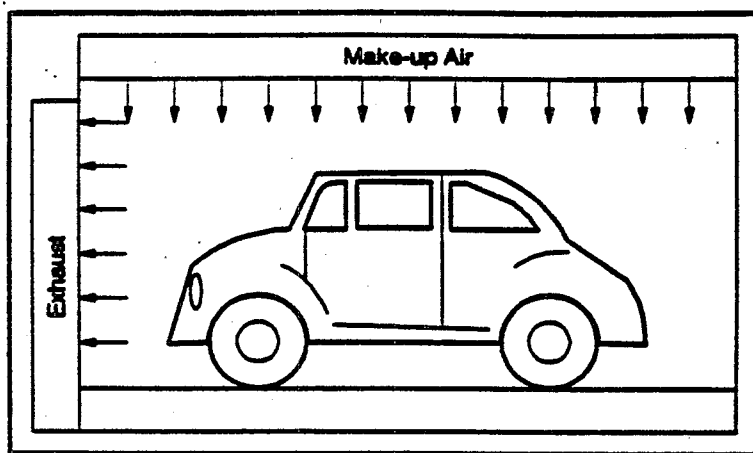


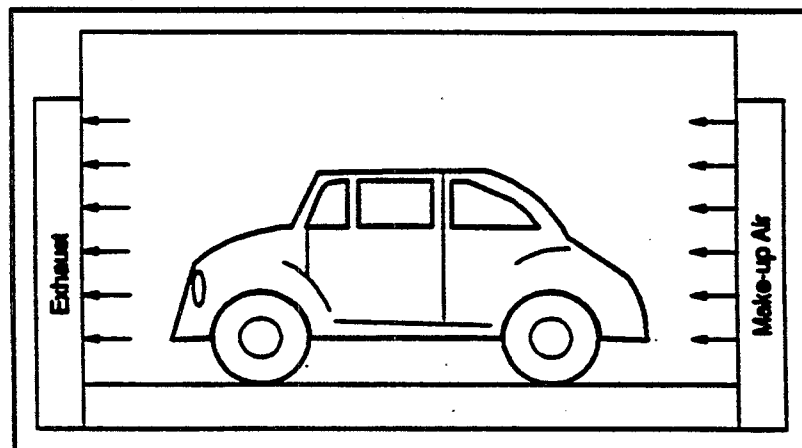
Figure 2-1. Typical Infrared Heating Unit



Downdraft



Semi-downdraft



Crossdraft

Figure 2-2. Spray booth make-up and exhaust air orientation

where coating overspray is removed. The air then exits through an exhaust stack, carrying with it any solvent vapors or other VOC's.

Downdraft booths have a vertical air flow (top to bottom) and are considered state-of-the-art because they provide the cleanest drying/curing environment. In a downdraft booth, the air is pulled in through filters in the roof, travels down over the top of the automobile, picks up coating solvent and overspray, and passes into a grate-covered pit in the floor of the booth.

The downdraft booth is a better design than the crossdraft booth because the air is less turbulent, which helps minimize the mixing of overspray with air in the rest of the booth. In addition, air circulation is more uniformly concentrated around the automobile and solvent vapor is drawn down and away from the painter's breathing zone.

Downdraft booths can utilize dry-filtration or wet-filtration (waterwash) systems to capture coating overspray. In wet-filtration booths, water is used to capture overspray. Both types of filters only remove coating solids; they do not reduce VOC emissions to the atmosphere.

The semi-downdraft spray booth is a combination of crossdraft and downdraft booth designs. Air enters the booth through the ceiling and is discharged at the back of the booth. Air in a semi-downdraft spray booth is more turbulent than in a downdraft booth but less turbulent than in a crossdraft booth.

In order to decrease the drying time after coating application, most shops with spray booths use heated air drying systems. Smaller shops may use traveling ovens that can be rolled out for use inside the booth after the automobile has been sprayed. Small, portable, infrared heating units are also available either to warm metal surfaces prior to coating application or to speed the drying time of the repair.

Approximately 40 percent of all body shops own crossdraft booths and 30 percent own downdraft or semi-downdraft booths.⁴⁵ The portion that can heat the booth air is not known. As the refinish industry continues to move away from lacquer coatings and toward slower drying higher-solids and waterborne coatings, shops that do not already have spray booths are expected to purchase them.

2.6 SPRAY EQUIPMENT

Current practice in the refinish industry is to apply coatings with hand-held spray guns that use air pressure to atomize the coating. There are two basic types of spray gun systems: pressure-feed and suction-feed. In a pressure-feed system, the coating is contained in a "pot" that is connected by hose lines to the spray gun. Compressed air introduced to the pot pushes the liquid through the hose and out of the spray gun nozzle. Pressure-feed systems generally require significantly more coating than suction-feed because of the amount of residual coating in the pressure pot and hose lines.

In a suction-feed system, coating is contained in a "cup" mounted on the spray gun. The rapid flow of air through the air line and spray gun creates a vacuum which draws the coating from the cup and forces it through the gun nozzle.

Based on available data, it is clear that some spray equipment is likely to give better transfer efficiency than others. Simply defined, transfer efficiency is the ratio of the amount of coating solids deposited onto the surface of the coated part to the total amount of coating solids that exit the gun nozzle. Paint that is sprayed but not deposited onto the surface is referred to as "overspray." Increased transfer efficiency, or reduction of coating overspray, has a number of benefits. Because coating overspray releases the same amount of solvent as the coating that adheres to the substrate, reducing overspray reduces VOC emissions.

Less overspray also benefits the refinisher. Solvent concentration in the booth is reduced, less time is spent applying coatings (because more reaches the substrate), and

solvent use for cleanup of overspray is reduced. Additionally, a shop that uses high-transfer efficiency spray equipment uses less coating, and therefore may also realize a savings in coating costs. The transfer efficiency of spray guns vary dramatically depending on a number of factors, such as the shape of the surface being coated, type of gun, velocity of the aerosol, skill and diligence of the operator, and extraneous air movement within the spray booth.

2.6.1 Conventional Air Spray Guns

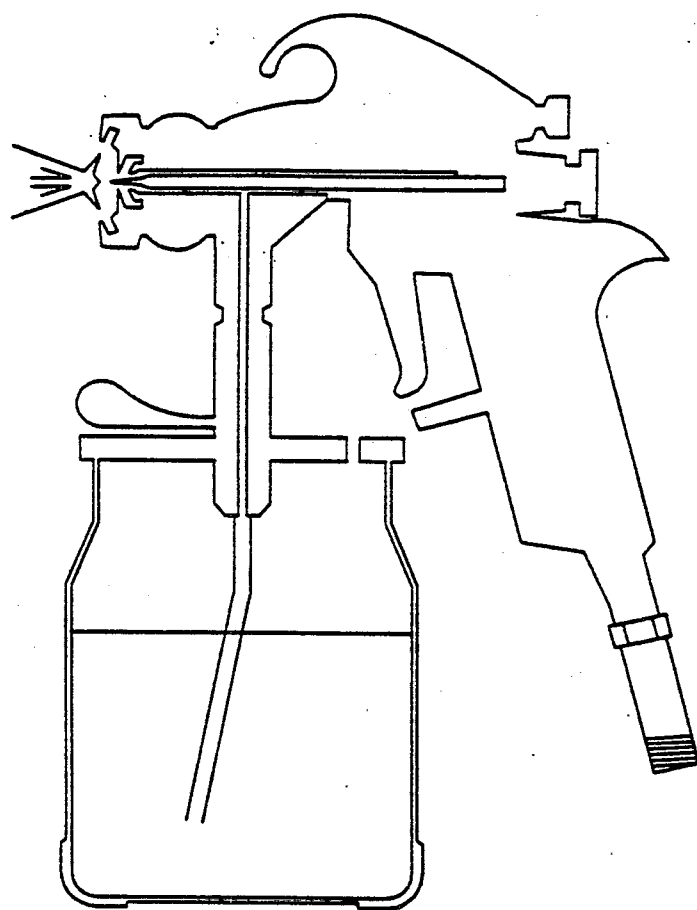
Conventional air spray guns are suction-feed and are the standard method of applying coatings. Figure 2-3 shows the two basic types of conventional spray guns: syphon-feed and gravity-feed. In syphon-feed guns the paint cup is attached below the spray gun, and the rapid flow of air through the gun creates a vacuum that siphons the coating out of the cup. Gravity-feed guns, which have the paint cup attached above the gun, require less air pressure to move the coating through the gun and provide substantially better transfer efficiency than syphon-feed guns.⁴⁶

The air pressure at which conventional spray guns operate is usually 30 to 90 pounds per square inch (psi). One of the major problems with these guns is that the high velocity of the aerosol causes the coating particles to "bounce", which increases overspray. The transfer efficiency of conventional spray guns is substantially lower than that of "high-volume, low pressure" (HVLP) spray guns.

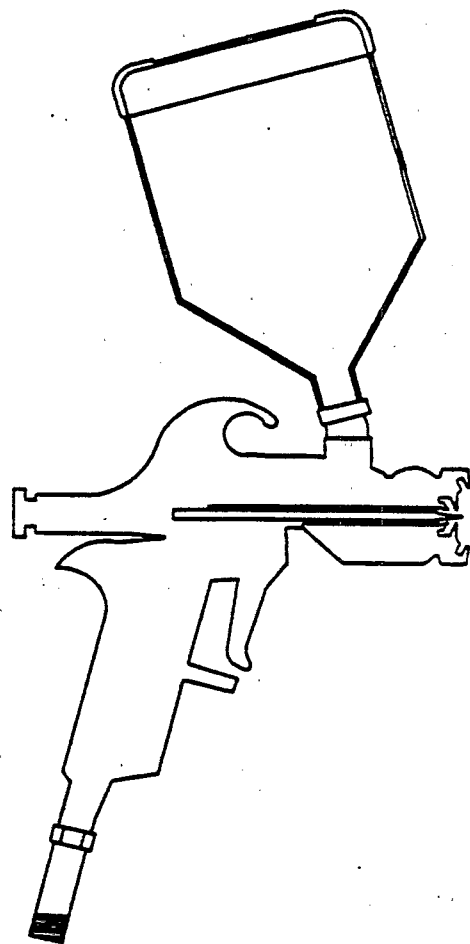
2.6.2 High-Volume, Low-Pressure Spray Guns

High-volume, low-pressure spray guns use large volumes of air at low pressure (10 psi or less) to atomize coatings. Because the atomized spray leaves the gun at a lower velocity than in conventional air spraying, there is less particle "bounce." As a result, higher transfer efficiency can be achieved, with overspray reportedly being reduced by 25 to 50 percent.⁴⁷

The air source in an HVLP spray system can be a turbine or conventional compressed air. Both systems can be purchased to



Syphon-Feed



Gravity-Feed

Figure 2-3. Conventional spray equipment

handle multiple spray guns. The materials of construction of most HVLP systems are designed to be compatible with a full range of coatings. Many HVLP spray systems are designed to atomize high-, medium-, and low-solids coatings.

When first using HVLP spray equipment, the painter must adjust to the different characteristics of the spray pattern. Initially, HVLP spray guns are more difficult to use, especially for color-matching, because the greater transfer efficiency requires that the painter move the gun more quickly in order to avoid applying an excessively thick coat. Thick films can cause splotching, which occurs when solvent initially trapped in the thicker coating escapes to the surface and causes a blemish. Also, thicker films retard the evaporation rate of the solvent, which can influence the positioning of metallic flakes. In addition, the HVLP spray requires more skill to blend.⁴⁸ Once a painter becomes experienced with HVLP guns, however, these problems are overcome, with a significant cost savings because the amount of waste coatings can be reduced with no sacrifice in the quality of the refinished surface.

2.6.3 Low-Volume, Low-Pressure Spray Guns

Low-volume, low-pressure (LVLP) spray guns are quite similar to HVLP spray guns in that atomized coatings are released at lower pressure (9.5 to 10 psi) and lower velocity than conventional air spray guns. The transfer efficiency of LVLP spray guns is reportedly about the same as for HVLP spray guns. The primary difference is that LVLP guns use a substantially smaller volume of air for paint atomization (45 to 60 percent less). Consequently, energy costs for air compression are less than with HVLP guns.⁴⁹

2.6.4 Electrostatic Spray Guns

Electrostatic spray systems create an electrical potential between the coating particles and the substrate. The charged coating particles are attracted to the substrate, thus reducing overspray and increasing transfer efficiency.

Typical electrostatic spray systems are pressure-feed. A large amount of coating is contained in the hose that connects the spray gun to the paint pot. It must be removed before the next coating can be applied with the gun. These designs appear impractical for the refinish industry, primarily because refinish facilities change coatings so often.⁵⁰ In addition, the cost of electrostatic spray systems may be prohibitive for most body shops.⁵¹

It has been reported that there are explosion and electrocution risks associated with use of electrostatic spray guns unless very strict operating procedures are observed.⁵² Foremost, it is necessary to establish and maintain proper electrical grounding of all metallic objects in electrostatic spray areas, especially solvent and paint containers. If improperly grounded, these objects can develop high-voltage charges as they come in contact with the electrified air molecules and paint molecules. A spark near these objects may easily ignite any surrounding solvent vapors.⁵³ Users of electrostatic spray equipment should carefully observe all manufacturers' operating procedures.

2.7 EQUIPMENT CLEANING

Spray equipment can be cleaned manually or with any of several types of gun cleaning systems specifically designed for this purpose. About 60 percent of all body shops reportedly use some type of gun cleaning system.^{54,55} Shops that do not have spray gun cleaning systems usually rinse the outside of the gun and cup, add solvent to the cup, and then spray the solvent into the air or into a drum set aside for spent solvent.⁵⁶

An enclosed gun cleaner or washer (Figure 2-4) consists of a closed container (much like an automatic dishwasher with a door or top that can be opened and closed) fitted with cleaning connections. The spray gun is attached to a connection, and solvent is pumped through the gun and onto the exterior of the gun. The paint cup is also placed in the cleaner, where the interior and exterior are sprayed with

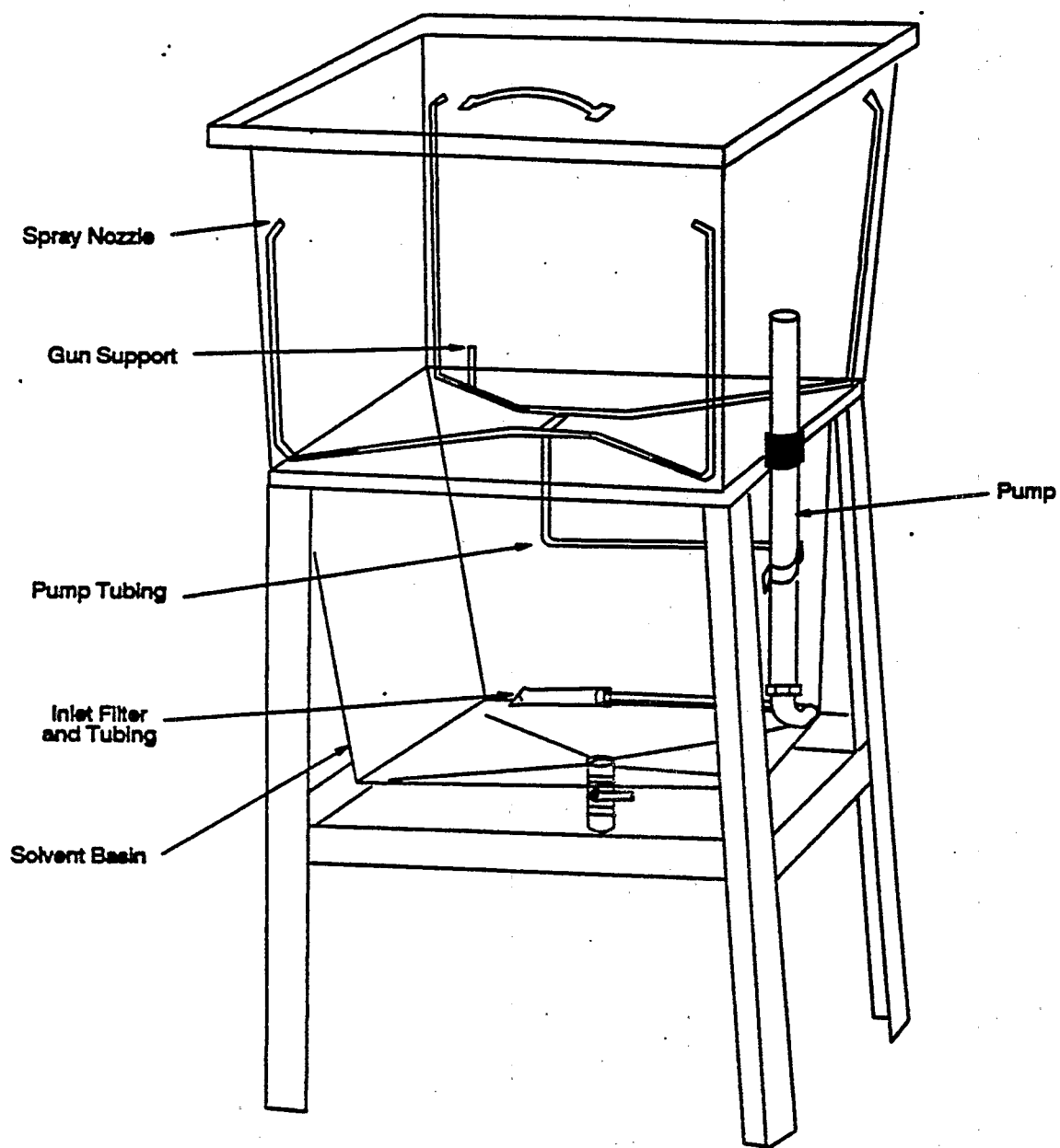


Figure 2-4. Typical enclosed gun cleaner

solvent. Many gun cleaners are capable of cleaning two guns and cups per cleaning and are typically designed to clean other equipment such as paint stirrers and strainers. Cleaning solvent falls back into the cleaner's solvent reservoir for recirculation. Solvent is recirculated until it is too contaminated for further use. Some enclosed gun cleaners are equipped with a second solvent reservoir that contains virgin solvent that is used as a final rinse.

A typical open gun cleaner, shown in Figure 2-5, consists of a basin similar to a sink in which the operator washes the outside of the gun under a solvent stream. The gun cup is filled with recirculated solvent, the gun tip is placed into a canister attached to the basin, and suction draws the solvent from the cup through the gun. The operator then removes the cup, places the gun's suction stem under the clean solvent spigot, pulls the trigger, and pumps solvent through the gun. The solvent gravitates to the bottom of the basin and drains through a small hole to a reservoir that supplies solvent to the recirculation pump. The recirculating solvent is changed when it no longer cleans satisfactorily.

Waste solvents generated by spray equipment cleaning are often disposed of by evaporation (via spraying into the air, or by placing in open drums) or incineration, or are reclaimed via distillation. Solvent can be reclaimed either at the shop or off-site. Off-site solvent reclaimers collect spent solvent from body shops, distill it, and return clean solvent to the shops. Some companies provide this service only for those shops that rent their gun cleaning systems.

In-house recycling can be as simple as letting spent solvents settle and decanting the "clean" layer for reuse. This method, gravity separation, is used where the purity of the solvent is not critical. Some on-site distillation units produce a more refined solvent, which reduces the amount of new solvent that must be purchased and eliminates disposal fees for the reclaimed solvent.

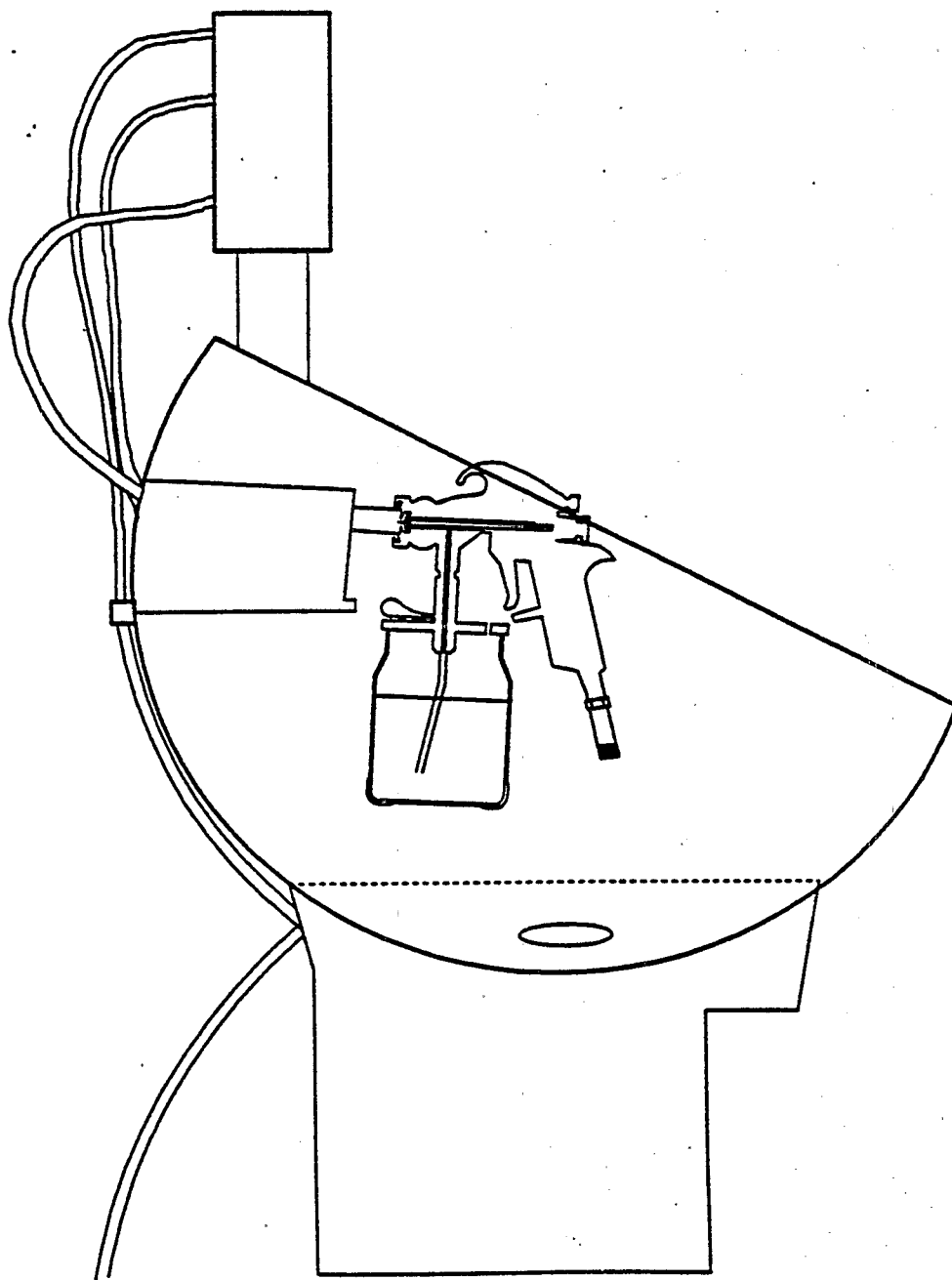
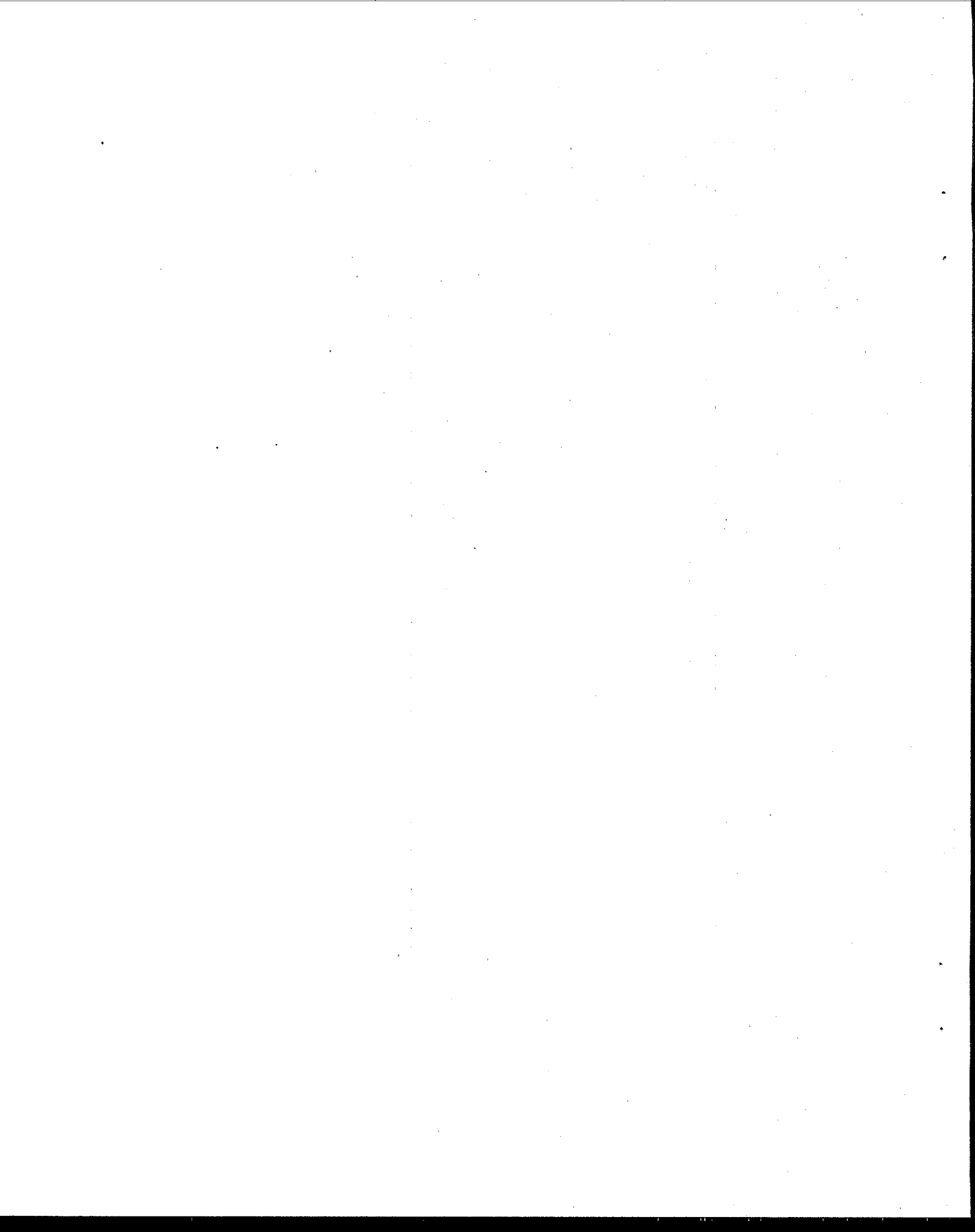


Figure 2-5. Typical open gun cleaner

Care must be taken when a solvent reclaim unit is to be placed in use. Solvents are combustible and can also be an explosion hazard.⁵⁷ Explosion hazards are possible from the distillation residues that contain nitrocellulose. Nitrocellulose is found in lacquer paint but would not be expected in enamels and urethanes.⁵⁸ In addition, some on-site reclaimers are not explosion-proof and may pose a hazard when operated near other non-explosion-proof electrical equipment. It is recommended that reclaim equipment be operated outdoors and away from spark-producing equipment, and that the power is turned off when the machine is being emptied.⁵⁹

The use of solvent for gun cleaning can reportedly be reduced by using teflon-lined paint cups, which makes paint removal easier. Some facilities use a small plastic liner inside the paint cup to make cleanup easier and reduce solvent use. The paint-covered plastic liner is discarded after each use and the paint cup remains essentially free of paint.



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3.0 EMISSION CONTROL TECHNIQUES

3.1 INTRODUCTION

The steps involved in automobile refinishing include surface preparation, coating application, and spray equipment cleaning. Although each of these steps can be a source of VOC emissions, regulated entities under the National Rule include only coating manufacturers and importers; therefore, coating application is the only source of emissions that can be reduced by standards for such entities. Achieving reductions from surface preparation and spray equipment cleaning would require standards at the coating user level. This chapter discusses the use of low-VOC coatings for reducing VOC emissions from coating application.

Before discussing techniques to reduce the VOC emissions from coating application, it is necessary to discuss the methodology used to determine the VOC content of coatings. As explained in Chapter 2, the solids portion of a coating remains on the substrate to form the film; therefore, the VOC content of a coating ideally would be related to its volume solids. There is as yet, however, no generally accepted method for the determination of the solids content of coatings. This document continues the EPA's approach of relating the mass of VOC in a coating to the combined volumes of VOC and solids, expressed as: mass of VOC per unit volume of coating, minus volume of water and any negligibly photochemically reactive ("exempt") compounds. Unless otherwise stated, the VOC contents discussed in this document represent the amount of VOC in the coating as it is applied,

that is, after it has been prepared for application according to the manufacturer's mixing instructions.

3.2 EMISSION REDUCTIONS FROM COATING APPLICATIONS

Information on low-VOC coatings was gathered through a survey of the major manufacturers of automobile refinish coatings conducted by the EPA in March of 1990¹ and from coating product literature. This information indicates that all of the major manufacturers have developed coatings that contain substantially less VOC than conventional coatings. Some of these coatings have been developed to comply with several State regulations that mandate their use.

Table 3-1 lists the various coatings used in automobile refinishing and the VOC contents of conventional coatings. This table also presents VOC content limits for the various coatings, which are organized into three options.

The limits of Option 1 were derived by evaluating the technical feasibility, cost, and reported limitations of coatings that are currently available. Coatings at the Option 1 limits would not require the purchase of any additional equipment by body shops. Therefore, shops at all levels of technical sophistication should be able to use these coatings with no loss of productivity or quality.

The Option 2 limits were suggested by coating manufacturers several years ago when they anticipated that such coatings could be developed before they were required by a rule. The Option 2 limit of 600 grams of VOC per liter (g VOC/l) for 3-stage topcoats is claimed by manufacturers to be "technology-forcing" because there are no coatings currently available at these limits. There are primer/primer surfacers available that meet the Option 2 limit; however, equipment (such as heating lamps) would likely have to be purchased by users to speed the drying of these slower-drying coatings.

The VOC limits of Option 3 are identical to the limits determined to be Best Available Retrofit Control Technology (BARCT) by the California Air Resources Board (CARB) (effective January 1, 1992 through December 31, 1994), except

TABLE 3-1. COATING CONTROL OPTIONS

Coating Category	VOC content (g/l)			
	Conventional (average)	Option 1	Option 2	Option 3
Primers				
Pretreatment	695 - 780 (755)	780	780	780
Precoat	550 - 850 (695)	-	-	-
Primer/primer surfacer	550 - 850 (685)	550	455	335
Primer sealer	600 - 805 (755)	550	550	420
Topcoats				
Single stage		600	600	600
Lacquer	695 - 805 (755)			
Enamel	575 - 720 (670)			
Basecoat	695 - 805 (745)			
Clearcoat	550 - 805 (625)			
3-Stage topcoats		625	600	600
Specialty	840	840	840	840

for the precoat.² These coatings are currently available; however, their longer drying times would also require the purchase of additional equipment by shops in geographical areas with weather conditions less favorable than California's.

The VOC contents of conventional pretreatment wash primers range from 695 to 780 g VOC/l; the average is approximately 755 g VOC/l.³ A limit of 780 g VOC/l is included in all options to ensure that this bare metal coating can be applied in a thin film and that it will be compatible with subsequent coatings. No emission reductions are anticipated from pretreatment wash primers, but significant reductions could not be expected since only about two percent of total automobile refinish emissions result from their application.

Precoats contain between 550 and 850 g VOC/l; the average is approximately 695 g VOC/l.⁴ As discussed in Chapter 2, a separate category for precoats is not necessary; therefore, none of the options contain precoat categories.

Since primer sealers are sometimes used as bare metal coatings, the primer sealer limits of the options (discussed below) were used to estimate the emissions reductions from precoats. The Option 1 and 2 limit of 550 g VOC/l would result in about a 60 percent reduction in VOC emissions from the average precoat; the Option 3 limit of 420 g VOC/l would result in about an 80 percent reduction.

Conventional primer/primer surfacers contain between 550 and 850 g VOC/l; the average is approximately 685 g VOC/l.⁵ The Option 1 limit of 550 g VOC/l would result in about a 55 percent reduction in VOC emissions from conventional primer/primer surfacers; the Option 2 limit of 455 g VOC/l would result in about a 70 percent reduction; the Option 3 limit of 335 g VOC/l would result in about an 85 percent reduction.

Conventional primer sealers typically contain between 600 and 805 g VOC/l; the average is approximately 755 g VOC/l.⁶ The Option 1 and 2 limit of 550 g VOC/l would result in about

a 75 percent reduction in VOC emissions from conventional primer sealers; the Option 3 limit of 420 g VOC/l would result in about a 90 percent reduction.

As discussed in Chapter 2, topcoats are typically applied as a single coating, or a 2-stage (basecoat/clearcoat) or 3-stage (basecoat/midcoat/clearcoat) system. The VOC content of a multi-stage topcoat is estimated by the following equation:

$$\text{VOC multi} = \frac{\text{VOC}_{bc} + \sum_{i=0}^M \text{VOC}_{mci} + 2(\text{VOC}_{cc})}{M + 3}$$

where:

VOC multi	=	VOC content of a multi-stage topcoat, g/l;
VOC _{bc}	=	VOC content of the basecoat, g/l;
VOC _{mci}	=	VOC content of the midcoat(s), g/l;
VOC _{cc}	=	VOC content of the clearcoat, g/l; and
M	=	Number of midcoats.

This equation is used because the basecoat is approximately one-third, and the clearcoat two-thirds, of the total film thickness of a 2-stage topcoat system. The basecoat and midcoat each are approximately one-quarter, and the clearcoat one-half, of the total film thickness of a 3-stage topcoat system. Additional midcoats present in topcoats of more than three stages are included in the middle term of the numerator.

The VOC contents of conventional refinish topcoats range from 550 to 805 g VOC/l.⁷ The average VOC contents of the different topcoat types are presented in Table 3-1. The emission reductions from conventional topcoats that would result from a 600 g VOC/l limit range from about 70 percent for lacquers to about 40 percent for all other topcoats. The 625 g VOC/l limit for 3-stage topcoats included in Option 1 would result in about a 30 percent reduction from conventional coatings.

The use of topcoats with VOC contents below the Option 3 limits reportedly can result in inferior color-match. Coating manufacturers contend that the use of such coatings could actually increase VOC emissions because painters could be forced to refinish substantially larger portions of an automobile in order to blend the refinished area into the existing finish.

3.3 EXISTING STATE REGULATIONS

A number of States containing ozone nonattainment areas have already adopted rules for automobile refinishing. A summary of these regulations is presented in Table 3-2. The following subsections briefly describe the regulations in these States.

3.3.1 New Jersey

The New Jersey regulation applies to the entire State, and specifies the maximum allowable VOC emissions per volume of coating. No requirements are specified regarding surface preparation or equipment cleaning operations.⁸

3.3.2 New York City

The New York City Metropolitan Area regulation applies to the five boroughs of New York City and four surrounding counties. The regulation limits the VOC content of automobile refinish coatings applied.⁹

3.3.3 Texas

In Texas, automobile refinishing is regulated under a rule covering several types of surface coating processes. The Texas regulation limits the VOC content of coatings and surface preparation products in all nonattainment areas. Body shops in these areas are also required to use enclosed gun cleaners.¹⁰

3.3.4 California

Several California air quality districts have adopted rules for automobile refinishing, including the Bay Area, South Coast, Ventura, San Joaquin, Santa Barbara, and Mojave. Others, such as San Diego and Sacramento, have rules in development. With minor differences, these rules contain the

TABLE 3-2. EXISTING REGULATIONS

Area	1995 coating VOC limits (g/l)
New Jersey ^a	Basecoat: 720 Clearcoat: 530 Others: 600
Texas ^b	Pretreatment: 780 Precoat: 660 Primers: 600 Primer sealer: 720 Topcoat: 600 3-stage topcoat: 625 Specialty coating: 840
New York City	Repair/touchup: 745 Overall (full job): 600
California Air Resources Board (CARB) c,d	Pretreatment: 420 Precoat: 420 Primer/primer surfacer: 250 Primer sealer: 335 Topcoat: 455 Metallic/Iridescent topcoat: 540 Specialty coating: 840

^aRegulation applies to entire state.

^bRegulation applies in nonattainment areas only.

^cMost air quality management districts in California are expected to adopt rules

with these requirements by January 1995.

^dCARB recommends lower limits for mobile equipment.

same requirements determined to be the "best available" control technology by CARB,¹¹ including VOC content limits for coatings and surface preparation products, and spray gun efficiency and cleaning requirements.

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4.0 BASELINE EMISSIONS AND EMISSIONS REDUCTIONS

This chapter presents estimates of the VOC emissions and emissions reductions from the use of low-VOC coatings. Since some States have already developed automobile refinish rules, 1995 emissions were used as the "baseline" from which emissions reductions were measured. Considering the reductions already achieved by State rules, estimates of baseline VOC emissions are presented in Table 4-1, along with estimates of the reductions achievable using low-VOC coatings.

4.1 COATING APPLICATION

4.1.1 Baseline Volatile Organic Compound Emissions from Coating Applications

Estimates of 1995 VOC emissions from coating applications were based on 1988 coating usage and emissions estimates provided by coating manufacturers^{1,2}. The amount of coating required for a refinish job ultimately depends on the solids content of the coating. The amount of coating solids projected for application in 1995 is presented in Table 4-2.

The relationship between the VOC (predominantly solvent) and solids in a solventborne coating was approximated using the following equation:

$$V_s = 1 - (VOC_c / d) \quad (4.1)$$

where:

- V_s = Volume solids content of coating (fraction);
- VOC_c = Solvent (VOC) content of coating (g/l); and
- d = Density of solvent (g/l).

TABLE 4-1. 1995 BASELINE VOLATILE ORGANIC COMPOUND EMISSIONS AND EMISSIONS REDUCTIONS
(Mg/yr)

Area	Baseline	Option 1	Option 2	Option 3
New Jersey	2,760	1,040	1,110	1,190
New York City	1,870	300	360	440
Texas	2,120	180	250	340
California	4,650	0	0	0
Remaining U. S. nonattainment areas	33,030	13,270	14,050	14,940
U. S. attainment areas	44,030	17,690	18,740	19,910
Total	88,460	32,470	34,520	36,820

TABLE 4-2. 1995 COATING SOLIDS USE

Coating category	Coating solids use (10 ³ l/yr)
Primers	
Pretreatment wash primer	260
Precoat	150
Primer/primer surfacer	3,940
Primer sealer	1,100
Topcoats	
Single stage	
Lacquer	910
Enamel	4,920
Basecoat	2,990
Clearcoat	13,700
Specialty	40
Total	28,010

The amount of coating solids applied in the United States was estimated by the following equation:

$$C_S = C_C * V_S \quad (4.2)$$

where:

- C_S = Liters of coating solids applied in the United States;
- C_C = Liters of coatings applied in the United States; and
- V_S = Volume solids content of coating (fraction).

The amount of coating solids applied in a particular area of the United States is assumed to be a function of the population of that area, and was estimated by the following equation:

$$C_{Sa} = C_S * (P_a / P_{US}) \quad (4.3)$$

where:

- C_{Sa} = Liters of coating solids applied in area;
- C_S = Liters of coating solids applied in the United States;
- P_a = Population of area; and
- P_{US} = U.S. population.

Census data for 1990 were used in this document to estimate 1995 populations. The U.S. population in 1990 was approximately 248,710,000.³ Population data for nonattainment areas were obtained from a 1994 EPA document on nonattainment area designations.⁴

By rearranging equation 4.2, the amount of coating used in a particular area ("area coating use") can be estimated by dividing the amount of coating solids applied in the area by the coating VOC content that is typical or, in the case of regulated areas, required in the area. Area coating use was

estimated by the following equation:

$$C_{ca} = C_{sa} / V_{sa} \quad (4.4)$$

where:

- C_{ca} = Area coating use (ℓ/yr);
- C_{sa} = Liters of coating solids applied in area; and
- V_{sa} = Volume solids content of coating (a function of the presence and stringency of the area's applicable rule) expressed as a fraction.

The VOC emissions in an area from coating application were estimated using the following equation:

$$E_t = (C_{ca} * \text{VOC}_c) / 10^6 \quad (4.5)$$

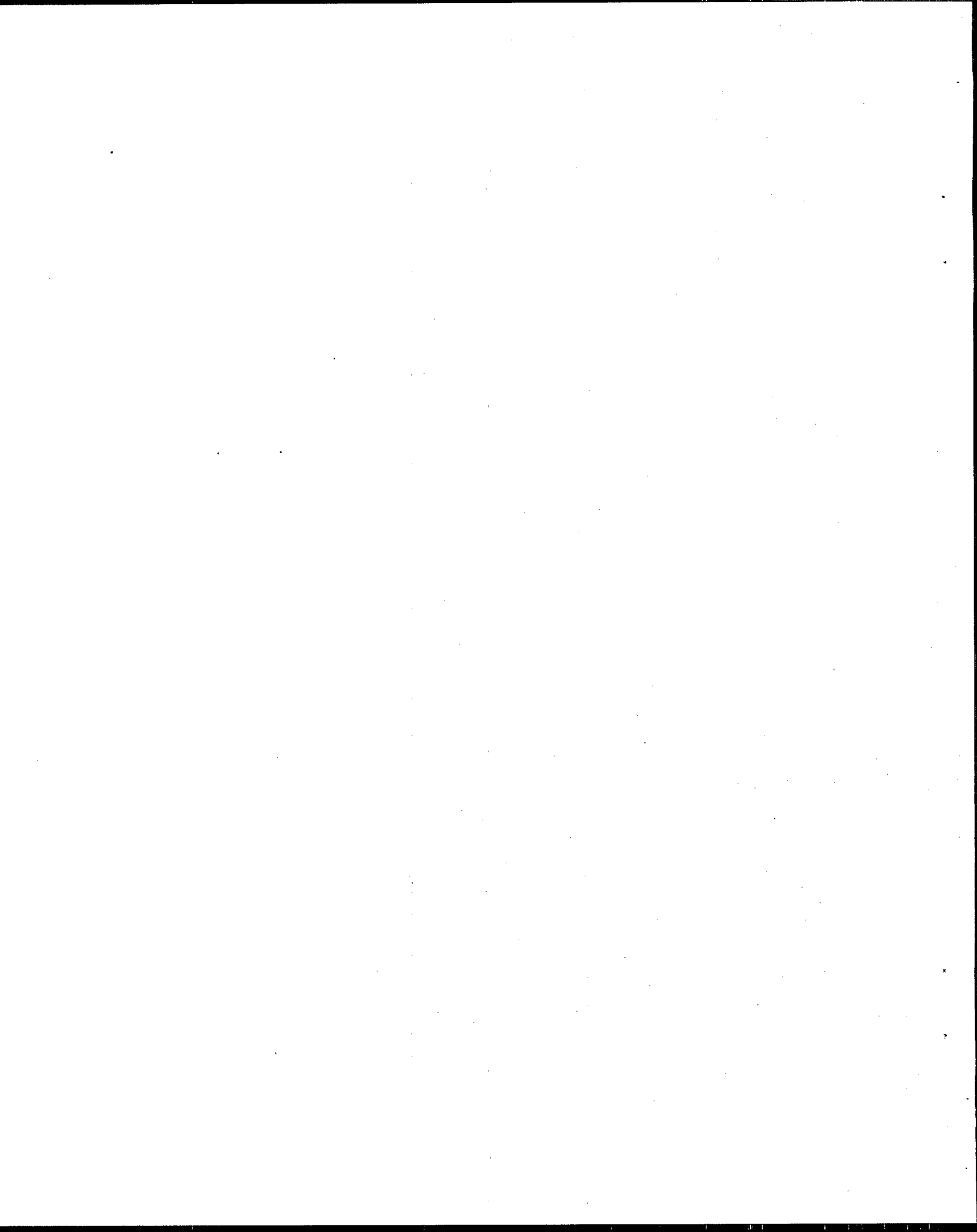
where:

- E_t = Area coating application emissions (megagrams/yr);
- C_{ca} = Area coating use (ℓ/yr);
- VOC_c = VOC content of coating (g/ℓ); and
- 10^6 = Grams per megagram.

Equations 4.1 through 4.5 were used for each coating category to estimate baseline VOC emissions and emissions reductions.

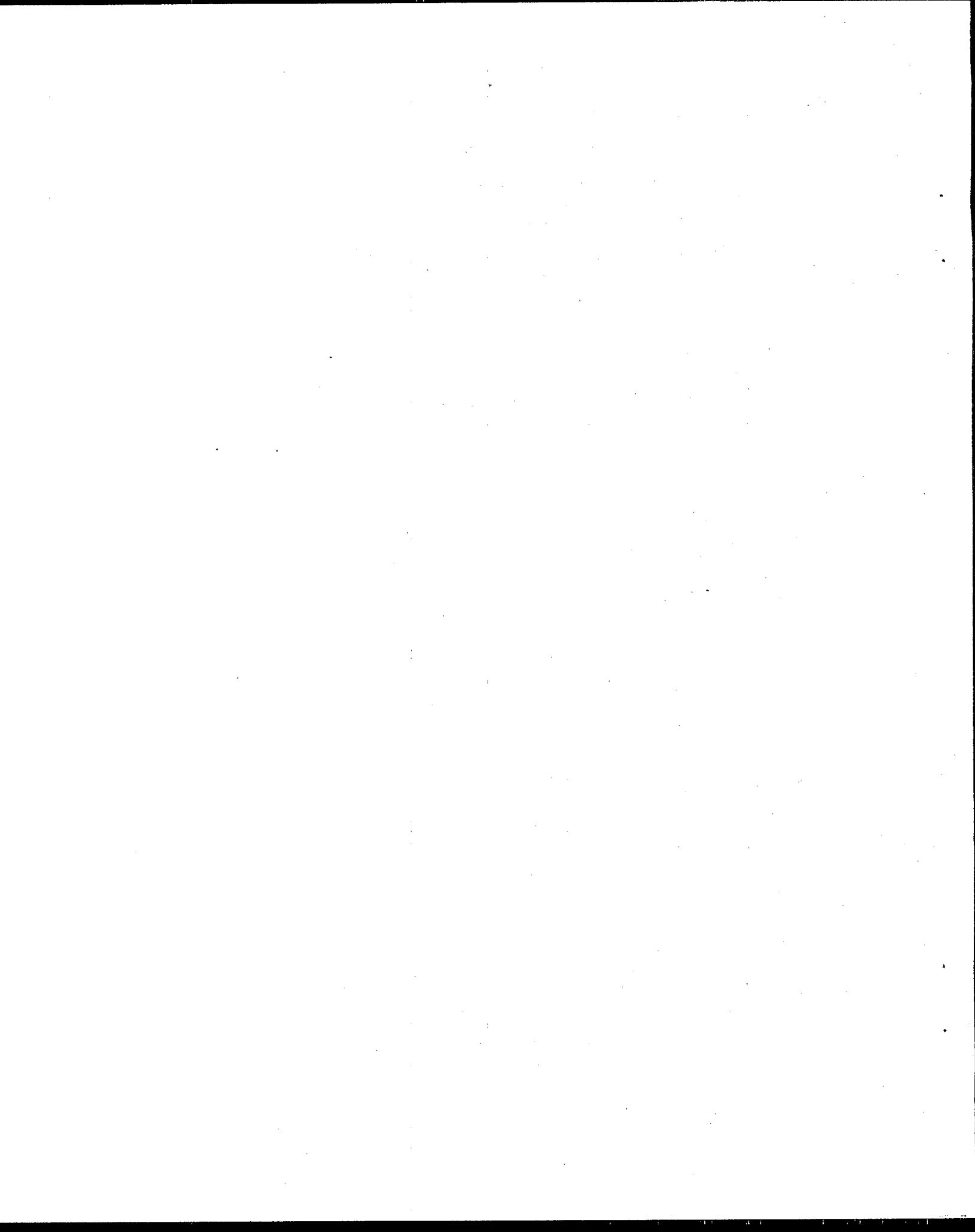
4.1.2 Reduction of Volatile Organic Compound Emissions from Coating Applications

As shown in Table 4-1, Option 1 reduces baseline emissions by about 32,470 megagrams per year (Mg/yr), or 37 percent; Option 2 reduces the baseline by about 34,520 Mg/yr, or 39 percent; and Option 3 reduces the baseline by about 36,820 Mg/yr, or 42 percent.



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5.0 COST IMPACTS

This chapter discusses the methods and assumptions used to estimate the cost impacts of implementing the control options described in Chapter 3. Sections 5.1, 5.2, and 5.3 present estimates of the costs that coating manufacturers, distributors, and body shops, respectively, would incur from the implementation of the coating options. Cost effectiveness of the control options are discussed in Section 5.4.

5.1 COSTS TO COATING MANUFACTURERS

Coating manufacturers will incur costs from the implementation of the VOC limits of the coating options due to process modifications and training. Research and development (R&D) costs associated with formulating low-VOC coatings were not considered, since these costs have generally already been forced by State regulations.

5.1.1 Process Modifications

Implementation of the coating options will require manufacturers to modify production facilities. Transition to coatings compliant with Options 1 and 2 is estimated to cost about \$10 million. Most of this cost would be to purchase pumping and mixing equipment that will process higher-solids coatings.¹ Although solventborne coatings are available that meet the primer and primer sealer VOC limits of Option 3, according to coating manufacturers these limits would likely be met using waterborne coatings because of difficulties in the application of high-solids coatings, such as the difficulty in applying a thin coat of primer sealer. Modifications required to produce waterborne coatings will cost about \$73 million, primarily to upgrade process equipment

from carbon steel to corrosion resistant materials.2-5

5.1.2 Training Costs

Implementation of the coating options would likely require that manufacturers teach their sales representatives, technicians/trainers, district/other managers, marketing personnel, and "product specialists" (personnel who provide the interface between R&D and marketing departments) to use the new coatings. It was estimated that approximately 2,500 employees would require one day of training.⁶ The cost for each was estimated at \$425, including travel, lodging, and wages.⁷ Training costs for all options are assumed to be equal.

5.1.3 Annual Costs to Coating Manufacturers

Process modification and training costs were annualized over 10 years at an interest rate of 7 percent. These costs are presented in Table 5-1.

5.2 COSTS TO DISTRIBUTORS

Coating distributors must be trained in order to provide essential services (e.g., mixing of topcoat colors, troubleshooting advice, general product information) to their customers. An estimated 4,450 distributors would have a representative attend a 1-day training seminar. The total cost for each distributor was estimated to be \$425, including travel, lodging and wages.^{8,9}

The training costs for distributors were also annualized over 10 years at an interest rate of 7 percent, and are presented in Table 5-1.

5.3 COSTS TO BODY SHOPS

Costs incurred by shops may include painter retraining, infrared heating system purchase/operation, and productivity losses. Shops would likely incur only training costs if the VOC limits of Option 1 were implemented, while Options 2 and 3 may trigger all of the costs mentioned above.

5.3.1 Training costs. Because compliant coatings may mix, spray, and dry differently than noncompliant coatings, painters must be retrained in these areas. It was estimated

Table 5-1. ANNUAL COSTS OF CONTROL TECHNIQUES (10^3 \$)

	Option 1	Option 2	Option 3
Manufacturer costs			
Process modifications	1,420	1,420	10,380
Training	150	150	150
Distributor training costs	270	270	270
Body shop costs			
Training	2,690	2,690	2,690
Heating systems	0	20,890	20,890
Total annual costs	4,530	25,420	34,380

that 44,500 painters will require training. Coating manufacturers, who will provide the training, estimate that the requisite 8 hours of instruction can be scheduled (during weekends or evenings) with no loss of shop revenue.^{10,11}

Because training may require overtime, it was assumed that shops will reimburse painters with overtime wages of \$12 per hour (1.5 times the normal hourly wage) and the cost of two meals (\$15).¹² It was also assumed that no travel costs will be incurred; training will be made available locally.¹³⁻¹⁴ The 8-hour course will be offered at no charge by coating manufacturers.^{15,16}

5.3.2 Infrared Heating System Costs. As discussed earlier, coatings compliant with Options 2 and 3 may require supplementary heat because their drying characteristics are affected by ambient conditions. Without supplementary heating they reportedly can require up to two days to dry.¹⁷ To minimize productivity losses, shops may purchase heating systems to use during periods of adverse ambient conditions.

Two moderate-to-large heaters were assumed to be necessary at shops. Most shops already own one heating system, so the costs presented in this document are for the purchase and operation of an additional heating system at 44,500 shops. Heating systems are estimated to cost \$2,120 each, and are used on approximately 25 percent of refinish jobs.^{18,19}

5.3.3 Potential Productivity Losses

Coatings that meet the limits of Options 2 and 3 may affect shop productivity because of their longer drying times. The following is a discussion of the potential effects on productivity of the various coatings.

Primer surfacers. Option 2 and 3 primer surfacers may affect shop productivity because they dry slower than conventional coatings. If supplemental heating is not used to speed drying, productivity losses may occur in some geographical areas if these surfacers are used. In humid, cool conditions, waterborne surfacers are reported to dry

slowly, and drying times of up to two days under such conditions are reportedly common in the absence of supplementary heating.²⁰

The impacts on productivity that would be caused by use of Option 2 and 3 surfacers are highly variable and impossible to quantify on a nationwide basis. For instance, a substantial number of shops would not lose any productivity because they would compensate for increased drying time by performing other work while the surfacers are drying, and by scheduling work flow through the shop differently. However, many shops cannot merely work on other refinish jobs while jobs with primer surfacer coats are drying because these shops do not have adequate floor space. Shops may need to use drying equipment, such as infrared heating systems, to reduce drying time. Shops that use infrared heating systems to accelerate drying may still lose up to 15 minutes per job positioning the heating systems.²¹ It should be noted that the use of heating systems may not totally eliminate productivity losses.

Primer sealers. No productivity losses are anticipated from the primer sealers of any option. Shop employees in the SCAQMD reported that primer sealers equivalent to Option 3 dry as quickly as conventional primer sealers.²²⁻²⁸

Topcoats. Coating manufacturers report that low-VOC topcoats do not dry significantly slower than conventional topcoats and, consequently, no productivity losses are expected from the use of low-VOC topcoats.²⁹ Manufacturers claim, however, that shops without spray booths that use lacquer topcoats will lose productivity when switching to compliant topcoats. The longer drying times of compliant topcoats leave the wet surface exposed to airborne contaminants. Manufacturers maintain that shops must expend more labor during polishing to remove the additional contamination.³⁰

Costs for shops without spray booths that use lacquers have not been included in this document, primarily because

lacquer use for automobile refinishing has steadily dropped over the last few years, a trend which would likely continue even in the absence regulatory action. In 1988 and 1993, lacquers were used on 25 percent and 14 percent of refinish jobs, respectively.^{31,32} Furthermore, there is evidence that most shops without spray booths are already using conventional enamels or urethanes, which, as mentioned previously, do not dry significantly faster than low-VOC topcoats.

5.3.4 Annual Costs to Shops

The capital costs of heating systems and training were annualized over 10 years at an interest rate of 7 percent. These annual costs are presented in Table 5-1.

5.4 COST EFFECTIVENESS

Average cost effectiveness is the cost to reduce VOC emissions by 1 megagram. Average cost effectiveness values were calculated by dividing annual costs by annual emission reductions. The annual costs of the coating options include costs for process modifications, manufacturer, distributor, and body shop training, and infrared heating systems (Options 2 and 3). The average cost effectiveness of Options 1 through 3 are \$140, \$740, and \$940 per megagram, respectively.

Incremental cost effectiveness is the cost to achieve the incremental emission reductions from implementing one option instead of another. The cost for the additional emission reductions achieved by Option 2 over Option 1 is about \$10,100 per megagram. The incremental cost effectiveness of implementing Option 3 (instead of Option 2) is about \$3,900 per megagram.

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