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Reduction of Volatile Organic Compound Emissions from Automobile Refinishing

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REDUCTION OF VOLATILE ORGANIC COMPOUND EMISSIONS FROM AUTOMOBILE REFINISHING

CONTROL TECHNOLOGY CENTER

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REDUCTION OF VOLATILE ORGANIC COMPOUND EMISSIONS FROM AUTOMOBILE REFINISHING

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PREFACE

The Automobile Refinishing investigation was funded as a project of EPA's Control Technology Center (CTC).

The CTC was established by EPA's Office of Research and Development (ORD) and Office of Air Quality Planning and Standards (OAQPS) to provide technical assistance to State and local air pollution control agencies. Three levels of assistance can be accessed through the CTC. First, a CTC HOTLINE has been established to provide telephone assistance on matters relating to air pollution control technology. Second, more in-depth engineering assistance can be provided when appropriate. Third, the CTC can provide technical guidance through publication of technical guidance documents, development of personal computer software, and presentation of workshops on control technology matters.

The technical guidance projects, such as this one, focus on topics of national or regional interest that are identified through State and Local agencies. This guidance provides technical information that agencies can use to develop strategies for reducing VOC emissions from automobile refinishing operations. It is of particular interest to those agencies that are seeking additional VOC emission reductions in ozone nonattainment areas. These areas tend to have a high population density and, therefore, a high frequency of automobile repair and repainting.

This report provides information on the coating application process, VOC emissions and emissions reductions, and costs associated with the use of alternative coating formulations and equipment used in the automobile refinishing industry. This information will allow planners to: 1) identify available alternative technologies for reducing VOC emissions from automobile refinishing operations; 2) determine VOC emissions and achievable VOC emission reductions; and 3) evaluate the cost and environmental impacts associated with implementing these alternatives.

ACKNOWLEDGEMENT

This report was prepared by staff in Midwest Research Instititute's Environmental Engineering Department located in Cary, North Carolina. Participating on the project team for the EPA were Robert Blaszczak of the Office of Air Quality Planning and Standards and Charles Darvin of the Air and Energy Engineering Research Laboratory. The data presented were generated through a literature search and surveys of paint formulators, equipment manufacturers, and industry trade organizations.

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1.0 INTRODUCTION

The Clean Air Act identified December 31, 1987, as the final date to attain the national ambient air quality standard (NAAQS) for ozone. Congress recently extended the compliance deadline to August 31, 1988. As of this writing, 345 counties including 68 cities are still in nonattainment of the ozone NAAQS. On May 26, 1988, the U. S. Environmental Protection Agency (EPA) mailed letters to 44 States and the District of Columbia that have ozone nonattainment areas stating that current State implementation plans (SIP's) to control ozone are inadequate and that a new round of planning is needed. (Bureau of National Affairs, Environment Reporter, May 6, 1988, p. 3 and June 3, 1988, p. 171).

Under the proposed ozone policy published in the Federal Register on November 24, 1987 (52 FR 45044), emissions of volatile organic compounds (VOC's) must be reduced to a level consistent with attaining the ozone NAAQS as demonstrated by atmospheric dispersion modeling. Once the State has determined the VOC emission reduction required to meet the NAAQS, it must identify and select control measures that will produce the required reductions as expeditiously as practicable.

Nonattainment areas are likely to be those with a high population density and, therefore, a high frequency of automobile repair and repainting. This report provides technical information that State and local agencies can use to develop strategies for reducing VOC emissions from automobile refinishing operations. The information in this document will allow planners to: (1) identify available alternative technologies for reducing VOC emissions from automobile refinishing operations; (2) determine VOC emissions and achievable VOC emission reductions; and (3) evaluate the cost and environmental impacts associated with implementing these alternatives.

This document provides information on the application processes, VOC emissions and emissions reductions, and costs associated with the use of alternative coating formulations and equipment used in the motor vehicle refinishing industry. This information was generated through a literature search, site visits, and surveys of equipment manufacturers, coating formulators, and industry trade associations. Section 2.0 presents a summary of the findings of this study. Section 3.0 provides a source characterization and description of the processes used to refinish automobiles. Section 4.0 provides VOC emission estimates for each of the automobile refinishing process steps and for typical facilities. Section 5.0 discusses each VOC emission reduction alternative in detail, including advantages and disadvantages. Section 6.0 provides emission estimates for each alternative and estimated emission reductions from current operating practice. Section 6.0 also describes the environmental impacts associated with the implementation of each alternative. Section 7.0 presents a cost analysis that includes a methodology for computing annualized equipment and material cost and anticipated incremental cost (savings) from baseline for each alternative. This discussion will assist the users of this document in developing the cost information necessary to develop a VOC reduction strategy specific to their area. Section 8.0 discusses existing Federal and State regulations that apply to this industry. Section 9.0 discusses factors to consider with regard to determining compliance with regulations that might be proposed for the automobile refinishing industry, and Section 10.0 presents a glossary of coating terminology.

2.0 SUMMARY

The purpose of this document is to provide technical information that State and local agencies can use to develop strategies for reducing VOC emissions from automobile refinishing operations. This section presents the findings of this study including alternative VOC reduction techniques, potential VOC emission reductions, and costs of implementing the alternatives.

Automobile refinishing operations can be categorized into four process steps. These steps are vehicle preparation, primer application, topcoat application, and spray equipment cleanup. Emissions of VOC's are the result of organic solvent evaporation during vehicle preparation and equipment cleanup and during and shortly after the application of primers and topcoats. Currently, there are several available VOC emission reduction techniques that are applicable to these four steps. These techniques are listed in Table 2-1.

To characterize the automobile refinishing industry and to take into account the large diversity in shop size, the estimated 83,000 shops were divided into the following three categories: (1) small shops with annual sales up to $150,000 that perform 6 partial vehicle jobs per week, (2) medium shops with annual sales between $150,000 and $750,000 that perform 13 partial and 1 complete vehicle jobs per week, and (3) volume shops with annual sales of greater than $750,000 that perform 14 partial and 15 complete vehicle jobs per week. Emission reduction techniques that were selected for evaluation include the use of alternative coatings, spray equipment with improved transfer efficiency, the installation of solvent recovery spray equipment cleaning systems and, for volume shops only, add-on control. In order to estimate VOC emissions, VOC emission reductions, and costs of emission reductions, assumptions were made on the types of coatings used and equipment available for each facility type. Tables 2-2, 2-3, and 2-4 summarize the emission and cost data for the baseline condition and alternative controls for typical small, medium, and volume shops, respectively. These tables present the alternative emission reduction techniques, estimated VOC emissions, VOC emission reductions from baseline, the total annualized cost of the alternatives, and the cost

TABLE 2-1. VOC EMISSION REDUCTION TECHNIQUES CURRENTLY AVAILABLE IN THE AUTOMOBILE REFINISHING INDUSTRY

Vehicle preparation	Primer application	Topcoat application	Equipment cleanup
Reduced-VOC cleaners	Enamel primers	Higher solids coatings (available for basecoats and clearcoats)	Cleanup solvent recovery systems
Detergents	Waterborne primers	Electrostatic spray equipment	
	Urethane primers	High-volume, low-pressure spray equipment	
	Electrostatic spray equipment	Add-on control	
	High-volume, low-pressure spray equipment		
	Add-on control		

TABLE 2-2. VOC EMISSIONS, EMISSION REDUCTIONS, AND TOTAL ANNUALIZED COSTS FOR ALTERNATIVE EMISSION REDUCTION TECHNIQUES APPLIED TO A SMALL FACILITY[a]

Emission reduction technique	VOC emissions, tons/yr	VOC reduction from baseline		Total annualized cost, $/yr	Cost (savings) compared to baseline, $/yr
		tons/yr	Percent		
Current practice (baseline)	1.27	NA	NA	7,400	NA
Replace lacquers with acrylic enamels[b]	0.69	0.58	46	6,200	(1,200)
Replace lacquers and enamels with urethanes[c]	0.59	0.68	54	8,600	1,200
Replace solvent-borne primers with waterborne primers	0.96	0.31	24	7,100	(300)
Replace conventional clear-coats with higher solids clears	0.95	0.32	25	8,600	1,200
Install cleanup solvent recovery systems	1.08	0.19	15	7,000	(400)
Replace conventional air atomizing spray guns with high-volume, low-pressure (HVLP) spray equipment	0.86	0.41	32	6,100	(1,300)

NA = not applicable.
[a]The assumptions for the small facility include: (1) lacquers are primarily used; (2) no spray booth; and (3) six partial jobs (10 square feet per partial job) are completed per week.
[b]This option involves replacing lacquer primers and topcoats with acrylic enamel primers and topcoats.
[c]This option involves replacing lacquer and enamel primers and topcoats with urethane primers and topcoats.

TABLE 2-3. VOC EMISSIONS, EMISSION REDUCTIONS, AND TOTAL ANNUALIZED COSTS FOR ALTERNATIVE EMISSION REDUCTION TECHNIQUES APPLIED TO A MEDIUM FACILITY[a]

Emission reduction technique	VOC emissions, tons/yr	VOC reduction from baseline		Total annualized cost, $/yr	Cost (savings) compared to baseline, $/yr
		tons/yr	Percent		
Current practice (baseline)	3.63	NA	NA	30,100	NA
Replace lacquers with acrylic enamels[b]	2.27	1.36	37	23,600	(6,500)
Replace lacquers and enamels with urethanes[c]	1.89	1.73	48	32,800	2,700
Replace solvent-borne primers with waterborne primers	2.73	0.90	25	29,600	(500)
Replace conventional clear-coats with higher solids clears	2.82	0.81	22	30,400	300
Install cleanup solvent recovery systems	3.08	0.55	15	28,900	(1,200)
Replace conventional air atomizing spray guns with high-volume, low-pressure (HVLP) spray equipment	2.46	1.17	32	23,300	(6,800)

NA = not applicable.
[a]The assumptions for the medium facility include: (1) enamels are primarily used, but some lacquers are used; (2) the shop has one spray booth; and (3) 13 partial jobs (10 square feet per partial job) and 1 entire vehicle job (100 square feet per entire vehicle job) are completed per week.
[b]This option involves replacing lacquer primers and topcoats with acrylic enamel primers and topcoats.
[c]This option involves replacing lacquer and enamel primers and topcoats with urethane primers and topcoats.

TABLE 2-4. VOC EMISSIONS, EMISSION REDUCTIONS, AND TOTAL ANNUALIZED COSTS FOR ALTERNATIVE EMISSION REDUCTION TECHNIQUES APPLIED TO A VOLUME FACILITY[a]

Emission reduction technique	VOC emissions, tons/yr	VOC reduction from baseline		Total annualized cost, $/yr	Cost (savings) compared to baseline, $/yr
		tons/yr	Percent		
Current practice (baseline)	11.1	NA	NA	127,600	NA
Replace enamels with urethanes[b]	9.1	2.0	18	177,300	49,700
Replace solvent-borne primers with waterborne primers	8.1	3.0	27	126,300	(1,300)
Replace conventional clear-coats with higher solids clears	10.4	0.7	7	143,000	15,400
Install cleanup solvent recovery systems	10.4	1.6	15	123,900	(3,700)
Replace conventional air atomizing spray guns with high-volume, low-pressure (HVLP) spray equipment	6.0	5.1	46	81,400	(45,700)
Add-on control: Thermal incineration	3.5	7.6	68	452,000	363,000

NA = not applicable.

[a]The assumptions for the volume shop include: (1) only enamels and urethanes are used; (2) the shop has two spray booths; and (3) 14 partial jobs (10 square feet per partial job) and 15 entire vehicle jobs (100 square feet per entire vehicle job) are completed per week.

[b]This option involves replacing enamel primers and topcoats with urethane primers and topcoats.

(savings) for implementation of the alternative controls compared to baseline.

The results of the study indicate that several control options result in no additional cost to implement, and in fact result in a cost savings. For the small, medium, and volume facilities, significant VOC reductions (30 to 45 percent) can be achieved by replacing conventional air-atomizing spray guns with high-volume, low-pressure (HVLP) spray equipment. A cost savings is expected from this control technique because the higher transfer efficiency (about 65 percent vs. about 35 percent for conventional air-atomizing spray guns) results in less paint usage, when HVLP spray equipment is used in conjunction with a paint mixing station. Experience with use of the HVLP spray equipment within the industry is limited. Some problems with color matching topcoats have been reported. However, some users are reporting acceptable color matching results and have indicated that experience with the equipment is a necessary factor in achieving good results. For all facilities, significant VOC emission reductions (about 15 percent) can be achieved by using a cleanup solvent recovery system. This control technique also results in a savings because solvent usage is reduced. The remaining alternative controls involving switching from conventional coatings to lower VOC coatings (e.g., urethanes) and, with a few exceptions, involve some additional cost. One exception is for small facilities, where switching from lacquers to acrylic enamels is expected to result in a 45 percent emission reduction, as well as a cost savings. The cost savings is a result of the lower cost of materials which offsets the capital cost (annualized over 10 years) for installing a spray booth to accomodate the additional drying time required for enamel coatings. Also, for all types of facilities, switching from conventional primers to waterborne primers is expected to result in a VOC emission reduction (approximately 20 percent) at no additional cost.

Add-on controls for spray booth emissions from large facilities were briefly investigated. Add-on controls are expected to control emissions effectively (greater than 60 percent reduction) but have a very high cost associated with their installation and operation.

Note that if multiple alternatives are implemented, the emission reduction achieved will not necessarily be the sum of the individual emission reductions presented in Tables 2-2, 2-3, and 2-4. Since all the emission reductions are calculated from the baseline condition, after one alternative has been implemented, subsequent implementation of other alternatives will have a different effect from that presented in the tables. Nonetheless, implementation of multiple alternatives will have a positive impact on VOC emission reduction. For each type of facility, several of the control alternatives can be implemented at no additional cost. Tables 2-5, 2-6, and 2-7 present matrices of emission reduction alternatives and estimated VOC emission reductions for small, medium, and volume automobile refinishing shops, respectively. The emission reductions attributed to add-on controls applied to the volume shop were not included in Table 2-7. These tables present the same coating alternatives described in Tables 2-2, 2-3, and 2-4. Additionally, Tables 2-5, 2-6, and 2-7 show the VOC emission reductions that may be achieved if a combination of both a coating change and an equipment change is implemented. While these tables are helpful in determining the potential total reductions achievable using multiple options, it should be noted that the reductions are from assumed baselines. Therefore, if the baseline for a particular automobile refinishing shop is different from that developed in this study, then the reduction for a particular alternative or multiple alternatives will likewise be different.

TABLE 2-5. MATRIX OF VOC EMISSION REDUCTION ALTERNATIVES FOR A SMALL AUTOMOBILE REFINISHING SHOP AND ESTIMATED EMISSION REDUCTIONS

Coating alternatives	VOC emission reduction alternatives: Solvent recovery, Yes	Solvent recovery, No	Transfer efficiency, percent, 35	Transfer efficiency, percent, 65	Emissions, tons/yr	Emission reduction, Tons/yr	Emission reduction, Percent
Exclusive use of lacquers (current practice)							
Baseline		X	X		1.27	NA	NA
Alternative 1	X		X		1.08	0.19	15
Alternative 2		X		X	0.86	0.41	32
Alternative 3	X			X	0.67	0.60	47
Replace lacquer primers with waterborne primers							
Alternative 4		X	X		0.96	0.31	24
Alternative 5	X		X		0.83	0.45	35
Alternative 6		X		X	0.65	0.62	49
Alternative 7	X			X	0.51	0.76	60
Replace lacquer clearcoats with higher solids clearcoats							
Alternative 8		X	X		0.95	0.32	25
Alternative 9	X		X		0.76	0.51	40
Alternative 10		X		X	0.69	0.58	46
Alternative 11	X			X	0.50	0.78	61
Replace lacquers with enamels							
Alternative 12		X	X		0.69	0.58	46
Alternative 13	X		X		0.50	0.77	61
Alternative 14		X		X	0.55	0.72	57
Alternative 15	X			X	0.36	0.91	72
Replace lacquers with urethanes							
Alternative 16		X	X		0.59	0.68	54
Alternative 17	X		X		0.40	0.87	69
Alternative 18		X		X	0.49	0.78	61
Alternative 19	X			X	0.30	0.97	76

TABLE 2-6. MATRIX OF VOC EMISSION REDUCTION ALTERNATIVES FOR A MEDIUM AUTOMOBILE REFINISHING SHOP AND ESTIMATED EMISSION REDUCTIONS

Coating alternatives	VOC emission reduction alternatives: Solvent recovery		Transfer efficiency, percent		Emissions, tons/yr	Emission reduction	
	Yes	No	35	65		Tons/yr	Percent
Use of lacquers and enamels (current practice)							
Baseline		X	X		3.63	NA	NA
Alternative 1	X		X		3.08	0.54	15
Alternative 2		X		X	2.46	1.17	32
Alternative 3	X			X	1.91	1.72	47
Replace lacquer and enamel primers with waterborne primers							
Alternative 4		X	X		2.73	0.90	25
Alternative 5	X		X		2.34	1.28	35
Alternative 6		X		X	1.83	1.80	50
Alternative 7	X			X	1.44	2.19	60
Replace lacquer and enamel clears with higher solids clears							
Alternative 8		X	X		2.82	0.81	22
Alternative 9	X		X		2.28	1.35	37
Alternative 10		X		X	2.02	1.61	44
Alternative 11	X			X	1.48	2.15	59
Replace lacquers with enamels							
Alternative 12		X	X		2.27	1.36	37
Alternative 13	X		X		1.73	1.90	52
Alternative 14		X		X	1.55	2.08	57
Alternative 15	X			X	1.00	2.63	72
Replace lacquers and enamels with urethanes							
Alternative 16		X	X		1.89	1.73	48
Alternative 17	X		X		1.35	2.28	63
Alternative 18		X		X	1.52	2.11	58
Alternative 19	X			X	0.98	2.65	73

TABLE 2-7. MATRIX OF VOC EMISSION REDUCTION ALTERNATIVES FOR A VOLUME AUTOMOBILE REFINISHING SHOP AND ESTIMATED EMISSION REDUCTIONS

Coating alternatives	VOC emission reduction alternatives: Solvent recovery		Transfer efficiency, percent		Emissions, tons/yr	Emission reduction	
	Yes	No	35	65		Tons/yr	Percent
Use of enamels and urethanes (current practice)							
Baseline		X	X		11.12	NA	NA
Alternative 1	X		X		9.45	1.67	15
Alternative 2		X		X	7.53	3.59	32
Alternative 3	X			X	5.86	5.26	47
Replace enamel and urethane primers with waterborne primers							
Alternative 4		X	X		8.14	2.98	27
Alternative 5	X		X		7.08	4.04	36
Alternative 6		X		X	5.35	5.77	52
Alternative 7	X			X	4.30	6.82	61
Replace enamel clears with higher solids clears							
Alternative 8		X	X		10.39	0.74	7
Alternative 9	X		X		8.72	2.40	22
Alternative 10		X		X	7.13	3.99	36
Alternative 11	X			X	5.46	5.66	51
Replace lacquers with enamels[a]							
Alternative 12							
Alternative 13							
Alternative 14							
Alternative 15							
Replace enamels with urethanes							
Alternative 16		X	X		9.08	2.04	18
Alternative 17	X		X		7.41	3.71	33
Alternative 18		X		X	6.43	4.69	42
Alternative 19	X			X	4.76	6.36	57

[a]Since the volume shops were assumed not to use lacquers at all, this category of coating alternative does not apply to volume shops.

3.0 AUTOMOBILE REFINISHING SOURCE CHARACTERIZATION AND PROCESS DESCRIPTION

The purpose of this section is to present an industry profile and to describe the process steps involved in automobile refinishing. This information will allow agencies to characterize shops in their area and to identify the process steps where VOC emissions occur. Section 3.1 provides information on the estimated number of automobile refinishing shops nationwide and categorizes these shops based on annual sales volume. Section 3.2 describes the process steps and materials involved in refinishing an automobile from beginning to end including vehicle preparation, coating application, descriptions of primers and topcoats, and equipment cleanup.

3.1 SOURCE CHARACTERIZATION

Approximately 66,000 auto body shops are operating in the United States, of which 2 percent are franchises and the remainder are classified as independents.[1,2] In addition, an estimated 68 percent of the nation's automobile dealerships (approximately 17,000 shops) have body shop operations.[3] These 83,000 body shops range in size from small shops having less than 5 employees and sales volume under $150,000 (40 percent) to volume shops with over 10 employees conducting $750,000 or more in sales (10 percent).[2] Combined, these shops perform over $10 billion in sales annually.[8] The typical refinishing shop employs 6 persons, conducts $400,000 worth of business annually, and performs an average of 13 jobs per week.[2] For a typical shop, approximately 90 percent of the work consists of spot and panel repainting. The entire vehicle is completely refinished only about 10 percent of the time.[4] These percentages are reversed for the franchise operations, which typically specialize in repainting entire vehicles.

3.2 PROCESS DESCRIPTION

Typically, automobile refinishing is performed in conjunction with other body repair necessitated by a collision involving the vehicle. Most refinishing jobs involve the repair and repainting of a small portion of the vehicle (a panel, or a "spot" on a panel). A minority of jobs involve the overall repainting of vehicles, which is generally performed in instances of coating failure.

Definite steps must be followed when refinishing a vehicle, whether the job is a spot, panel, or overall repair. The surface of the vehicle must be thoroughly cleaned to ensure proper adhesion of the coating, the metal surface must be primed, a topcoat (either a color coat or a two-stage basecoat and clearcoat) must be applied, and the spraying equipment must be cleaned with solvent. Emissions of VOC's from automobile refinishing operations are the result of organic solvent evaporation during vehicle preparation, during the application and drying of primers and topcoats, and during spraying equipment cleanup.

3.2.1 Vehicle Preparation

Vehicle preparation, the first step in refinishing an automobile, is generally performed in two stages. First, the surface to be refinished is washed thoroughly with detergent and water to remove dirt and water soluble contaminants and is allowed to dry. Then the surface is cleaned with solvent to remove wax, grease, and other contaminants. This step is important to ensure proper adhesion of the primer and topcoats. The solvent typically used is 100 percent VOC's and is usually a blend of toluene, xylene, and various petroleum distillates. Solvent cleaning of vehicles currently accounts for approximately 8 percent of the total VOC emissions generated by automobile refinishing.[5,6] The area to be repainted is then sanded or chemically treated to remove the old finish and is given a final solvent wipe.

3.2.2 Primers

After the surface of the vehicle has been thoroughly prepared, the next step is the application of primer. Approximately 13 million gallons of primer are sold each year to the automotive refinishing industry in the United States.[7] Primers provide corrosion resistance, fill in surface imperfections, and provide a bond for the topcoat. A breakdown of the relative properties and costs for the different types of primer formulations is presented in Table 3-1. The values presented for each primer type in Table 3-1 are average values for each parameter based on a review of industry surveys and are not intended to represent a particular primer. These primers fall into four basic categories: prepcoats, primer-surfacers, primer-sealers, and sealers.

TABLE 3-1. TYPICAL PRIMER PARAMETERS[a]

	Lacquer	Enamel	Waterborne	Urethane
Solids content				
As sold, wt.%[b]	46	65	45	57
As sprayed, wt.%[c]	21	50	45	49
Solids content				
As sold, vol.%[b]	33	36	33	37
As sprayed, vol.%[c]	13	24	33	30
VOC content				
As sold, lb/gal coating[d]	4.6	4.1	2.5	3.6
As sprayed, lb/gal coating[e]	6.0	5.1	2.5	4.3
As sprayed, lb/gal solids[c]	45.4	21.0	7.6	14.4
Density, lb/gal				
Coating as sold[e]	8.4	11.8	9.6	10.4
Coating as sprayed[c]	7.5	10.2	9.6	9.7
Density of solids	14.5	--	17.5	--
Reduction ratio[b f]	1:1.5	1:0.5	None	1:0.25
Dry film thickness, mils[g]	2.0	2.0	2.0	2.0
Volume/vehicle				
As sprayed, gal[h]	2.7	1.5	1.1	1.2
Cost				
As sold, $/gal[e]	27	31	38	53
As sprayed, $/gal[c]	16	23	38	44
Per vehicle, $[h]	42	35	42	53

[a]The values presented in this table are average values for the parameters listed. The parameters for each primer type are not intended to represent a particular primer.

[b]References 1 and 9.

[c]Calculated values based on recommended reduction ratio and 6.95 lb VOC/gal thinner (reducer).

[d]Reference 1.

[e]References 1, 4, and 9.

[f]Volume of coating:volume of reducer.

[g]Reference 15.

[h]Calculated value based on one vehicle = 100 ft^2 coated area and 35 percent transfer efficiency.

Prepcoats provide corrosion resistance and an adhesive surface for subsequent topcoats, but they do not fill grinder marks and sand scratches. For this reason, they are frequently used in conjunction with a primer-surfacer.

Primer-surfacers, which can be used to fill surface imperfections, are the most versatile primers, providing adhesion, corrosion resistance, and build (filling ability). The three types of primer-surfacers are nitrocellulose lacquer, acrylic lacquer, and alkyd enamel. Of the primer-surfacers, nitrocellulose lacquer primer-surfacer is the most commonly used, primarily because it dries in 20 minutes and is easier to sand than the other primer-surfacers. However, it does not provide the degree of corrosion resistance and durability offered by the other formulations, so its use is limited to small repairs.[8] Enamel primer-surfacers, which offer improved corrosion resistance and durability, are generally used for panel repairs and complete repainting. Drying time for these coatings is 1 to 2 hours. Acrylic lacquer primer-surfacers combine the fast drying of the nitrocellulose product with the durability of enamels.

Primer-sealers provide the same adhesion and corrosion protection as prepcoats, some of the filling ability of primer-surfacers, and the ability to seal an old finish that is being repainted. Drying time is about 30 minutes. Sealing is necessary to hide sand scratches and to promote adhesion when spraying alkyd enamel over lacquer, enamel over enamel, and lacquer over enamel. Sealers differ from primer-sealers in that they cannot be used as a primer and must be sprayed over a prepcoat, a primer-surfacer, or an old finish. Primer-sealers are typically enamel-based, while sealers are acrylic lacquer-based products.

Lacquer-based primers average 5.8 lb VOC/gal coating, as sprayed, while enamel-based primers average 5.1 lb VOC/gal coating, as sprayed.

Waterborne primers offer an alternative to the conventional solvent-borne primers. While the initial purchase price is higher than that of lacquer-based primers and enamel-based primers, waterborne acrylic primers offer the advantages of high filling and sealing capability. In addition, waterborne primers are impervious to attack by solvents, thus they prevent the swelling of sand scratches in an old surface caused by solvents in a new surface. Waterborne primers, unlike conventional primers, can be sprayed over old, cracked finishes. The drying time for waterborne primers is comparable to that for enamels.[10]

3.2.3 Topcoats

The topcoat, which is generally a series of coats, is applied over the primer and determines the final color of the refinished area. Since most repairs are spot and panel repairs, the automobile refinisher is concerned with matching the original equipment manufacturer (OEM) color as closely as possible. Usually, this matching is accomplished by blending the repair into the surrounding area. The first coat is applied to the immediate area being repaired, with subsequent coats extending beyond this area. In some cases, a heavily reduced blend coat is used to further improve the color match. Because this coat is less dense, it allows a portion of the original color to show through and effect a gradual transition from the color of the refinished area to the original color.[4,8,11] As OEM topcoats have become more complex, the precise matching of original colors by refinishers has become more difficult, and, in many cases, increased solvent usage has resulted from an effort to achieve blending.

From the standpoint of appearance, topcoats may be either solid colors or metallics and may be applied in one stage or in a two-stage basecoat/clearcoat (BC/CC) system for improved gloss and "depth." Three-stage mica coatings have also been developed.[11]

Metallic finishes differ from solid color finishes because they contain small metal flakes, typically aluminum, that are suspended in a mixture of binders, solvent, and pigment. Light enters the finish and is reflected by these metal flakes to produce the metallic color effect. As a result, these finishes are among the more difficult to color match successfully. The solvents in the coating begin to evaporate as soon as the material is sprayed. This rate of evaporation determines the alignment and depth of the metallic flakes. If evaporation occurs very quickly, the flakes will be frozen in random patterns near the film surface, giving the finish a light silvery appearance. Conversely, if evaporation occurs too slowly, the flakes will sink further, resulting in a reduced metallic effect and a darker finish.

Basecoat/clearcoat systems consist of a basecoat, which may be either a solid color or a metallic (although usually the latter), followed by a clearcoat. These systems have become popular with vehicle owners because they provide a deep, rich look that cannot be duplicated by a single-stage coating.

The chemistry of coating systems, whether solid colors, metallics, single stage or two stage, is classified into several categories. These are: acrylic lacquer, alkyd enamel, acrylic enamel, and polyurethane. A breakdown of the relative properties and costs for the different types of topcoat formulations is presented in Table 3-2. The values presented for each coating type in Table 3-2 are average values for each parameter based on a review of industry surveys and are not intended to represent a particular coating. Lacquers account for approximately 34 percent by volume of the coatings used by the automobile refinishing industry based on a recent market survey.[12] Lacquers are preferred for spot repairs because they dry quickly by solvent evaporation and are easily redissolved in solvent and removed when necessary.[8] Alkyd enamel, also referred to as synthetic enamel, is the chemical combination of an alcohol, an acid, and an oil. Developed by DuPont in 1929, alkyd enamel is less expensive than acrylic enamel but has inferior durability. Acrylic enamels, the most frequently used coating in the automobile refinishing industry, are characterized by excellent durability. Unlike lacquer coatings, enamels have a natural high gloss and do not require compounding (polishing), which reduces labor costs, especially for refinishing panels or entire vehicles.[8] Enamels (including alkyd and acrylic) account for approximately 54 percent of the paint currently sold.[12] Polyurethane coatings, which are the most recently developed coatings, comprise the remaining 12 percent of the market.[12] Polyurethane coatings typically are used by the more technically sophisticated refinishing shops and generally offer superior gloss retention and durability. They are frequently used for overall painting jobs, such as painting fleet vehicles.[4]

There is a difference between the coatings applied by the OEM's and those applied by refinishing shops. At OEM facilities, coatings once applied to the vehicles are subsequently baked in large ovens to shorten drying times and to cure the coatings. Automobile refinishing shops

TABLE 3-2. TYPICAL TOPCOAT PARAMETERS[a]

	Basecoats			Clearcoats		
	Acrylic lacquer	Acrylic enamel	Polyurethane (isocyanate)	Acrylic lacquer	Acrylic enamel	Polyurethane
Solids content						
As sold, wt.%[b]	32	46	37	33	32	45
As sprayed, wt.%[c]	14	33	37	11	32	45
Solids content						
As sold, vol.%[b]	25	36	34	26	28	33
As sprayed, vol.%[c]	10	24	26	9	28	33
VOC content						
As sold, lb/gal coating[d]	5.2	4.5	5.2	5.2	5.6	4.4
As sprayed, lb/gal coating[e]	6.3	5.3	5.2	6.4	5.6	4.4
As sprayed, lb/gal solids[c]	62.5	22.2	15.3	73.5	20.0	13.3
Density, lb/gal						
Coating as sold[e]	7.7	8.5	8.2	7.0	8.2	9.5
Coating as sprayed[c]	7.3	8.0	8.2	7.0	8.2	9.5
Density of solids	11.0	11.0	10.0	10.0	--	9.5
Reduction ratio[b f]	1:1.5	1:0.5	1:0.33	1:2.0	None	None
Dry film thickness, mils[g]	1.5	1.5	1.5	2	2	2
Volume/vehicle, as sprayed, gal[h]	2.7	1.1	0.8	3.9	1.3	1.1
Cost						
As sold, $/gal[e]	72	52	100	31	22	49
As sprayed, $/gal[c]	34	38	100	16	22	49
Per vehicle, $	91	41	80	61	29	54

[a]The values presented in this table are average values for the parameters listed. The parameters for each coating type are not intended to represent a particular coating.
[b]References 1 and 9.
[c]Calculated values based on recommended reduction ratio and 6.95 lb VOC/gal thinner (reducer).
[d]Reference 1.
[e]References 1, 4, and 9.
[f]Volume of coating:volume of reducer.
[g]Reference 14.
[h]Calculated value based on one vehicle = 100 ft^2 coated area and 35 percent transfer efficiency.

cannot use such drying ovens because the high temperatures would likely damage the car's upholstery, glass, wiring, and plastic fittings. The coatings used at refinishing shops must have the ability to either air dry or dry when baked at low temperatures; therefore, automobile refinishing coatings require solvents that allow the coatings to dry faster.

3.2.4 Application Techniques

Current practice in the automobile refinishing industry is to apply all coatings, whether primer, basecoat, or clearcoat, using a hand-held air atomized spray gun. This gun atomizes the coating into tiny droplets by means of air pressure. The two basic types of spray guns are pressure feed and suction feed. In a pressure feed spray system, the paint is contained in a pressure pot that is connected by hose lines to the spray gun. Compressed air pushes the liquid out of the spray gun nozzle. Pressure feed spray guns generally consume significantly more paint than the suction feed guns due to the paint required to fill the pressure pot and hose lines.[13] In a suction feed gun, the rapid flow of the air through the air line above the paint cup creates a vacuum in the paint intake tube causing the paint to rise and mix with the air before exiting the gun. The suction gun is the more popular gun and is used almost exclusively in the automotive refinishing industry.[13] The transfer efficiency, the percent of paint solids sprayed that actually adheres to the surface being painted, provided by these guns varies dramatically depending on the configuration of the part being painted, the type of gun used, and the skill of the operator, but can be assumed to be approximately 35 percent.[14] Consequently, around 65 percent of the paint that is sprayed is wasted because it does not strike the surface being painted.

Spray booths provide dirt-free, well-lit, and well-ventilated enclosures for coating application. Because of their longer drying times, enamel, waterborne, and polyurethane coatings are best applied in a spray booth to minimize the possibility of dirt adhering to the damp coating. Spray booth ventilation is necessary to provide clean, dirt-free air to remove paint overspray and solvent vapors, to hasten drying, and to provide a safer work environment for the painter. Traditionally, the airflow in spray booths has been horizontal or crossdraft. However, downdraft booths with vertical airflow (top to bottom) are gaining in popularity. In the crossdraft design, incoming air is pulled into the booth through filters located in the entrance door, travels along the length of the car, passes through paint arrestor filters at the opposite end which remove paint overspray, and finally exhausts through an exhaust stack. In contrast, incoming air in a downdraft booth is pulled in through filters in the roof, travels down over the top of the vehicle to remove paint overspray, and passes into a grate-covered pit in the floor of the booth. The downdraft booth is perceived to be the better design because overspray in the rest of the booth is minimized, air circulation is more uniformly concentrated around the vehicle, and solvent vapor is drawn down and away from the breathing zone of the painter.

In order to decrease the drying time after coating application, some shops use forced drying systems. Large volume shops may have a drying chamber attached to the back of the spray booth that contains infrared units mounted in the chamber walls or mounted in a traveling oven that rolls along the length of the vehicle. At smaller shops, these traveling ovens may be located in a storage vestibule next to the spray booth to be rolled out for use inside the booth after the vehicle has been sprayed. Small, portable infrared units in various sizes are also available either to warm cold metal surfaces prior to coating application or to speed the drying time of spot and panel repairs. Forced drying systems typically are used in shops that use slower drying enamel, waterborne, and polyurethane coatings to speed drying, which reduces the possibility of dirt adhering to the damp coating.

Because it is impossible to stock enough paint to match all the colors used in the automobile industry, many repair shops use an in-house color mixing machine system. This system comprises a paint measuring scale, a catalog of color chips and formulas, and a rack containing forty to sixty, 1-gallon cans of mixing colors. From these basic colors, almost any OEM color can be matched and also can be adjusted for fading and weathering of older finishes. In-house mixing of paints allows the repair shop to prepare the proper amount of paint needed for each job rather than buying in the unit quantities offered by paint manufacturers. It also ensures that color matching can be done quickly and that slight adjustments to the color can be made without having to reorder from the supplier.

3.2.5 Equipment Cleanup

The final phase of automobile refinishing consists of cleaning the spray gun and any other equipment used. Typically, cleanup consists of thoroughly rinsing the affected equipment with solvent to remove any paint particles present. The solvent may be reused but is usually discarded.

3.3 REFERENCES FOR SECTION 3

1. Letter from R. Hick, DuPont, Wilmington, Delaware, to R. Blaszczak, ESD/EPA. Research Triangle Park, North Carolina. February 8, 1988.

2. Industry Profile, Body Shop Business. June 1987.

3. Letter from D. Greenhaus, National Automobile Dealers Association (NADA), McLean, Virginia, to R. Blaszczak, ESD/EPA. Research Triangle Park, North Carolina. February 2, 1988.

4. Minutes of meeting with G. Ocampo, The Sherwin-Williams Company, Cleveland, Ohio, at EPA/OAQPS, Research Triangle Park, North Carolina. February 4, 1988.

5. Letter from R. Hick, DuPont, Wilmington, Delaware, to A. Bell, Texas Air Control Board, Austin, Texas. October 29, 1987.

6. Telecon of conversation between R. Hick, DuPont, Wilmington, Delaware, and M. McLaughlin, MRI, Cary, North Carolina. February 5, 1988.

7. Attachment to letter from L. Bowen, South Coast Air Quality Management District, El Monte, California, to interested parties. December 30, 1987.

8. Auto Refinishing Handbook, DuPont, Wilmington, Delaware. 1987.

9. Attachment to letter from D. Braun, BASF Corporation, Whitehouse, Ohio, to R. Blaszczak, ESD/EPA. Research Triangle Park, North Carolina. February 22, 1988.

10. BASF Corporation, Whitehouse, Ohio, product bulletin. 1988.

11. Minutes of meeting with representatives of the National Paint and Coatings Association (NPCA), Washington, D.C., at EPA/OAQPS, Research Triangle Park, North Carolina. January 20, 1988.

12. Minutes of meeting with representatives of Akzo Coatings (Sikkens), Norcross, Georgia, at EPA/OAQPS, Research Triangle Park, North Carolina. December 16, 1987.

13. Attachment and letter from G. Levey, Speedflo Manufacturing Corporation, Houston, Texas, to R. Blaszczak, ESD/EPA. Research Triangle Park, North Carolina. January 4, 1988.

14. Attachment to letter from R. Rondinelli, The Devilbiss Company, Toledo, Ohio, to R. Blaszczak, ESD/EPA. Research Triangle Park, North Carolina. February 12, 1988.

15. The Sherwin-Williams Company, Cleveland, Ohio, product bulletins. 1988.

4.0 EMISSION ESTIMATES

This section provides VOC emission estimates for each of the automobile refinishing process steps identified in Section 3 as they are currently practiced in the industry. These process steps include surface preparation, primer application, topcoat application, and spraying equipment cleanup. Emissions of VOC's from automobile refinishing operations are the result of organic solvent evaporation from these process steps. Table 4-1 presents the major emission sources within the industry and the estimated percentage of total nationwide emissions from each source. The VOC emission estimates presented in this section provide a baseline with which to compare the emission reduction techniques and resulting emission reductions discussed in Sections 5 and 6, respectively.

State or local agencies should conduct a survey of shops in their area to determine their baseline VOC emissions from automobile refinishing operations. An area survey would likely provide more accurate emission estimates than using the data presented here because the VOC emissions presented in this section are based on broad assumptions as outlined in Section 4.1.

4.1 BACKGROUND

To establish a consistent basis (the baseline) for determining current VOC emissions from the automobile refinishing industry, typical coating parameters and facilities were selected based on surveys of the industry. Appendix A presents the methodology used to develop three general categories of refinishing shops, the number of jobs per shop per category, and the coating usage per category. The categories developed using this methodology include small shops, which perform an average of 6 partial repairs per week; medium-sized shops, which average 13 partial repairs and 1 complete vehicle job per week; and volume shops, which typically perform 15 complete vehicle jobs and 14 partial repairs per week. Table 4-2 presents the typical coating parameters used in calculating the VOC emission estimates for each type of shop. Table 4-3 summarizes the size, equipment, and coating consumption assumed for each of the typical facilities. For the purposes of this analysis, it is assumed that topcoats consist of a basecoat and clearcoat, and that

TABLE 4-1. VOC EMISSION SOURCES AND PERCENTAGES OF TOTAL NATIONWIDE VOC EMISSIONS[1]

Source	Percent of total emissions
Surface preparation/cleaning	8
Primers	17
Topcoats	55
Equipment cleaner	20

TABLE 4-2. TYPICAL COATING PARAMETERS FOR VOC CALCULATIONS

	Primers				Base coats			Clear coats		
	Lacquer	Enamel	Waterborne	Urethane	Acrylic lacquer	Acrylic enamel	Polyurethane (isocyanate)	Lacquer	Enamel	Higher solids polyurethane
Solids content										
As sold, volume percent[a]	33	36	33	37	25	36	34	26	28	33
As sprayed, volume percent[b]	13	24	33	30	10	24	34	9	28	33
VOC content										
As sold, lb/gal coating[a]	4.6	4.1	2.5	3.6	5.2	4.5	5.2	5.2	5.6	4.4
As sprayed, lb/gal coating[a]	6.0	5.1	2.5	4.3	6.3	5.3	5.2	6.4	5.6	4.4
Reduction ratio[c d]	1:1.5	1:0.5	None	1:0.25	1:1.5	1:0.5	None	1:2	None	None
Dry film thickness, mils[e]	2	2	2	2	1.5	1.5	1.5	2	2	2

[a]References 1 and 2.
[b]Calculated value based on reduction ratio.
[c]References 1 through 3.
[d]Volume of coating:volume of reducer.
[e]Reference 2.

TABLE 4-3. TYPICAL AUTOMOBILE REFINISHING PAINT USAGE AND EQUIPMENT BY FACILITY TYPE

Facility description	No. of facilities nationwide[b c]	Sales, $1,000/yr[b]	Jobs/week[b]		Paint usage, gal/wk as sprayed[a]									Equipment[b]	
					Lacquer			Enamel			Urethane				
			Full	Partial	P[d]	B	C	P	B	C	P	B	C	Spray booth	Mixing station
Small shop	32,200	<150	0	6	1.6	1.6	2.5	0	0	0	0	0	0	No	No
Medium shop (includes dealers)[e]	41,300	150-750	1	13	3.8	3.7	5.8	1.3	1.0	1.2	0	0	0	Yes	No
Volume shop (includes franchises)[f]	8,600	>750	15	14	0	0	0	18.4	13.8	15.8	4.8	3.1	4.3	Yes	Yes

[a]Assumes 100 ft^2 for full job; 10 ft^2 for partial job.
[b]See Appendix A.
[c]Reference 7.
[d]Primer coat = P; basecoat = B; clearcoat = C.
[e]Assumes one full job and four partial jobs are coated with lacquer and the remaining nine partial jobs are coated with enamel.
[f]Assumes 11 full and 4 partial jobs are coated with enamel and 4 full jobs are coated with urethane.

coating one complete vehicle is equivalent to coating 100 ft^2 of surface area. Partial jobs (e.g., spot and panel repair) are assumed to average 10 ft^2. Coating usage values were calculated based on the parameters given in Tables 3-1 and 3-2 and on the following assumptions. Small shops paint an average of 6 partial jobs (60 ft^2) per week and use lacquers exclusively. Medium shops paint 5 partial jobs (50 ft^2) with lacquer, 11 partial jobs (110 ft^3) with enamel, and one full job (100 ft^2) with enamel. Volume shops paint 4 partial jobs and 18 full jobs (1,840 ft^2 total) per week and use enamel for half of the work and urethanes for the other half.

These assumptions are intended to represent the range of typical facilities. Because of localized trends within the industry, source-specific information should be used for determining emission estimates from this industry in a particular locale, if at all possible. Users of this document should not attempt to use these values to estimate emissions from specific shops.

4.2 BASELINE VOC EMISSIONS

The baseline nationwide VOC emissions from the motor vehicle refinishing industry were calculated from the information in Tables 4-2 and 4-3, and are presented in Table 4-4. Small shops, which typically perform spot and panel repairs using lacquer coatings and rarely repaint entire vehicles, account for 15 percent of the total VOC emissions from this industry (10.2 lb VOC/d per shop). Medium-sized shops, which include approximately 17,000 automobile dealerships that maintain body shop operations, perform a range of repairs and use both lacquers and enamels. These facilities account for 52 percent of VOC emissions (29.0 lb VOC/d per shop). Finally, the high-volume shops, which specialize in repainting entire vehicles using both enamels and urethanes, account for 33 percent of the overall emissions (89.0 lb VOC/d per shop).

4.3 CALCULATIONS

The calculation methodology used to estimate VOC emissions is presented in Appendix B. Agencies may elect to use this methodology to calculate VOC emissions from their area if enough information from an area shop survey is available.

TABLE 4-4. BASELINE VOC EMISSIONS FROM AUTOMOBILE REFINISHING BY FACILITY TYPE

Facility description	No. of shops[a,b]	Percent of total No. of shops	VOC emissions, lb/d per shop				Total lb VOC/d, per shop	Total tons VOC/yr, nationwide	Percent of total VOC emissions
			Primer	Basecoat	Clearcoat	Solvent			
Small shop	33,200	40	1.9	2.0	3.2	3.1	10.2	42,200	15
Medium shop (includes dealers)	41,300	50	5.9	5.8	8.7	8.7	29	149,900	52
Volume shop (includes franchises)	8,600	10	22.9	17.9	21.5	26.7	89	95,600	33
Total industry	83,100	100	6.1[c]	5.5[c]	7.8[c]	8.3[c]	27.7[c]	287,700	100

[a]Reference 6.
[b]Reference 7.
[c]Weighted average values.

4.4 REFERENCES FOR SECTION 4

1. Letter from R. Hick, DuPont, Wilmington, Delaware, to R. Blaszczak, ESD/EPA. Research Triangle Park, North Carolina. February 8, 1988.

2. Attachment to letter from G. Ocampo, Sherwin-Williams, Cleveland, Ohio, to R. Blaszczak, ESD/EPA. Research Triangle Park, North Carolina. February 3, 1988.

3. Attachment to letter from D. Braun, BASF Corporation, Whitehouse, Ohio, to R. Blaszczak, ESD/EPA. Research Triangle Park, North Carolina. February 22, 1988.

4. DuPont Auto Refinishing Handbook, The DuPont Company, Wilmington, Delaware. 1987.

5. Minutes of meeting with representatives of Akzo Coatings (Sikkens), Norcross, Georgia, at EPA/OAQPS, Research Triangle Park, North Carolina. December 16, 1987.

6. Industry Profile, Body Shop Business. June 1987.

7. Letter from D. Greenhaus, National Automobile Dealers Association (NADA), McLean, Virginia, to R. Blaszczak, ESD/EPA. Research Triangle Park, North Carolina. February 2, 1988.

8. Letter from L. Bowen, California South Coast Air Quality Management District, El Monte, California, to interested parties. December 30, 1987.

9. The National Paint and Coatings Association, Washington, D.C. The U. S. Paint Industry: Technology Trends, Markets, Raw Materials. September 1986.

5.0 EMISSION REDUCTION TECHNIQUES

This section presents information on VOC emission reduction techniques and alternative low-VOC coatings that currently are available to reduce VOC emissions from the automobile refinishing industry. The information will allow planners to identify advantages and disadvantages associated with the implementation of these options. The options may be used singly or in combination to achieve required VOC reductions. Options are available for each of the four process steps involved in automobile refinishing.

Sections 5.1, 5.2, 5.3, and 5.4 present alternatives for reducing VOC emissions during vehicle preparation, primer application, topcoat application, and equipment cleanup, respectively. The VOC emission reductions associated with implementation of these options are presented in Chapter 6.

5.1 ALTERNATIVES FOR REDUCING VOC EMISSIONS DURING VEHICLE PREPARATION

As discussed in Section 3.0, vehicle preparation is critical in assuring proper coating adhesion to the vehicle. Failure to properly clean the surface to be painted may result in the need to reapply the coating, resulting in increased labor and raw materials cost, and increased VOC emissions. The conventional vehicle preparation procedure is a two-step process. The surface is washed with detergent and copious volumes of water, followed by a thorough cleaning with solvent to remove grease, wax, silicones, and other possible contaminants.[1] However, reduced-VOC cleaners and detergents are two alternatives to the standard practice that can be used to reduce VOC emissions.

5.1.1 Reduced-VOC Cleaners

At least one major coating supplier offers a product for use during the second step of vehicle preparation that contains less than 20 percent of the VOC found in conventional cleaners.[2] This aqueous-based cleaner, introduced in late 1981, contains 80 percent water, 15 percent solvent (a mixture of toluene and xylene), and 5 percent surfactant.[3] The resulting emulsion, which has the appearance of heavy cream, was formulated for degreasing surfaces for spot repair. Despite its claimed superior cleaning efficiency in this application, it has not gained widespread acceptance in the refinishing industry because it is inherently limited to removing wax and grease during preparation, and is not a general purpose solvent.[3] Typically, body shop owners prefer to purchase those solvents that have multiple uses in the shop (e.g., vehicle preparation, paint thinning, and cleanup) to minimize inventory.[3] Use of this or a similar cleaner would, however, reduce worker exposure to VOC's during vehicle preparation, and reduce overall VOC emissions.

5.1.2 Detergents

The use of a second detergent wash to clean the vehicle is an option that would totally eliminate VOC emissions during vehicle preparation. While the typical automobile refinisher relies upon the use of a solvent rinse, detergents alone have been used successfully for many metal cleaning applications.[4,5] One area of concern is the complete removal of silicones, which, if present, tend to cause a common coating defect called "fish eyes." These are small, crater-like openings in the new finish where silicones have prevented the coating from leveling to a smooth finish. In order to avoid this defect, refinishers tend to use solvents rather than detergents. Nonetheless, when properly used, detergents are effective in cleaning the metal surfaces to be coated. Furthermore, commercial products are available that will reduce the surface tension of the coating film, thus allowing it to flow over and around any contamination (such as silicone) that might be present.[1,4-6]

5.2 ALTERNATIVES FOR REDUCING VOC EMISSIONS DURING PRIMER APPLICATION

Two alternatives for reducing VOC emissions are improving transfer efficiency (the percentage of the coating sprayed that actually adheres to the surface being coated), and using lower-VOC primers (waterbornes and urethanes) in place of conventional lacquer and enamel primers.

5.2.1 Improved Transfer Efficiency

As discussed in Section 3.0, the spraying equipment preferred by the automobile refinishing industry is the conventional hand-held air-atomizing gun, which is typically outfitted with a 1-quart cup and has an estimated transfer efficiency of approximately 35 percent.[7,8] This rate of transfer efficiency means that approximately 65 percent of the coating sprayed fails to deposit on the vehicle, resulting in unnecessary coating consumption and VOC emissions. Two alternative coating application techniques, both of which allow transfer efficiencies up to 65 percent, are electrostatic spraying and high-volume, low-pressure (HVLP) spraying.[9-11]

Electrostatic spraying involves using an electrical transformer capable of delivering up to 60,000+ volts to create an electrical potential between the paint particles and the surface of the vehicle. These charged paint particles are thus electrically attracted to the surface, increasing transfer efficiency. Although used by original equipment manufacturers in great numbers, electrostatic spraying has not been adopted by the automobile refinishing industry for three primary reasons.[7,12] One problem is that typically these systems use a pressure pot connected to the spray gun via a hose. Coating is left over in the hose after each job. Since color changes occur with each job, this extra material is discarded (once mixed with the appropriate reducer and additives, most coatings have a limited pot life, or period in which they are usable). This offsets coating savings through the increased transfer efficiency. Another factor is the cost of the electrostatic system. A typical air-atomized spray gun costs around $160 (excludes hoses, air regulator, and compressor), while an electrostatic gun costs from $3,000 to $5,000 (includes gun, power cable, and power supply and excludes compressor, hoses, air regulator).[8,12,13] The compressor, hoses, and air regulator for each system can cost an additional $2,000 to $3,000.[8] Finally, electrical shocks and fire hazards are two potential safety problems associated with electrostatic spraying, although the degree of hazard is controversial.[10,14] For these reasons, the use of electrostatic spraying is probably not a practical option for the majority of the refinishing industry.

High-volume, low-pressure spraying, also known as turbine spraying, involves the use of a turbine to generate and deliver atomizing air. The turbine draws in filtered air which is driven through several stages at up to 10,500 revolutions per minute (rpm).[11] The result is a high volume of warm, dry, atomizing air that is delivered to the spray gun at less than 7 pounds per square inch (psi).[11] This low-pressure air gives greater control of the spray, with less overspray and paint fog due to the absence of the blasting effect common with conventional high-pressure systems.

This blasting effect is caused when the compressed air released from the gun suddenly expands and returns to atmospheric conditions, which tends to over-atomize the coating and propel it at high velocity, causing overspray, rebounding, and fog, and reducing transfer efficiency. At present, less than 5 percent of automotive refinishers use HVLP spraying.[11] The cost of HVLP equipment varies significantly ranging from around $1,000 for a basic one-gun system, up to $18,000 for a heavy-duty complete system with multiple guns. However, the potential savings in paint usage due to the higher transfer efficiency over conventional equipment makes the HVLP equipment an attractive option for coating application.

5.2.2 Waterborne Primers

Waterborne primers formulated for the requirements of automobile refinishing recently have been developed and currently are offered by at least one supplier. These primers typically contain 2.5 lb VOC/gal (as sprayed) compared with the 6.0 lb VOC/gal and 5.1 lb VOC/gal (as sprayed) typically contained in conventional lacquer and enamel primers, respectively. Unlike conventional primers, waterborne primers do not require that old, cracked and crazed finishes be stripped prior to application of the primer because the primer fills in the cracks. According to the manufacturer, these primers can be topcoated with virtually any topcoat system including basecoat/clearcoat systems.[6] In addition, waterborne primers are not subject to attack by solvents in the topcoats, eliminating sandscratch swelling, lifting, or other coating problems. They also can be applied with conventional spray equipment. The major disadvantage with waterborne primers, from the refinisher's perspective, is the relatively long drying time associated with these formulations--60 minutes as opposed to 20 to 30 minutes for conventional primers.[6,15] This increased drying time interferes with the timely refinish of the vehicle and, depending on the workload and available space in the shop, may leave the painter with no productive work for that hour. Furthermore, the drying times of waterborne coatings vary greatly with changes in temperature and humidity, factors which are often difficult to control under shop conditions. Waterborne primers are, however, cost competitive with lacquer and enamel primers. Slow drying time and sensitivity to ambient conditions, along with shop unfamiliarity with these relatively new products, probably explains why these products currently account for less than 6 percent of the total volume of primer sold in the United States.[16]

5.2.3 Urethane Primers

The use of urethane primers is another option for reducing VOC emissions from the automobile refinishing industry. These primers typically contain 4.3 lb VOC/gal (as sprayed) compared with the 6.0 lb VOC/gal and 5.1 lb VOC/gal (as sprayed) contained in conventional lacquer and enamel primers, respectively. These products provide excellent filling of scratches and holdout (the ability of a primer to prevent the topcoat from sinking into it).[17] Drying times, however, average about 45 minutes, and urethane primers may also contain isocyanate hardeners. The presence of isocyanates requires the use of supplied-air respirators, which are not available at many shops.[1,17] Urethane primers also cost about 25 percent more than conventional lacquer primers and about 50 percent more than conventional enamel primers.[17]

5.3 ALTERNATIVES FOR REDUCING VOC EMISSIONS DURING TOPCOAT APPLICATION

5.3.1 Improved Transfer Efficiency

Methods of improving transfer efficiency were discussed in Section 5.2.1, and that information generally applies to the application of topcoats. However, there are additional considerations related to color matching that warrant discussion.

5.3.1.1 Color Coats. The unique problem associated with applying topcoats that is not an issue for primer or clearcoat application is the problem of color match. Approximately 90 percent of the refinishing work in a typical shop involves spot repairs, and customers will reject an otherwise satisfactory repair if the color of the repaired area fails to match the rest of the vehicle.[18] Shops frequently must blend the refinish color over the original color to reduce the disparity between the original and repair colors as much as possible. Color can also be varied by adjusting the amount of solvent used to thin the paint, the speed (volatility) of the solvent, the distance between the gun and the surface being painted, and the air pressure used. For example, the painter could hold the gun farther from the surface thereby creating a thinner coat and allowing the original color to show through.

Metallic finishes, which have become very popular, present additional color matching difficulties. These finishes, which include small flakes of aluminum, depend on the proper alignment of these flakes for optimum appearance. This alignment, in turn, is dependent upon the rate of solvent evaporation.

High transfer efficiency spray guns may make color matching more difficult because they tend to produce thicker coats which makes it more difficult to apply increasingly thinner coats of paint when blending or feathering. The problems associated with the application of metallic coatings are also exacerbated when high transfer efficiency equipment is used since film thickness affects the evaporation rate of solvent which determines the positioning of the metallic flakes in the coating. Another adverse effect of a higher transfer efficiency is splotching, which is caused when solvent initially trapped in the thicker coating escapes to the surface and causes a blemish.

Based upon conversations with several facilities in California, it appears that the HVLP equipment is being used with some success. The manager at one shop stated that it is the painter who determines the quality of the job.[19] He stated that the HVLP spray gun has a different feel than the conventional air-atomizing spray gun and it takes some time to get accustomed to its use.[19] A painter from another shop maintained that, initially, some problems were encountered with color match.[20] However, experience with the equipment and changing the paint-to-solvent ratio to 1:1 instead of the recommended reduction ratio solved these problems and provided excellent results on a wide range of vehicles.[20] This solution, however, points out a potential problem with implementing the use of high transfer efficiency equipment to reduce VOC emissions. If the coating is further reduced with solvent, the advantage of a higher transfer efficiency will be partially or totally offset. Proper operator training will be required. Another shop is currently applying primers with HVLP and expects to apply topcoats with it in the near future.[21] It appears that while some drawbacks exist with the use of HVLP, these may be overcome with experience. As with any change in operating procedures, some resistance may be encountered from body shop operators if a change from the conventional spray gun to the HVLP spray gun is implemented.

Nevertheless, the California South Coast Air Quality Management District is proposing to require a minimum 65 percent transfer efficiency for spray equipment. This requirement is based on observation of the HVLP equipment.

5.3.1.2 Clearcoats. There are no significant technical reasons for not using high transfer efficiency spray equipment to apply clearcoats. The industry probably has not yet done so because of the relative newness of the technology, operator unfamiliarity with the equipment, and initial capital cost. Also, shop owners are probably reluctant to maintain two types of systems, a conventional system for color matching shop repairs, and a high transfer efficiency system (HVLP) for primers, clearcoats, and completely repainting vehicles.

5.3.2 Reduced-VOC Coatings

The use of coatings that contain a lower concentration of VOC's (higher solids content) than the baseline coatings will result in a reduction of VOC emissions. Lacquers generally have the highest VOC content of the coatings applied in this industry. The replacement of these coatings with enamels can reduce VOC emissions significantly. Likewise, the replacement of lacquers or enamels with polyurethane coatings further reduces emissions. Contemporary polyurethane clearcoats typically have a solids content, as purchased, of 45 percent by weight, compared to about 32 percent by weight for a typical lacquer or enamel clearcoat. The emission reduction potential for polyurethane coatings is even more apparent when considered in terms of the VOC usage required to deposit 1 gallon of solids on the automobile. Polyurethane clearcoats typically contain about 13 pounds of VOC per gallon of coatings solids (lb VOC/gal solids). Enamels contain about 20 lb VOC/gal solids, and lacquers typically contain about 73 lb VOC/gal solids. This dramatic increase in VOC content of lacquers results from the solvent additions that must be made at the repair shop prior to spraying the materials.

Low-VOC coatings (primarily polyurethanes) have been adopted by many automobile manufacturers for their production lines. The performance of these coatings is, in most aspects, superior to that of lacquers and enamels. Refinishing shops have been much slower to adopt polyurethane coatings, primarily because of the longer drying times. However, recent advances in the coating chemistry have reduced the drying time of polyurethanes to a range of 4 to 6 hours. These drying times can be reduced even more if forced drying (using heat lamps, for example) is used.

Another advantage of most higher solids coatings is the reduction in the number of coats that must be applied to achieve the desired dry film thickness. Two or three coats of polyurethane coatings can normally be used in cases where four to six coats of lacquer would be required. The combination of superior performance, the requirement for fewer coats than enamels or lacquers, and improved drying times has made higher solids coatings more acceptable to auto refinishers.

Research is being conducted by several paint formulators to produce coatings with even higher solids contents. Increases in solids content (up to 45 percent) have been accomplished by using strong solvents (solvents with the ability to dissolve large quantities of a particular resin while maintaining a sprayable viscosity). In order to increase paint solids content beyond 45 percent while continuing to maintain satisfactory spray characteristics, the viscosity of the paint polymers must not be allowed to increase. Lower molecular weight polymers (i.e., shorter chain molecules) allow viscosities to be maintained, but there is a corresponding decrease in certain coating properties, especially durability. Research has not overcome this problem, and these coatings are not yet available to the automobile refinishing industry.

5.4 ALTERNATIVES FOR REDUCING VOC EMISSIONS DURING EQUIPMENT CLEANUP

The solvent cleaning of leftover paint from the spray equipment typically results in a significant quantity of VOC emissions. Systems are available, however, that can reduce cleaning solvent consumption and, therefore, VOC emissions. The simplest of these systems, usually called a gun washer, consists of a closed container fitted with hose connections. The spray gun is placed in the container, and the hoses are connected to the suction and discharge nozzles of the spray gun. Solvent is then pumped through the gun and back to the enclosed storage receptacle. Because the system operates as a closed loop once the gun is attached, there is considerably less spillage and less solvent evaporation than in the standard practice. Solvent is recirculated through the gun washer system until it is too contaminated for further use. The number of guns that can be cleaned with one solvent charge is highly variable and depends primarily on the quantity and characteristics of the coatings used in the guns. However, solvent consumption is typically reduced by 75 to 80 percent compared to conventional gun cleaning.[22,23]

The spent solvent from a gun washer system may be sent out of the facility for recovery or disposal or it may be recovered in-house using a distillation system. Small distillation systems that are capable of recovering around 90 percent of the spent solvent are available.[24,25] The residue from these systems may be used as a rustproofing undercoat for vehicles.

5.5 ALTERNATIVES FOR SHOP ADD-ON CONTROL OF VOC EMISSIONS

Add-on controls are an option that may be applied to the auto refinishing industry to reduce VOC emissions from spray booths. Potential add-on controls include thermal incineration, catalytic incineration, and carbon adsorption. Thermal incineration has been used successfully in OEM spray booths to control emissions. However, even though the application of add-on controls to automobile refinishing operations is technically feasible, it has been limited. Data on the number of automobile refinishing operations in this country, if any, using add-on controls were not obtained during this study. Cost is the primary limiting factor in applying add-on controls in the automobile refinishing industry. The intermittent use of the spray booths in this industry generates an intermittent high-volume air stream with low concentrations of VOC's that is costly to control with add-on techniques. In addition, small facilities that do not have a spray booth also would need to install a spray booth before an add-on control could be used.

A recent study conducted for the State of New Jersey evaluated the use of thermal incineration, carbon adsorption, and catalytic incineration for control of automobile refinishing spray booth emissions in New Jersey. Although all of the alternatives investigated were found to have some technical limitations in their applicability to automobile refinishing, they are technically feasible.[14]

Thermal incineration is capable of achieving 99 percent destruction of VOC. Because the spray booths are not used continuously, long lead times to bring the incinerator up to operating temperature would be required. The fuel requirements needed to incinerate the large volume of air with a low concentration of VOC (including the fuel needed for frequent startups) is high. The combustion of the fuel results in NO_x formation and since NO_x also is a precurser to ozone, the benefit of reducing VOC's is partially offset.[14]

The positive and negative aspects of catalytic incineration are similar to those of thermal incineration. High destruction efficiencies can be achieved. The fuel requirements will be lower, because VOC destruction is achieved at a lower temperature (900°F) than that required for a thermal incinerator (1400°F). The potential for fouling the catalyst exists because the spray booth exhaust gas stream contains particulate matter.[14]

Although carbon adsorption is a well established VOC control technique, its application to the automobile refinishing industry poses some problems. The potential problems are primarily due to the low VOC content of the air stream being treated and to the intermittent nature of the spray booth operation. During the painting process, several spray coats are applied; the coats are allowed to dry between applications. Consequently, the VOC concentration in the air stream to the carbon adsorber varies widely. During the drying period, relatively pure air will be passing over the carbon beds, which could result in VOC desorbing from the beds.[14]

5.6 REFERENCES FOR SECTION 5

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10. Letter from A. Walberg, Electrostatic Consultants, Downers Grove, Illinois, to J. Berry, CPB/OAQPS. Research Triangle Park, North Carolina. November 30, 1987.

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20. Telecon of conversation between F. Paolini, Pasha Group, Long Beach, California, and M. Turner, Midwest Research Institute, Cary, North Carolina. June 21, 1988.

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6.0 ENVIRONMENTAL ANALYSIS

This section discusses the environmental impacts associated with implementation of the various alternative control technologies discussed in Section 5.0, either alone or in combination with each other. The primary emphasis is on a quantitative assessment of VOC emissions in the absence of control technology (baseline emissions) and after implementation of one or more of the control alternatives. The impacts of these control technologies upon water quality, solid waste, and energy consumption are also briefly discussed in this section.

6.1 AIR POLLUTION

The implementation of any of these control alternatives would reduce VOC emissions from automobile refinishing operations. The procedures for calculating VOC emissions are presented in Appendix A. The estimated VOC reduction potential for each technique is presented in Table 6-1. These values are calculated using the coating parameters and facility characteristics presented in Section 4.0. For each reduction technique, the resulting VOC emissions (lb/d) from a typical small, medium, and volume shop are presented. The total estimated VOC emissions (tons/yr) resulting from implementing each technique at all shops nationwide also are presented. Finally, for each technique, the reduction from baseline in tons/yr and percent are presented. Although each of the techniques is presented separately, several techniques could be implemented together to reduce emissions from this industry further. Solvent recovery systems and HVLP spraying, for example, could be used in conjunction with any of the other options, such as replacement of lacquers with either enamels or urethanes.

6.2 OTHER CONSIDERATIONS

6.2.1 Water Pollution

The implementation of any of these control technologies would result in no adverse water pollution impacts because no hazardous wastewater is produced by these operations. Wastewater from cleanup after spraying waterborne primers would be processed through the local wastewater treatment system.

TABLE 6-1. COMPARISON OF VOC EMISSIONS FROM AVAILABLE REDUCTION TECHNIQUES

Reduction technique	Facility VOC emissions, lb/d: Small shop	Medium shop	Volume shop	Weighted average	Total VOC emissions, tons/yr	Reduction from baseline, tons/yr	Percent reduction
Current practice (baseline)	10.2	29.0	89.0	27.7	287,700	NA[a]	NA
Replace lacquers with acrylic enamels[b c]	5.5	18.2	89.0	20.5	212,500	75,200	26
Replace lacquers and enamels with urethanes[b]	4.7	15.2	72.6	17.0	176,000	111,700	39
Replace solvent-borne primers with waterborne primers[b]	7.7	21.8	65.1	20.6	214,500	73,200	25
Replace conventional clearcoats with higher-solids clears[b]	7.6	22.6	83.1	22.9	237,500	50,200	17
Install solvent recovery systems[d]	8.6	24.7	75.6	23.5	244,500	43,200	15
Replace conventional air-atomizing spray guns with high-volume, low-pressure (HVLP) spray equipment[b e]	6.9	19.6	60.2	18.7	194,500	93,200	32

Note: While certain control alternatives can be combined, VOC percent reductions are not additive in all cases.

[a]Not applicable.
[b]Assumes baseline solvent consumption.
[c]Assumes that small shops will acquire the ability to spray enamels (i.e., acquire spray booths).
[d]Assumes 75 percent recovery of spent solvent and no recovery of surface preparation solvents.
[e]Assumes a 65 percent transfer efficiency (the baseline condition assumes 35 percent).

6.2.2 Solid Waste Disposal

The quantity of solid waste generated by implementation of these technologies would be insignificant. The waste generated would consist of used solvent, which could be recovered through distillation either onsite or at a commercial recycling facility. The resultant still bottoms could be used either for sound deadening or as an undercoat for corrosion prevention.[1,2] The filters used to collect overspray in the spray booth would be disposed of in a local municipal waste facility.

6.2.3 Energy

The implementation of these control technologies would result in an insignificant change in energy consumption. The increased use of spray booths would result in a slight increase in energy consumption from the operation of fans for the ventilation system and from heat lamps used to accelerate drying of enamel and urethane coatings.[3] The HVLP spraying equipment, however, uses less energy than the conventional high-pressure equipment.[4]

6.3 REFERENCES FOR SECTION 6

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2. Product Brochure, BT Associates, Garden Grove, California. 1987.

3. Letter and attachments from R. Rondinelli, The Devilbiss Company, Toledo, Ohio, to R. Blaszczak, ESD/EPA. Research Triangle Park, North Carolina. February 12, 1988.

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7.0 CONTROL COST ANALYSIS

A cost analysis was performed for each type of facility (small, medium, and large) introduced in Sections 3 and 4. Various emission reduction options were evaluated for each shop type. These options included the following: replace lacquers with acrylic enamels; replace lacquers and enamels with urethanes; replace solvent-borne primers with waterborne primers; replace conventional clearcoats with higher solids clears; install cleanup solvent recovery systems; replace conventional air-atomizing spray guns with HVLP spray equipment; and add-on a thermal incinerator to the spray booth (volume shop only).

The costs presented in this chapter were developed using the facility data given in Table 4-3 and costs generated through industry surveys. The costs should be used for comparison purposes only because the parameters used to generate the costs will likely vary considerably. This chapter presents the cost methodology planners can use to perform their own cost analysis based on area shop surveys. Alternatively, the costs presented in this section may be used as default values. Section 7.1 presents the basis for the capital costs, Section 7.2 presents the basis for annualized costs, and Section 7.3 discusses the emission reduction cost and cost effectiveness.

7.1 BASIS FOR CAPITAL COSTS

Table 7-1 presents the capital equipment costs for each model shop for various pieces of equipment including conventional high-pressure, air-atomized spray equipment, spray booths, HVLP spray equipment, mixing stations, solvent recovery systems, and add-on controls. It is assumed that a one-compressor system will support two spray guns. The spray booth capital costs are based on the cost for a commercial crossdraft booth ($10,000) for the small shops and for a commercial downdraft booth ($50,000) for the medium and volume shops. The volume shops were assumed to require two spray booths to handle their large production volume. The shop's existing compressor, hoses, etc., will not be usable in conjunction with the HVLP equipment, so these costs are based on installation of a complete system. The cost of mixing stations was included where HVLP was used because with increased transfer efficiency spray equipment, smaller

TABLE 7-1. CAPITAL EQUIPMENT COSTS, IN $

Equipment description	Small shop	Medium shop	Volume shop
Conventional spray equipment (two guns per compressor)[a]	3,500	7,000	10,500
Spray booth[a]	10,000	50,000	100,000
High-volume, low-pressure (HVLP) spray equipment[b]	12,000	15,000	18,000
Mixing station[c]	700	2,800	4,200
Solvent recovery system[d]	600	600	1,200
Add-on control (thermal incinerator)	--	--	150,000

[a]References 4 and 8.
[b]Reference 5.
[c]Reference 3.
[d]Reference 6.

quantities of coatings will be required. The installation of a mixing station will allow the facility to mix only the quantity of coating required. The capital costs for the medium and volume shops include the cost of two units each because both of these types of shops use two different paint chemistries and would require two dedicated units. Capital costs for solvent recovery systems are for an enclosed spray gun cleaning and recycling station and include one unit for small and medium shops and two units for the volume shop. It is assumed that the solvent will be reused to clean as many guns as practical before being discarded. The relative costs and benefits of solvent recovery through distillation are not included.

The capital cost of an add-on control (thermal incinerator) for the volume shop was estimated using the procedure in the EAB Control Cost Manual.[11] The assumptions made include: (1) control of a total gas stream of 24,000 scfm (two spray booths); (2) an incinerator temperature of 1600°F with no heat recovery and operating for 8 hours per day; and (3) a total capital investment cost of 1.5 times the capital equipment cost. Appendix C provides further details of the add-on control cost estimates.

7.2 BASIS FOR ANNUALIZED COSTS

7.2.1 Annualized Raw Material Costs

Typical coating costs, in dollars per gallon, are presented in Table 7-2. The cost of thinner or reducer used with each coating and the cost of the surface preparation solvent are assumed to average $8.10 per gallon. The cost of the low-VOC, aqueous-based cleaner described in Section 5.1.1 was not included in any of the cost analyses. However, while the cost of this material is $13.60 per gallon, the cost to prepare a given area of an automobile for refinishing would be comparable to that of solvent because it covers more area per unit volume.[10] As discussed in Section 4.0, typical small facilities are assumed to coat the equivalent of 60 ft^2 (6 partial jobs) per week, medium-sized facilities coat 230 ft^2 (13 partial jobs and 1 full job) per week, and volume shops coat 1,640 ft^2 (14 partial jobs and 15 full jobs) per week. The coating usage is presented in Section 4.0. Total coating cost, in dollars per job, is calculated as follows:

TABLE 7-2. TYPICAL COATING COSTS, $ PER GALLON

Coating	As sold[a]	Reduction ration[b]	As sprayed[c]
Primers			
Lacquer	27	1:1.5	16
Enamel	31	1:0.5	23
Waterborne	38	None	38
Urethane	53	1:0.25	42
Base coats			
Acrylic lacquer	72	1:1.5	34
Acrylic enamel	52	1:0.5	37
Polyurethane (isocyanate catalyzed)	100	None	100
Clear coats			
Lacquer	31	1:2	16
Enamel	22	None	22
Polyurethane (higher-solids)	49	None	49

[a]References 1 and 2.
[b]References 1, 2, and 3.
[c]Calculated values based on reduction ratio and an average thinner/reducer cost of $8.10/gallon.

$$Ct = (VpCp+VbCb+VcCc+JpCs)$$

where

Ct = the total coating cost in dollars per partial job

Vp = the volume of primer sprayed, in gallons per partial job

Cp = the primer cost, in dollars per gallon, as sprayed

Vb = the volume of basecoat sprayed, in gallons per partial job

Cb = the basecoat cost, in dollars per gallon, as sprayed

Vc = the volume of clearcoat sprayed, in gallons per partial job

Cc = the clearcoat cost, in dollars per gallon, as sprayed

Jp = the volume of cleanup solvent used, in gallons per partial job

Cc = the cleanup solvent cost, in dollars per gallon

Annualized coating costs are calculated as follows:

$$Ca = Ct(N)50 \text{ weeks/yr}$$

where

Ca = the annual cost, in dollars per year

Ct = the total coating cost in dollars per job

N = the number of partial jobs performed per week

7.2.2 Annualized Equipment Costs

Annualized equipment costs are based on the capital costs presented in Table 7-1 and an interest rate of 9.5 percent. The interest rate is based on the commercial loan rate (one point above the prime rate) quoted in the March 8, 1988, issue of the Wall Street Journal. Equipment life is estimated to be 10 years.[7] The annualized equipment cost is calculated by the following equation:

$$AEC = P \frac{[i\ (1+i)^n]}{(1+i)^n-1}$$

where

AEC = the annualized equipment cost in dollars per year

P = the installed cost of the equipment in dollars

n = the life of the equipment in years

i = the annual interest rate = 9.5 percent

7.2.3 Annualized Operating Costs for Add-On Controls

Annualized operating costs for the thermal incinerator were estimated using the procedures in the EAB Control Cost Manual.[11] Appendix B provides details of the operating cost estimates.

7.3 EMISSION REDUCTION COSTS AND EFFECTIVENESS

The costs and effectiveness of the various alternatives for reducing VOC emissions from the automobile refinishing industry are presented in Tables 7-3 (small shop), 7-4 (medium-sized shop), and 7-5 (volume shop).

For the small facility, it was assumed that lacquers were used exclusively in primer, basecoat, and clearcoat applications and that the facility does not own a spray booth. Spray booths are not required for the application of lacquers. Consequently, the use of alternatives that involve the replacement of topcoats (i.e., replacing lacquers with acrylic enamels, replacing lacquers and enamels with urethanes, or replacing conventional clearcoats with higher solids clears) will include an additional capital and annualized equipment cost for a spray booth. The capital cost of the spray booth is estimated at $10,000.

For the small facilities, replacing lacquers or enamels with urethanes and replacing conventional clearcoats with higher solids clearcoats each results in an additional cost of $1,200/yr. The higher cost is due almost entirely to the cost of the spray booth required to apply the alternative coatings. However, there is a cost savings of $1,200/yr for replacing lacquers with acrylic enamels because the costs of the spray booth are offset by the significantly lower material costs for acrylic enamels. For those small facilities that already own spray booths, a switch to alternative topcoats would have little effect in terms of cost. The slight cost savings of $300/yr incurred when solvent-borne primers are replaced with waterborne primers shows that the costs for application of both of these primers is comparable. The installation of a solvent recovery system generates a savings of $580/yr because the use of solvents during equipment cleanup is reduced significantly (75 to 80 percent less). Replacing conventional air-atomizing spray guns with HVLP spray equipment results in a savings of $1,300/yr. This option assumes that lacquers would continue to be used but that less paint is required due to the higher transfer efficiency (about 65 percent versus about 35 percent).

TABLE 7-3. COST OF AVAILABLE TECHNIQUES FOR REDUCING VOLATILE ORGANIC COMPOUND EMISSIONS FROM A SMALL AUTOMOBILE REFINISHING FACILITY[a]

Reduction technique	Raw material cost, $/partial job[b,c]	Capital cost, $	Annualized raw material cost, $/yr	Annualized equipment cost, $/yr[d]	Total annualized cost, $/yr	Cost (savings) from baseline, $/yr	VOC emissions, tons/yr	VOC reduction from baseline		Incremental cost, $/ton VOC
								Tons/yr	Percent	
Current practice (baseline)	22.65	3,500	6,800	560	7,400	NA[e]	1.27	NA	NA	NA
Replace lacquers with acrylic enamels	13.39	13,500	4,000	2,200	6,200	(1,200)	0.69	0.58	46	0
Replace lacquers with urethanes	21.41	13,500	6,400	2,200	8,600	1,200	0.59	0.68	54	2,100
Replace solvent-borne primers with waterborne primers	21.72	3,500	6,500	560	7,100	(300)	0.96	0.31	24	0
Replace conventional clear coats with higher solids clears	21.47	13,500	6,400	2,200	8,600	1,200	0.95	0.32	25	3,900
Install cleanup solvent recovery systems	21.17	4,100	6,400	650	7,000	(400)	1.08	0.19	15	0
Replace conventional air-atomizing spray guns with high-volume, low-pressure (HVLP) spray equipment	13.56	12,700	4,100	2,000	6,100	(1,300)	0.86	0.41	32	0

[a]Values (except raw material costs) have been rounded according to the rules of significant figures.
[b]Partial jobs are defined as being equivalent to coating a 10-ft^2 area.
[c]Based on typical basecoat, clearcoat systems.
[d]Values are based on an interest rate of 9.5 percent (one point above the March 7, 1988, prime rate).
[e]NA = not applicable.

TABLE 7-4. COST OF AVAILABLE TECHNIQUES FOR REDUCING VOLATILE ORGANIC COMPOUND EMISSIONS FROM A MEDIUM AUTOMOBILE REFINISHING FACILITY[a]

Reduction technique	Raw material cost, $/partial job[b,c]	Capital cost, $	Annualized raw material cost, $/yr	Annualized equipment cost, $/yr[d]	Total annualized cost, $/yr	Cost (savings) from baseline, $/yr	VOC emissions, tons/yr	VOC reduction from baseline: Tons/yr	VOC reduction from baseline: Percent	Incremental cost, $/ton VOC
Current practice (baseline)	18.27	57,000	21,000	9,100	30,100	NA[e]	3.63	NA	NA	
Replace lacquers with acrylic enamels	12.63	57,000	14,500	9,100	23,600	(6,500)	2.27	1.36	37	0
Replace lacquers and enamels with urethanes	20.65	57,000	23,700	9,100	32,800	2,700	1.89	1.73	48	1,600
Replace solvent-borne primers with waterborne primers	17.80	57,000	20,500	9,100	29,600	(500)	2.73	0.90	25	0
Replace conventional clear coats with higher solids clears	18.53	57,000	21,300	9,100	30,400	300	2.82	0.81	22	370
Install solvent recovery systems	17.17	57,600[f]	19,700	9,200	28,900	(1,200)	3.08	0.55	15	0
Replace conventional air-atomizing spray guns with high-volume, low-pressure (HVLP) spray equipment	10.86	67,800[g]	12,500	10,800	23,300	(6,800)	2.46	1.17	32	0

[a]Values (except raw material costs) have been rounded according to the rules of significant figures.
[b]Partial jobs are defined as being equivalent to coating a 10-ft^2 area.
[c]Based on typical basecoat, clearcoat systems.
[d]Values are based on an interest rate of 9.5 percent (one point above the March 7, 1988, prime rate).
[e]NA = not applicable.
[f]Assumes baseline capital cost plus an additional $600 for a solvent recovery system.
[g]Assumes $15,000 for HVLP spray equipment, $50,000 for a spray booth, and $2,800 for a mixing station.

TABLE 7-5. COST OF AVAILABLE TECHNIQUES FOR REDUCING VOLATILE ORGANIC COMPOUND EMISSIONS FROM A VOLUME AUTOMOBILE REFINISHING FACILITY[a]

Reduction technique	Raw material cost, $/partial job[b,c]	Capital cost, $	Annualized raw material cost, $/yr	Annualized equipment cost, $/yr[d]	Total annualized cost, $/yr	Cost (savings) from baseline, $/yr	VOC emissions, tons/yr	VOC reduction from baseline Tons/yr	VOC reduction from baseline Percent	Incremental cost, $/ton VOC
Current practice (baseline)	13.33	114,700	109,300	18,300	127,600	NA[e]	11.1	NA	NA	NA
Replace lacquers and enamels with urethanes	19.39	114,700	159,000	18,300	177,300	49,700	9.1	2.0	18	24,900
Replace solvent-borne primers with waterborne primers	13.17	114,700	108,000	18,300	126,300	(1,300)	8.1	3.0	27	0
Replace conventional clear coats with higher solids clears	15.21	114,700	124,800	18,300	143,000	15,400	10.4	0.7	7	22,000
Install solvent recovery systems	12.86	115,900	105,400	18,500	123,900	(3,700)	9.5	1.6	15	0
Replace conventional air-atomizing spray guns with high-volume, low-pressure (HVLP) spray equipment	7.62	122,200	62,400	19,500	81,900	(45,700)	6.0	5.1	46	0
Thermal incineration	13.33	264,700	449,000[f]	42,000	491,000	363,000	3.5[g]	7.6	68	46,500

[a]Values (except raw material costs) have been rounded according to the rules of significant figures. Replacing lacquers with enamels was not considered because volume shops were assumed to use enamels and urethanes only.
[b]Partial jobs are defined as being equivalent to coating a 10-ft^2 area.
[c]Based on typical basecoat, clearcoat systems.
[d]Values are based on an interest rate of 9.5 percent (one point above the March 7, 1988, prime rate).
[e]NA = not applicable.
[f]Includes annual operating cost of $340,000.
[g]Assume 98 percent control of spray booth emissions.

The costs for the typical medium-sized facility were developed under the assumption that both lacquers and enamels were used and that this facility owns a spray booth. The capital cost of two sets of conventional spray equipment and the cost of a spray booth were included in the baseline capital cost. Replacing lacquers and enamels with urethanes and replacing conventional clearcoats with higher solids clears result in annualized costs above baseline at $2,700/yr and $300/yr, respectively. This increase is due to higher costs for the urethane coatings. Replacing lacquers with acrylic enamels again shows a significantly lower annualized raw material cost that results in an annualized cost savings of $6,500/yr. Replacing solvent-borne primers with waterborne primers results in a cost savings of $500/yr; the overall difference in annualized cost between the use of the two primers is relatively small and indicates that the cost of using each primer is comparable. (Note that for both the small and the medium facilities, a slight cost savings is associated with switching to waterborne primers.) As for the small facility, the installation of a solvent recovery system and the use of HVLP spray equipment instead of conventional spray equipment at medium facilities both show savings from baseline. These savings are $1,200/yr and $6,800/yr, respectively, and result from reduced cleanup solvent consumption (approximately 75 percent reduction) and reduced coating consumption (about a 50 percent reduction in coating usage), respectively.

The costs for the typical volume facility assume that enamels and urethanes are used and that two spray booths and two mixing stations are available. Therefore, replacing lacquers with enamels was not considered as an option for this analysis. The capital cost of three sets of conventional spray equipment, two spray booths, and two mixing stations, were included in the baseline capital cost.

Replacing enamels with urethanes and replacing conventional clearcoats with higher solids clears result in significant increases in annualized costs above baseline--$49,700/yr and $15,400/yr, respectively. Replacing solvent-borne primers with waterborne primers results in a savings of $1,300/yr. The installation of solvent recovery systems and the use of HVLP spray equipment both result in significant savings from baseline. These savings are $3,700/yr and $45,700/yr, respectively, and are based upon reduced cleanup solvent consumption (approximately 75 percent) and reduced coating consumption (approximately 50 percent), respectively.

The cost of control of spray booth emissions by thermal incineration was estimated for the volume facility. The thermal incinerator was assumed to achieve a 98 percent control of the spray booth emissions (100 percent capture, 98 percent control efficiency). This control level results in an overall VOC reduction of 68 percent. However, the cost of control is high; the total annualized operating cost is $363,000 above baseline. The cost of the auxiliary fuel (natural gas) is a significant portion of the annual operating cost. The cost of controlling spray booth emissions by carbon adsorption were not estimated during this study. A recent study conducted for the State of New Jersey estimated the total annualized operating cost of controlling a single spray booth by carbon adsorption at $50,000/yr.[9] Similarly, in a recent study, the State of New York estimated the total annualized operating cost for a carbon adsorption control system at $66,000/yr.[8] (Note: These two studies estimated the cost of control by incineration at $160,000 and $43,000 per year, respectively.) The wide variation in cost estimates for add-on controls suggests that the assumptions used for specific applications should be carefully considered.

Traditionally, the incremental cost effectiveness of a control alternative is calculated by dividing the additional cost above baseline by the VOC emission reduction below baseline level. The incremental costs ($ per unit of VOC reduction) may then be used to evaluate whether the cost of achieving a unit reduction is reasonable. When the cost to achieve an emission reduction results in a negative value (i.e., a cost savings), the calculated cost-effectiveness value has no meaning because there is no additional cost associated with achieving the emission reduction. Several of the control alternatives presented in this study result in a cost savings. The incremental cost for these alternatives are reported as zero. The incremental costs of VOC reduction for the various alternatives associated with the typical small, medium, and large facilities are presented in Tables 7-3 through 7-5, respectively.

It is apparent that, in each case, the use of HVLP spray equipment instead of conventional air spray guns and the installation of a solvent recovery system result in a cost savings. Switching to acrylic enamels at those facilities that use lacquers also will result in a cost savings. The costs of switching from traditional primers to waterborne primers are comparable. Cost increases are associated with the other alternatives presented.

7.4 REFERENCES FOR SECTION 7

1. Letter from R. Hick, DuPont, Wilmington, Delaware, to R. Blaszczak, ESD/EPA. Research Triangle Park, North Carolina. February 8, 1988.

2. Attachment to letter from G. Ocampo, Sherwin-Williams, Cleveland, Ohio, to R. Blaszczak, ESD/EPA. Research Triangle Park, North Carolina. February 3, 1988.

3. Attachment to letter from D. Braun, BASF Corporation, Whitehouse, Ohio, to R. Blaszczak, ESD/EPA. Research Triangle Park, North Carolina. February 22, 1988.

4. Letter and attachments from R. Rondinelli, The DeVilbiss Company, Toledo, Ohio, to R. Blaszczak, ESD/EPA. Research Triangle Park, North Carolina. February 12, 1988.

5. Letter and attachments from M. Bunnell, Can-Am Engineered Products, Livonia, Michigan, to R. Blaszczak, ESD/EPA. Research Triangle Park, North Carolina. December 29, 1987.

6. Product Bulletin from Herkules Equipment Corporation, Walled Lake, Michigan. 1987.

7. Peters, M. A., and Timmerhaus, J. D. Plant Design and Economics for Chemical Engineers, 2nd Edition. McGraw-Hill Book Company, New York. 1968.

8. An Evaluation of Alternatives to Reduce Emissions From Automobile Refinishing in the New York Metropolitan Area. New York State Department of Environmental Conservation. August 1987.

9. Radian Corporation, Austin, Texas. Economic Energy and Environmental Impacts of Add-On VOS Controls on the Automobile Refinishing Industry in New Jersey. August 31, 1987.

10. Telecon of conversation between R. Hick, DuPont, Wilmington, Delaware, and M. Turner, Midwest Research Institute, Cary, North Carolina. June 23, 1988.

11. EAB Control Cost Manual (Third Edition), EPA 450/5-87-001A. U. S. Environmental Protection Agency, ESD/EPA, February 1987.

8.0 EXISTING REGULATIONS

8.1 INTRODUCTION

This section presents the current status of regulatory development work by State and local air pollution control agencies to limit VOC emissions from the automobile refinishing industry. The agencies presented here are those participating in the reasonably available control technology (RACT) clearinghouse project. The information presented in this section is not intended to provide an exhaustive source of information on regulatory development nationwide, but rather to give an overview of State and local regulatory positions regarding emissions from the automobile refinishing industry.

8.2 FEDERAL REGULATIONS

No regulations have been promulgated under the Clean Air Act specifically to address emissions from automobile refinishing operations.

8.3 STATE AND LOCAL REGULATIONS

Twenty State and local agencies were contacted to provide an overview of the current level of regulation being applied to the automobile refinishing industry across the United States. A list of the State and local agencies contacted is found in Section 8.4.

Of those agencies contacted, only the States of New York and Texas have adopted regulations that directly govern the automobile refinishing industry. The State of Oregon regulates automobile refinishing under a surface coating and refinishing regulation. The California Bay Area and South Coast Air Quality Management Districts (BAAQMD and SCAQMD) and the State of New Jersey are actively considering imposing regulations on the automobile refinishing industry. Currently, the remaining States contacted have either no regulations governing automobile refinishing or have general rules governing industrial sources that have emission rates above a certain threshold level. States with threshold levels that would likely impact some automobile refinishing shops include Connecticut (maximum 8 lb VOC/h, 40 lb VOC/d), Delaware (maximum 5 lb VOC/h, 40 lb VOC/d), the District of Columbia (maximum 40 lb VOC/d), Georgia (maximum 3 lb VOC/h, 15 lb VOC/d), North Carolina (maximum 40 lb VOC/d) and Rhode Island (new source maximum 10 lb VOC/h).

The following sections briefly describe the regulatory activities in New York, Texas, Oregon, New Jersey, and the California BAAQMD and SCAQMD.

8.3.1 New York

In its revised State implementation plan (SIP), the State of New York committed to investigate the feasibility of adopting a control program to reduce VOC emissions from automobile refinishing operations.[1]

8.3.2 Texas

The Texas Air Control Board adopted specific regulations for the automobile refinishing industry in 1987. Coatings used are limited to the following maximum VOC concentrations: primers, 2.1 lb VOC/gal coating; acrylic lacquers, 6.2 lb VOC/gal coating; acrylic enamels, 5.2 lb VOC/gal coating; alkyd enamels, 5.0 lb VOC/gal coating; clearcoat, 5.2 lb VOC/gal coating. In addition, recycling of cleanup solvents is required.[2]

8.3.3 Oregon

The Oregon Department of Environmental Quality regulates automobile refinishing operations under a surface coating and refinishing regulation. Shops that process less than 35 vehicles per day are considered to emit less than 40 tons VOC per year and are exempt from regulation. Nonexempt shops must install control equipment.[3] The Portland metropolitan area is an ozone nonattainment area.

8.3.4 New Jersey

The New Jersey Department of Environmental Protection, Division of Environmental Quality, included in its revised SIP a commitment to regulate the automobile refinishing industry.[4] It is currently studying this industry and expects to adopt a regulation within the next year.

8.3.5 California

8.3.5.1 Bay Area Air Quality Management District. The BAAQMD is actively considering imposing regulations on automobile refinishers. A questionnaire has been distributed to approximately 2,500 facilities under the BAAQMD jurisdiction, and the responses are being evaluated. No regulatory decision had been made at the time of this writing.[5]

8.3.5.2 South Coast Air Quality Management District.[6,7] The SCAQMD has proposed Rule 1151 that would require the use of equipment that can achieve a 65 percent transfer efficiency at a pressure of 10 psi or less (i.e., HVLP, electrostatic) and would limit the amount of VOC allowed in various automobile coatings used in both coating new vehicles and refinishing vehicles. These VOC limitations would be implemented in two phases. The first phase would take effect on January 1, 1990, and would set the following VOC limits for coatings used on passenger cars, light-duty trucks, medium-duty vehicles, and motorcycles: pretreatment and precoat operations, 6.7 lb VOC/gal coating; primer, 2.1 lb VOC/gal coating; acrylic enamel, 5.2 lb VOC/gal coating; alkyd enamel, 4.9 lb VOC/gal coating; polyurethane enamel, 5.2 lb VOC/gal coating; and lacquer, 6.2 lb/gal coating. The second phase would take effect on July 1, 1991, and would apply to 1992 and subsequent model year vehicles and complete (full body) paint jobs regardless of model year. These second-phase VOC limitations are identical to the first-phase limitations for pretreatment, precoat, and primers but set a significantly lower VOC limit of 3.5 lb VOC/gal coating for all topcoats regardless of their formulation. A public hearing to consider adoption of Proposed Rule 1151 is scheduled for July 8, 1988.

8.4 AGENCIES CONTACTED

The following State and local agencies were contacted to provide an overview of the current level of regulation being applied to the automobile refinishing industry in the U.S.:

- Alaska
- Arkansas
- California
  - Bay Area Air Quality Management District
  - South Coast Air Quality Management District
- Colorado
- Connecticut
- Delaware
- Washington, D.C.
- Florida
- Georgia
- Illinois
- Kentucky
- Maine
- Maryland
- Massachusetts
- North Carolina
- Oregon
- Pennsylvania
- Rhode Island
- South Carolina

8.5 REFERENCES FOR SECTION 8

1. New York State Department of Environmental Conservation, Albany, New York. An Evaluation of Alternatives to Reduce Emissions from Automobile Refinishing in the New York Metropolitan Area. August 1987.

2. Texas Air Control Board, Austin, Texas. Regulation V, Chapter 115 Volatile Organic Compounds, revision 115.191 (b) (8)(D), Emission Limitations. 1988.

3. Telecon of conversation between C. Ayer, Oregon Department of Environmental Quality, Portland, Oregon, and J. Obremski, Midwest Research Institute, Cary, North Carolina. December 8, 1987.

4. Radian Corporation, Austin, Texas. Economic, Energy, and Environmental Impacts of Add-On VOS Controls on the Automotive Refinishing Industry in New Jersey. August 31, 1987.

5. Telecon of conversation between J. Guthrie, California Bay Area Air Quality Management District, San Francisco, California, and M. McLaughlin, MRI, Cary, North Carolina. January 15, 1988.

6. Telecon of conversation between B. Wallerstein, California South Coast Air Quality Management District, El Monte, California, and M. Turner, Midwest Research Institute, Cary, North Carolina. June 23, 1988.

7. Correspondence from B. Wallerstein, California South Coast Air Quality Management District, El Monte, California, to R. Blaszczak, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina. May 16, 1988.

9.0 COMPLIANCE EVALUATION CONSIDERATIONS

Several available techniques for reducing VOC emissions have been presented in this document; the techniques utilize different approaches for reducing VOC, including (a) reducing the VOC content of the coatings, (b) employing equipment modifications to improve transfer efficiency and reduce coating usage, and (c) employing work practice modifications such as solvent recycling and recovery to reduce solvent emissions during cleanup operations.

Section 8 presented a summary of current regulations for VOC emissions from the auto refinishing industry. The current regulations fall into four categories: (1) regulation of coating VOC content (e.g., SCAQMD, Texas); (2) emission limits in terms of pounds per hour or tons per day (e.g., Colorado, Connecticut, Delaware); (3) performance standards (e.g., 65 percent transfer efficiency, SCAQMD); and (4) equipment/work practice standards (e.g., required recycling of cleanup solvents, Texas).

The reduction technique chosen, as well as the type of regulation written, will have an impact on how compliance can be determined. The available techniques and factors to be considered in determining compliance for the techniques are discussed in this section. Table 9-1 summarizes several compliance evaluation techniques and their applicability to the available reduction techniques. The compliance evaluation techniques that are applicable include recordkeeping, testing the VOC content of coatings, inspections, emission testing, and equipment testing.

Ultimately, recordkeeping is the most universal approach for evaluating compliance with VOC emissions regulations. This is especially true if a regulation is written in terms of emission rate (e.g., lb/day) without regard to the techniques employed for achieving the reduced emission limit. In this case, accurate records on solvent and coating usage, combined with their respective VOC contents, will provide the data necessary to calculate emission rates. The minimum recordkeeping should include the following information for properly evaluating compliance with a VOC emissions standard:

TABLE 9-1. APPLICABILITY OF COMPLIANCE EVALUATION TECHNIQUES

Alternative control techniques	Recordkeeping	Coating testing	Inspections	Emission testing	Equipment testing
Reduced VOC cleaners	x	x	x		
Improved transfer efficiency	x		x		x
Lower VOC coatings (primers and topcoats)	x	x	x		
Solvent recovery during cleanup	x		x		
Add-on control	x		x	x	

1. The volume of each type of coating used.

2. The volume of thinners and reducers used.

3. The volume of vehicle preparation/equipment cleanup solvents used.

4. The VOC content of each coating, thinner/reducer, and vehicle preparation equipment cleaning solvent used. (This information can usually be obtained from the manufacturer's material safety data sheet for the product.)

5. The number and type of jobs completed. Daily records are recommended.

Note that recordkeeping of solvent/coating usage would not be directly applicable as a compliance evaluation technique for a regulation which specifies add-on controls or a specific transfer efficiency.

Testing the solvents and coatings to determine their VOC content is a compliance evaluation technique that can be used to augment record-keeping. Testing of the materials is especially applicable to the cases where a regulation explicitly limits the VOC content of the coatings. In such cases, specific criteria (e.g., test methods and frequency of testing) for determining compliance should be established in conjunction with the regulation.

Emission testing has very limited applicability as a compliance tool due to the fugitive (unconfined) nature of the emissions from this industry. Emission testing only will be applicable in cases where an add-on control device is being used and where a control efficiency is stipulated. In such cases, emission testing of the control device inlet and outlet air streams will provide data on the control device efficiency for removing VOC's from the captured air stream.

Equipment testing is a compliance technique that can be used if specific equipment performance standards have been included in a regulation, for example, if a specific transfer efficiency is stipulated. However, this technique is limited in its field application. Field evaluation of spray equipment for the automobile refinishing industry is impractical due to the expense involved and the variability of shop conditions. A more straightforward approach is to require evaluation of specific equipment by the manufacturer or by an independent laboratory under controlled conditions to determine if the equipment meets specific performance criteria. Compliance with the regulation would be based on use of equipment that has been demonstrated to meet the performance criteria.

Inspections are a compliance tool that augment all other compliance evaluation techniques and are applicable in all cases. Inspections can be used to evaluate (a) records and recordkeeping procedures; (b) types and quantities of solvents used; (c) operating conditions and use of required special equipment (e.g., cleanup solvent recovery systems, high transfer efficiency spray systems, add-on controls); and (d) general work practices.

Inspections are a valuable part of any compliance program since they provide the opportunity for a "hands-on" evaluation of facility operation. This enables the inspector to evaluate other information (such as records of solvent/coating usage) available for determining compliance.

10.0 GLOSSARY OF COATING TERMS[1,2]

Acrylic: A thermoplastic resin made from the polymerization of acrylic derivatives, chiefly from the esters of acrylic acid and related compounds, and characterized by excellent durability and color retention.

Additives: Chemical substances added to a finish in small quantities to impart or improve desirable properties such as corrosion resistance, durability, or curing rate.

Alkyd: A thermosetting synthetic resin made from the combination of an alcohol, an acid, and an oil. While properties vary widely with ingredients, alkyd enamels are generally not as durable as acrylic enamels.

Basecoat: A color coat requiring a clear final coat.

Body filler: A thick plastic material which is used to fill small dents.

Build: The amount of paint film deposited, specifically the film thickness in mils.

Cast: Describes where a color lies in relation to others. Also known as hue.

Clearcoat: A transparent coating over the color coat (basecoat) in basecoat/clearcoat systems.

Color coat: The paint layer that contains pigment; may constitute the topcoat by itself or serve as the basecoat portion of a basecoat/clearcoat system.

Compatibility: The ability of one coating to adhere properly to another.

Compounding: The action of using an abrasive material (i.e., compounding agent) to smooth and improve the gloss of lacquer topcoats. Also referred to as polishing.

Curing: The chemical reaction that takes place in the drying of nonlacquer coatings.

Degreasing: Cleaning a substrate by removing greases, oils, and other surface contaminants. Generally performed as part of vehicle preparation.

Drying: The change from a liquid to a solid that occurs after the paint is deposited on a surface. This change includes evaporation of the solvent and any chemical curing that might occur.

Dry spray: Spraying under-reduced coatings. In metallic finishes, this traps the metallic particles near the surface, causing a highly metallic color effect.

Electrostatic spray: A method of applying a spray coating in which opposite electrical charges are applied to the substrate and the coating. The coating is attracted to the object by the electrostatic potential between them.

Emulsion: A two-phase liquid system in which small droplets of one liquid are uniformly dispersed throughout the second.

Enamel: A coating that cures by chemical cross-linking of its base resin. Enamels can be readily distinguished from lacquers because enamels are not resoluble in their original solvent.

Evaporation: The change from a liquid to a gas; the means through which solvents leave a coating film as it dries.

Face: The color of a finish when viewed perpendicular to the surface.

Filler: A heavily pigmented coating used to fill small imperfections such as scratches in a substrate.

Film: A very thin continuous sheet of material.

Flash: The initial stage of drying when some of the solvent evaporates, dulling the surface from a high gloss to a normal gloss.

Flat: Lacking in gloss.

Flocculation: Formation of clusters of pigment particles.

Flooding: The phenomenon that occurs when metallic particles settle in the paint film, causing a strong pigment color effect.

Flop: The color of a finish when viewed from an acute angle.

Flow: The leveling characteristics of a wet paint film.

Gelation: The development of insoluble polymers in paints. Normally irreversible.

Gloss: A property of paints and enamels which can be characterized by measuring the specular reflectance of the film using ASTM test D 523-67 (1972) Test for Specular Gloss. The 60-degree specular gloss test is used for all except flat paints. A measurement of 65 or more characterizes the material as "gloss." Semigloss paints are those with readings between about 30 to 65; "flats" when tested at an 85 degree angle have readings below 15.

Hardener: An additive designed to promote a faster cure of an enamel finish.

Hardness: That quality of a dry paint film that provides resistance to surface damage.

Haze: The development of a cloud in a film or a clear liquid.

Hiding: The degree to which a paint obscures the surface to which it is applied.

Hold out: The ability of a coating to prevent the topcoat from sinking in.

Inhibitor: A paint additive which slows or prevents some process (e.g., corrosion inhibitor).

Lacquer: A coating which dries primarily by solvent evaporation and, hence, is resoluble in its original solvent.

Leafing: The orientation of metal flake pigments in a paint film which results in a bright metal appearance and a concentration of the particles at the surface of the film.

Lifting: The attack by the solvent in a coating on the previously applied coating, which results in distortion or wrinkling of the new coating.

Lightness: The amount of white or black in a given color, measured by the amount of light reflected by a surface. Also called value.

Metal conditioner: An acidic metal cleaner which removes rust and corrosion from bare metal, etches the surface for improved coating adhesion, and forms a film to inhibit further corrosion.

Metallic paint: Paint containing tiny flecks of aluminum or other metal often used for painting automobiles because of the attractive appearance of the paint.

MEK: Methyl ethyl ketone. Used as a fast-evaporating solvent, primarily with lacquers.

Micas: Finishes which contain mica flakes (aluminum silicate) in addition to the pigment.

MIBK: Methyl isobutyl ketone. Used as a medium-evaporating solvent.

Mist coat: A coat of rich, slow-evaporating thinner with little color added. Also called a blend coat.

Mottling: A film defect appearing as blotches or surface imperfections. Occurs in metallics when the flakes float together.

Orange peel: A paint surface appearance, characterized by small pits, resembling the surface texture of an orange. Depending on the product, this may be desirable (appliances) or highly undesirable (automobiles).

Overall repainting: Repainting the entire vehicle.

Overspray: That solids portion of a coating sprayed from a spray applicator which fails to adhere to the part being sprayed. (Applied solids plus overspray solids equal total coating solids delivered by the spray application system.)

P/B: The pigment-to-binder ratio. The ratio of the weight of pigment to the weight of binder in a coating.

Paint remover: A chemical that breaks down an old finish by liquifying it.

Panel repair: A repair in which a complete section (e.g., hood, door) is repainted.

Particle size: The size of the pigment particles in a coating. Measured in mils (1/1,000th of an inch).

Pigment: A finely ground insoluble powder dispersed in a coating to give a characteristic color.

Plasticizer: A substance added to a polymer composition to soften and add flexibility to the product.

Polyurethane: Urethane resins are primarily produced by reacting isocyanates with carboxylic compounds. They may be sold as one- or two-component systems, and are characterized by high resistance to stains, water, and abrasion.

Primer: First layer of coating applied to a surface.

Primer-sealer: A primer that improves adhesion of the topcoats and that seals old painted surfaces.

Primer-surfacer: A coating, usually applied over a thin primer, which gives "body" to the surface, fills irregularities, and, unlike the primer, is intentionally thick enough to permit sanding without cutting through the bare metal. A topcoat is applied over a primer-surfacer.

Reduce: To lower the viscosity of a coating by adding solvent.

Reducing solvent: A solvent added to dilute a coating usually for the purpose of lowering the coating's viscosity.

Retarder: A solvent added to a coating to reduce the evaporation rate.

Rubbing compounds: Abrasives that smooth and polish the coating film. Used primarily with lacquer coatings.

Runs: Excessive vertical flow resulting in poor adhesion.

Sagging: Sprayed material that fails to adhere properly to the surface.

Sandscratch swelling: A painting problem characterized by a swelling of sandscratches in the old surface caused by solvents in the new coat.

Sealer: A material that protects the substrate from subsequent coatings or protects coatings from something in the substrate.

Semi-gloss: An intermediate gloss between high and low gloss.

Sheen: The gloss or flatness of a coating film when viewed at a low angle.

Show through: Flaws in the primer which are visible through the topcoat.

Solids: The percentage, on either a weight or volume basis, of solid (i.e., nonsolvent) material in a coating.

Spot repair: A type of refinish repair job in which a section of vehicle smaller than a full panel is repaired. This is the most frequent repair.

Spray booth: An enclosed, ventilated area used for spray painting.

Spray gun: A tool for directing atomized coating at the surface to be painted. Atomization may be by high-pressure air, by high-pressure steam, by high fluid pressure, by electrical means (electrostatic process), or by high-volume, low-pressure (HVLP) air.

Stabilizer: A chemical compound added to a coating to prevent degradation.

Strength: The opacity and/or tinting power of a pigment. This is a measure of the ability of a pigment to color.

Substrate: The surface to which a coating is applied.

Surfacer: A coating applied over a primer to provide a uniform surface thick enough to permit some sanding before application of a topcoat. Surfacer is also known as primer-surfacer.

Tack: The stickiness of a coating film. The time required for a coating to become tack-free at ambient conditions is a common measure of drying speed.

Thinner: A liquid that is used to reduce the viscosity of a coating and that will evaporate before or during the cure of a film.

Tint: To add color to another color.

Tinting strength: The ability of a pigment to change the color of a coating to which it is added.

Toluene: A fast-evaporating solvent, frequently used.

Topcoat: The last coat applied in a coating system.

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.

Undercoat: A first coat; primer, sealer, or surfacer. Should not be confused with the "undercoat" applied underneath new vehicles for rust protection.

Undertone: The color of a pigment that becomes visible when that pigment is mixed with a white pigment.

Weathering: The change in a paint film over time.

Xylene: A widely used solvent with a medium evaporation rate.

Yellowing: A yellow discoloration of a coating film.

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2. DuPont Auto Refinishing Handbook, E. I. du Pont de Nemours & Company, Inc., Wilmington, Delaware. 1987.

APPENDIX A.

METHODOLOGY FOR DETERMINING AUTOMOBILE REFINISHING SHOP SIZE CATEGORIES, THE NUMBER OF AUTOMOBILE REFINISHING JOBS PER SHOP, AND THE TYPES AND AMOUNTS OF COATINGS USED IN EACH SHOP

APPENDIX A. METHODOLOGY FOR DETERMINING AUTOMOBILE REFINISHING SHOP SIZE CATEGORIES, THE NUMBER OF AUTOMOBILE REFINISHING JOBS PER SHOP, AND THE TYPES AND AMOUNTS OF COATINGS USED IN EACH SHOP

In order to develop a categorization scheme for automobile refinishing shops, it was necessary to have a good understanding of the industry including trends in types of repairs, types of coatings used in the industry, the level of sophistication of the shops, and the number of jobs performed on a weekly basis. A source of valuable information in developing the categorization scheme was the Body Shop Business Industry Profile, 1987. This publication provided its own categorization scheme that included the following information for six categories: sales volume, average number of jobs per shop, and percent of total number of shops per category. The first four columns of Table A-1 present this information. The remainder of the table reflects some manipulation of the data based on the 83,100 automobile refinishing shops nationwide. This number was multiplied by the appropriate percentage for each category to obtain the total number of shops per category. The total number of jobs per category was then calculated by multiplying the number of shops per category by the average number of jobs per shop. Categories A and B were combined to form the small shop category; categories C, D, and E were combined to form the medium shop category; and category F formed the volume shop category. This categorization was developed because: three model shops were desired; the volume shop clearly stood out on its own having an average of 28.4 jobs per shop; categories C, D, and E lay relatively close to the average of 13.2 jobs per shop and combined to produce a weighted average of 14 jobs per shop (near the average of all shops); and categories A and B combined to produce a weighted average of six jobs per shop.

The coatings used in the automobile refinishing industry vary significantly by shop size and by the availability of a spray booth. A spray booth prevents deposition of windblown dust particles and dirt on the freshly painted surface of the slower drying enamel and urethane coatings. Lacquer coatings, due to their relatively fast drying time, do not require a spray booth to produce a satisfactory finish. The following assumptions were made in order to simplify the analysis. It was assumed that small shops do not own a spray booth and, therefore, spray lacquers exclusively. The medium shops were assumed to own a spray booth and were, therefore, able to spray enamels in addition to lacquers. The volume shops were assumed to own two spray booths and were able to spray enamels and the more sophisticated urethane coatings.

In a conversation between Mr. Raymond Conner of the National Paint and Coatings Association and Mr. Mark Turner of Midwest Research Institute, Mr. Conner provided an estimate of 36,000,000 gal of coatings sold in the United States in 1983. This estimate was made up of 13,000,000 gal of primer and 23,000,000 gal of topcoat. The following analysis shows how paint usage was allocated among the model shops developed above.

1. Find the coating usage by coating type:

   lacquers = 34 percent of coatings sold

   enamels = 54 percent of coatings sold

   urethanes = 12 percent of coatings sold

To account for any increase in coating usage, 40,000,000 gal of coating were assumed to be sold in 1987. Therefore:

lacquers = (0.34)(40,000,000) = 13,600,000

enamels = (0.54)(40,000,000) = 21,600,000

urethanes = (0.12)(40,000,000) = 4,800,000

2. Find the amount of lacquer coatings used at small shops:

A small shop will use lacquers exclusively on the six partial jobs performed.

For a partial lacquer job, 0.3518 gal coating are used.

(0.3518 gal/job)(6 jobs/week shop)(50 weeks/yr)(33,200 shops)

= 3,503,928 gal lacquer/yr

= 3,504,000 gal lacquer/yr

3. Find the number of lacquer partial jobs performed at medium shops:

Total lacquer coating usage = 13,600,000

Small shop lacquer coating usage = 3,504,000

∴ medium shop lacquer coating usage = 10,096,000 gal/yr

(10,096,000 gal/yr)(job/0.3518 gal)(yr/50 weeks)(41,300 shops)
= 13.9 jobs/week-shop
= 14 jobs/week-shop (lacquer partial jobs per week at medium shops)

∴ 1 full job and 4 partial lacquer jobs (5 total jobs) are performed (1 full job = 10 partial jobs)

4. Find the number of enamel partial jobs performed at medium shops:

From Table A-1, 14 jobs are performed at each medium shop. If 5 of the 14 are lacquer jobs (1 full and 4 partial), then 9 enamel jobs are performed at each medium shop. Typically, medium shops perform three to four full jobs per month. Therefore, since one full lacquer job is assumed to be performed at medium shops each week, all nine enamel jobs are assumed to be partial jobs.

For a partial enamel job, 0.3004 gal coating are used.

(0.3004 gal/job)(9 jobs/week-shop)(50 weeks/yr)(41,300 shops)
= 5,582,934 gal enamel/yr
= 5,583,000 gal enamel/yr

5. Find the number of urethane jobs (partial and full) performed at volume shops:

For a partial urethane job, 0.2828 gal of coating are used. Additionally, 4,800,000 gal/yr of urethane are used.

(4,800,000 gal/yr)(job/0.2828 gal)(yr/50 weeks)(8,600 shops)
= 39.5 jobs/week-shop
= 40 jobs/week-shop (urethane partial jobs per week at volume shops)

Although urethanes are gaining in popularity, most urethane paint jobs are full body paint jobs. Therefore, it was assumed that four full urethane jobs are performed per week at volume shops.

6. Find the number of enamel jobs (partial and full) performed at volume shops:

Total enamel coating usage = 21,600,000
Medium shop enamel coating usage = 5,583,000
∴ Volume shop enamel coating usage = 16,017,000 gal/yr

(16,017,000 gal/yr)(job/0.3004 gal)(yr/50 weeks)(8,600 shops)
= 124 jobs/week-shop (enamel partial jobs per week at volume shops)

Because 4 full urethane jobs are performed, we know that there are 24 enamel jobs. However, 124 partial jobs translate into 1,240 ft^2. Therefore, the breakdown is as follows:

11 full enamel jobs (1,100 ft^2)and 14 partial enamel jobs (140 ft^2) (25 total enamel jobs; and 1,240 ft^2 area coated)

Although this breakdown gives one more job than the total 28 jobs for this category, it is not expected to have a significant impact on emission estimates. The breakdown will have no impact on emissions per job, cost per job, or expected emission reductions.

APPENDIX B.

TYPICAL COATING PARAMETERS FOR VOC CALCULATIONS
(CALCULATIONS FOR TABLE 4-2)

TYPICAL COATING PARAMETERS FOR VOC CALCULATIONS
(CALCULATION FOR TABLE 4-2)

Percent coating solids, as sprayed, is calculated as follows:

$$G_{as} = \frac{G_s}{V_t/100 \text{ percent}}$$

where

G_{as} = coating solids, volume %, as sprayed
G_s = coating solids, as sold, in gallons solids/gallon of coating sold
V_t = total coating volume, as sprayed (volume of coating as sold plus volume of reducer added), gallons

The gallons of coating solids applied per week are calculated as follows:

$$G_a = \frac{(N)(T)(A)(7.4805 \text{ gal/ft}^3)}{12{,}000 \text{ mils/ft}}$$

where

G_a = gallons of coating solids applied per week
T = final coating thickness in mils
A = surface area being coated in ft^2 (assumes 10 ft^2 for partial job)
N = number of partial jobs performed per week (one total job = 10 partial jobs)

The gallons of coating solids used per week are calculated as follows:

$$G_u = \frac{Ga}{TE/100 \text{ percent}}$$

where

G_u = coating solids used in gallons of solids per week
G_a = coating solids applied in gallons of solids per week
TE = transfer efficiency in percent (baseline TE = 35 percent)

Coating volume in gallons per week as sprayed, is calculated as follows:

$$V_{as} = \frac{G_u}{G_{as}/100\ \text{percent}}$$

where

V_{as} = volume of the coating sprayed in gallons per week

The VOC emissions calculations from Table 4-4 for coatings as pounds per day are calculated as follows:

$$VOC_t = \frac{V_{as}\ (C_{VOC})}{5\ \text{days/week}}$$

where

VOC_t = total daily VOC emissions for a particular coating type (i.e., primer, basecoat, or clearcoat) in pounds per day

C_{VOC} = VOC content of the coating type (i.e., primer, basecoat, or clearcoat) as sprayed in pounds per gallon

The volume of solvent used for cleanup and surface preparation is calculated as follows:

$$J = \frac{VOC_s}{6.95\ \text{lb/gal}}$$

where

J = the volume of solvent in gallons per day

VOC_s = the solvent VOC emissions from cleanup and surface preparation in pounds per day

The VOC emissions from the use of cleanup and surface preparation solvents are estimated as follows:

$$VOC_s = (VOC_{tp}+VOC_{tb}+VOC_{tc}) \times \frac{30}{70}$$

where

VOC_{tp} = total daily VOC emissions from application of primer in pounds per day

VOC_{tb} = total daily VOC emissions from application of basecoat in pounds per day

VOC_{tc} = total daily VOC emissions from application of clearcoat in pounds per day

The 30/70 ratio is based on an estimate that emissions from the use of cleanup solvents account for 30 percent of the total VOC emissions.[1] Therefore, if:

VOC_D = total daily VOC emissions from the facility in pounds per day

VOC_s = total daily VOC emissions from cleanup and preparation solvents in pounds per day = 0.3 VOC_D

VOC_c = total daily VOC emissions from coatings as sprayed in pounds per day = 0.7 VOC_D

$VOC_c = VOC_{tp} + VOC_{tb} + VOC_{tc}$; and

$VOC_D = VOC_c + VOC_s$

then:

$$VOC_s = VOC_c\left(\frac{30}{70}\right)$$

The total emissions, in tons/yr, for each option are calculated as follows:

$$VOC_y = \frac{VOC_{wa}\ (83{,}100)(250\text{d/yr})}{2{,}000\ \text{lb/ton}}$$

where

VOC_y = the total VOC emissions in tons per year

VOC_{wa} = the weighted average VOC emissions per shop in pounds per day

83,100 = the total number of automobile refinishing shops nationwide.

[Note: The weighted average VOC emissions per shop was determined as follows: VOC_{tp}, VOC_{tb}, VOC_{tc}, and VOC_s were summed to obtain VOC_D for each shop category. Then, VOC_D for each category was multiplied by the number of shops in the appropriate category to obtain the total emissions in each category. The emissions total from each category was then summed to obtain the total daily emissions for all shops. This total daily emissions was then divided by the total number of shops to obtain the weighted average VOC emissions per shop.]

Reference for Appendix B

1. Letter from R. Hick, DuPont, Wilmington, Delaware, to R. Blaszczak, ESD/EPA. Research Triangle Park, North Carolina. February 8, 1988.

APPENDIX C.

CALCULATION OF THERMAL INCINERATION ADD-ON CONTROL COSTS

APPENDIX C. CALCULATION OF THERMAL INCINERATION ADD-ON CONTROL COSTS

Table C-1 summarizes the costs for the thermal incinerator. The costs were calculated according to the procedures in the U. S. Environmental Protection Agency, EAB Control Cost Manual (3rd Edition), EPA 450/5-87-001A, February 1987. The following assumptions were used:

1. For volume facility, two spray booths must be controlled;
2. Each downdraft spray booth has a volumetric flow rate of 12,000 scfm, based upon the following spray booth dimensions: 14 ft wide, 25 ft long, and 9 ft high. Average air velocity is 35 ft/min.

$$14\ \text{ft} \times 25\ \text{ft} \times 35\ \text{ft/min} = 12{,}250\ \text{ft}^3\text{/min}$$

3. The incinerator operates at 1600°F, has no heat recovery, and operates on natural gas;
4. The spray booth off-gas has a VOC concentration of less than 100 ppm, is at 70°F, and has no heating value; and
5. The total capital investment costs, including installation costs, were estimated as 1.5 times the purchased equipment costs.

<u>Calculations</u>

1. Calculate auxiliary fuel requirement:

Fuel used, ft^3/ft^3 waste gas:

$$\frac{Q_3}{Q_2} = \frac{1.1\ C_{p5}\ \Delta T_5 - C_{p2}\Delta T_2 - h_i}{h_3 - 1.1 C_{p5}\Delta T_5}$$

where:

Q_3 = auxiliary fuel flow rate, scfm

Q_2 = waste gas flow rate, scfm

C_{p_5} = mean heat capacity of flue gas for temperature interval ΔT_5, reference temperature (70°F) to combustion temperature

ΔT_5 = Temperature differential from reference (70°F) to outlet of combustion chamber

C_{p_2} = mean heat capacity of waste gas for temperature interval ΔT_2, reference temperature (70°F) to combustion chamber inlet

ΔT_2 = temperature differential from reference (70°F) to combustion chamber inlet

TABLE C-1. THERMAL INCINERATION COSTS

	Cost
Capital costs	
Purchased equipment cost	100,000
Total capital investment (1.5xpurchased equipment)	150,000
Operating costs	
Direct costs:	
Auxiliary fuel	324,000
Electricity	2,000
Operating labor	1,500
Maintenance labor	1,500
Materials	1,500
Supervisory labor	250
Indirect costs:	
Overhead (60 percent labor and materials)	2,850
G&A (4 percent total capital investment)	6,000
	339,600

h_1 = waste gas heat content, Btu/scf

h_3 = lower heating value of fuel, Btu/scf

$$\frac{Q_3}{24{,}000} = \frac{(1.1)(0.0194)-0-0}{900-(1.1)(0.0194)}$$

Q_3 = 903 scfm

2. Determine cost of incinerator:

Total gas flow through incinerator is equivalent to waste gas (24,000 scfm) plus auxiliary fuel (900 scfm) = 25,000 scfm.

From Figure 3-3, EAB Control Cost Manual, the purchase equipment cost is $100,000.

3. Calculate total capital investment:

The EAB Control Cost Manual indicates that installation costs can vary from 25 percent to 300 percent of the purchased equipment cost. A value of 50 percent was chosen. The capital investment cost is 1.5 times the purchased equipment cost.

4. Calculate auxiliary fuel cost:

Natural gas cost = 900 ft^3/minx60 min/hx2,000 h/yrx$3.00/1,000 ft^3

= $324,000

5. Calculate electrical costs:

$$C_E = \frac{(0.746)(Q)(\Delta P)(S)(O)P}{6{,}356\ n}$$

where

C_E = cost of electricity

Q = gas flow rate, acfm

ΔP = pressure drop through system, in H_2O

S = specific gravity of gas

O = operating factor, h/yr

P = price of electricity

n = fan and motor efficiency

$$C_E = \frac{(0.746)(24{,}000)(4)(1)(2{,}000)(0.05)}{6{,}356\ (0.60)} = \$1{,}877$$

6. Estimate operating labor:

$$0.5\ h/d \times 250\ d \times 12/\$/h = \$1,500$$

7. Estimate maintenance labor:

Same as operating labor

8. Estimate maintenance materials:

Same as maintenance labor

9. Estimate supervisory labor:

Fifteen percent of operating labor = (0.15)(1,500) = $225

10. Estimate overhead costs:

Estimate is 60 percent of labor and materials

Overhead = (0.60)(1,500+1,500+1,500+225) = $2,835

11. Estimate taxes, insurance, etc. (G&A):

Estimate used is 4 percent of total capital investment

G&A = (0.04)(150,000) = $6,000

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(Please read Instructions on the reverse before completing)

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16. ABSTRACT

Automobile refinishing (repainting) is a source of volatile organic compound (VOC) emissions. This study was conducted to evaluate available techniques that can be used to reduce VOC emissions from this source. This document provides information on the steps involved in the refinishing process which result in emissions, available emission reduction techniques, VOC emission levels, VOC emission reductions, and costs associated with the reduction techniques. Techniques investigated include: (1) reduced-VOC cleaners, (2) replacement of lacquers with enamels, (3) replacement of enamels with polyurethanes, (4) replacement of solvent borne primers with waterborne primers, (5) replacement of conventional clearcoats with higher-solids clearcoats, (6) installation of cleanup solvent recovery systems, (7) replacement of conventional spray guns with higher transfer efficiency equipment, and (8) add-on controls

The primary conclusions from the study are: (1) the use of available techniques could result in VOC emission reductions ranging from 3 percent to 50 percent of the current estimated baseline emissions from typical refinishing shops; and (2) the annualized costs for many of the available techniques are less than the cost of current practices.

17. KEY WORDS AND DOCUMENT ANALYSIS

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Automobile Refinishing Volatile Organic Compound Emissions VOC's		

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