NEW CHEMICALS ENVIRONMENTAL TECHNOLOGY INITIATIVE

GENERIC SCENERIO FOR AUTOMOBILE SPRAY COATING

DRAFT REPORT

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Introduction

Paint is comprised of binders, pigments, solvents, and various additives. Most automobile paint components for which PMNs have been submitted in the past are nonvolatile; a volatile PMN used for automobile paint may in fact be a monomer which would be consumed during the paint formulation step. Therefore, this generic scenario is most applicable in evaluating nonvolatile PMNs that are part of the paint solids; caution should be used when using this generic scenario in evaluating other paint components.

During automobile refinishing and in many (but not all) automobile manufacturing operations, the paint is sprayed onto the automobile. This generic scenario is applicable only for spray painting operations. Further details on the painting processes are discussed in detail below.

This generic scenario will not address the manufacture of the paint components or the formulation of the components into a paint. Use submitter-supplied data and CEB's *Manual for the Preparation of Engineering Assessments* for these scenarios.

Key Assumptions Used in this Scenario

Submitter-supplied information should be used to estimate the following values. The submitter should be contacted for this or other information as needed.

- Use volume for automobile refinishing and new automobile manufacture: the submitter may or may not intend to market the PMN to both the original equipment and the refinishing industry. If the submitter is ambiguous about the use (e.g., submitter states use as "automotive paint"), assume half of this volume is used in new automobile manufacture and half is used in refinishing.

- **Mass to volume or mass fraction of PMN in liquid paint.** In most cases, the submitter will only provide the percentage of PMN in the finished paint. It is typically unknown if this percentage is calculated on a mass or volume basis. The generic scenario requires mass to volume fraction and the mass fraction of the PMN in the paint; assume for default purposes that both of these values equal the concentration given by the submitter.

- **Solids fraction of paint.** This value is used to calculate the fraction of PMN in solids, as follows: Mass fraction of PMN in solids = mass fraction of PMN in paint / solids fraction of paint. A default value for solids fraction is 0.25. "High solids paint" for automobiles can have a solids content of up to 45-50 volume percent for top coats (Kirk-Othmer, 1993), however, solids content varies widely.

Process Description

In automobile original equipment manufacturing (OEM), several layers of paint are applied to the car alternated with heating to cure the paint or drive off moisture. A generic process flow diagram for this sequence, showing the typical paint thickness applied at each step, is presented in Figure 2. In this diagram, oven temperatures are as high as 450°F to cure the paint, although lower temperatures are used to simply remove water (Pfanstiehl, 1992). Individual sites may add additional painting steps to achieve protection in certain areas, and may modify the drying/curing steps.

Automobile OEM painting is conducted by robots and overspray is collected in waterwash booths of downdraft or crossdraft design. Water is used almost exclusively to collect overspray in new automobile manufacture (USEPA, 1994b). During assembly line activities following painting, the paint may be scratched or damaged and necessitate "touch-up" repair. In these cases, the paint is applied manually and cured at temperatures up to 180°F, which is lower than the curing temperature used upstream to avoid damaging the automobile's other components. A generic process flow diagram of an automotive assembly plant paint booth is presented in Figure 3.

In automobile refinishing, almost all spray coating operations are expected to involve a worker spraying the vehicle, typically in a ventilated spray booth with dry filters to collect overspray. The car can dry at atmospheric conditions, or at elevated temperatures through the use of heated paint booth air or portable heat sources (USEPA, 1994a). The curing temperature is likely to be comparable to that used in OEM "touch-up" activities (i.e., up to 180°F).

Control Technologies

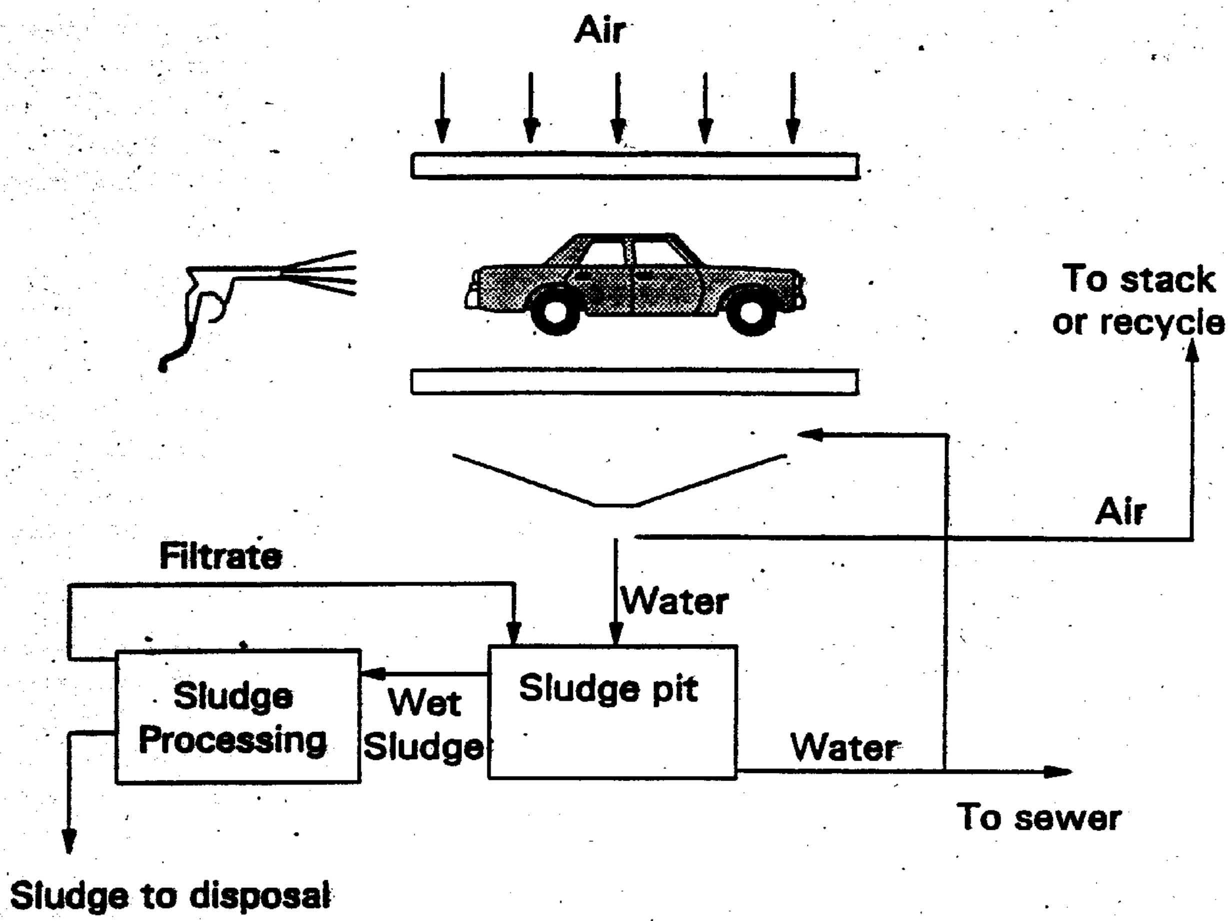
<u>Gun Type</u>

- Conventional high pressure spray gun: In this method, air is pressurized and forced through a nozzle; the paint is atomized in the air at the nozzle throat. Air pressure is typically 30 to 90 psig (USEPA, 1994a). Conventional spray guns are used in automobile refinishing.

- High Volume Low Pressure (HVLP) spray gun: large quantities of low pressure air (typically less than 10 psig) is used to atomize the paint (USEPA, 1994a). HVLP spray guns are interchangeably used with conventional guns in automobile refinishing; 64 percent of auto shops surveyed reported owning this type of gun (BSB, 1995).

Figure 2

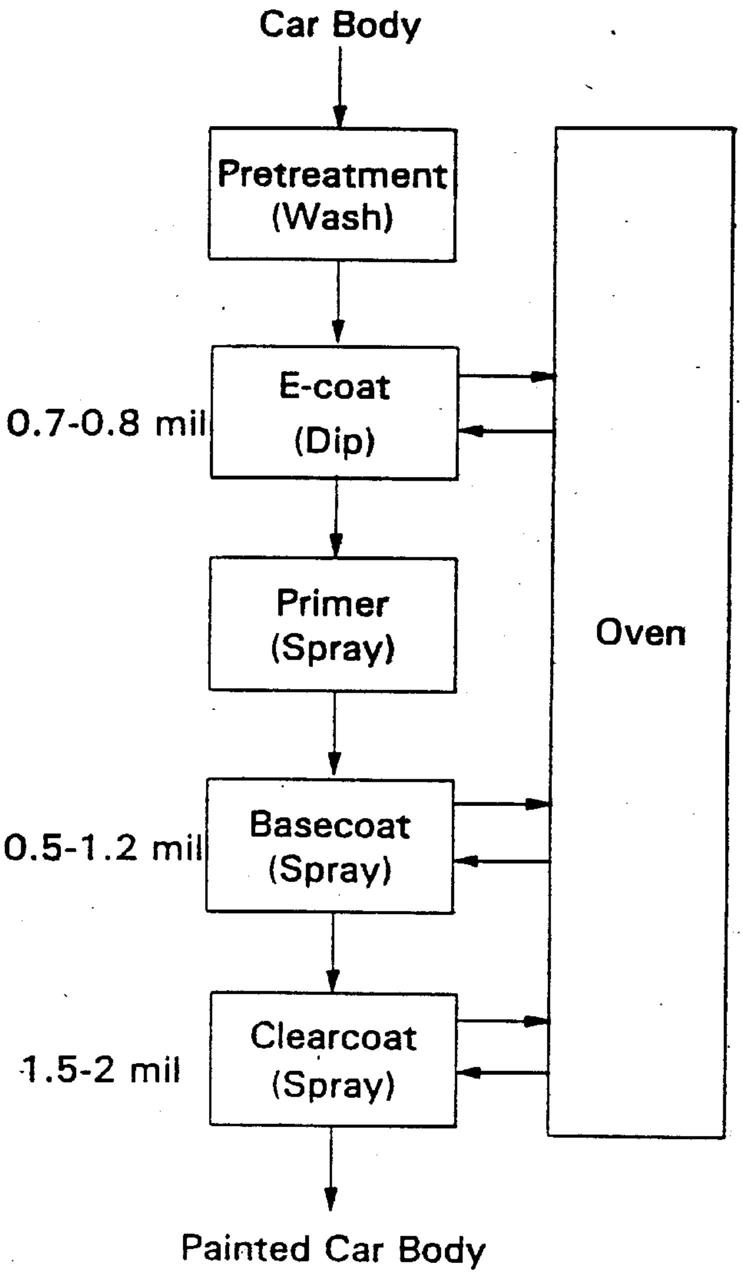
PROCESS FLOW DIAGRAM FOR AUTOMOTIVE ASSEMBLY PAINTING



Note: Chemicals such as detactifiers and flocculants are added to the pit to aid in paint solids removal.

Figure 3

GENERIC DIAGRAM OF AUTOMOTIVE ASSEMBLY PLANT SPRAY BOOTH



Reference: Pfanstiehl, 1992

- Electrostatic application: Various electrostatic methods are used to increase transfer efficiency. In electrostatic spraying, the paint is charged and the substrate is grounded (Kirk-Othmer, 1993). This type of technique is not used in automobile refinishing because of increased safety concerns and because it is ill-suited for the high paint turnover rates common in this industry (USEPA, 1994a). This method is used for automated painting in new automobile manufacturing (Donovan, 1986).

Spray Booth Technology

Spraying is often conducted in a spray booth to protect workers from paint spray toxics, to provide a mechanism for forced air drying, and to remove volatiles and paint solids from the workplace. In automobile refinishing, spraybooths vary in design from spray "areas" to well designed and operated downdraft booths. Between 50 and 80 percent of automobile refinishing shops have some engineering controls. As expected, the larger shops are more likely to have spray booths (BSB, 1995). In new automobile manufacture, all painting is expected to be performed in spray booths.

- Crossdraft booths move overspray along the length of the car. Approximately 50 percent of automobile refinishing shops have crossdraft booths (BSB, 1995). Of 155 spray booths in 15 OEM automobile plants surveyed, 7 percent of the spray booths are of crossdraft design (USEPA, 1994b).

- Downdraft booths move overspray from the ceiling to the floor, out of the breathing zone. Approximately 30 percent of automobile refinishing shops have downdraft booths (BSB, 1995). Downdraft booths represent the better design, however, and more shops are buying the downdraft booths than the crossdraft booths (BSB, 1995). Of 155 spray booths in 15 OEM automobile plants surveyed, 92 percent of the spray booths are of downdraft design (USEPA, 1994b).

Number of Days/year Operation

For new automobile manufacturing: Assume 250. Basis: one automobile assembly plant operates one of its painting lines 2 shifts per day, 5 days per week (Donovan, 1986).

For automobile refinishing: Assume 170. Basis: Assume 250 days per year of shop operation, with the paint containing the PMN used 67% of the time. Full-time usage is not assumed because a typical shop uses 1.5 brands of paint (BSB, 1995) and it is further assumed that a PMN present in one brand would not be available to the brand's competitors.

Number of Sites

There are 61 sites manufacturing new automobiles in the U.S., as follows: General Motors (28), Ford (15), Chrysler (7), Nissan (2), Honda (2), Subaru-Isuzu (2), Toyota (1), Saturn (1), Other (3) (USEPA, 1994b). To estimate the number of sites using the PMN-containing paint, use the following calculation: Nsites = UV/(166,000*8*C)

UV = PMN annual use volume, kg/year
Number of cars painted per site: 166,000 (range: 81,563 to 262,000 for 14 plants, with one outlier plant producing 1,071,000 not included) (USEPA, 1994b).
Quantity of paint (as purchased) used per car: 8 L (range: 5 L for primer to 10 L for topcoat) (Rodriguez, 1987).
C = PMN concentration in paint, weight/volume

There are thousands of sites conducting automobile refinishing in the U.S. Of course, not all these sites are expected to use the PMN-containing paint. To better estimate the number of automobile refinishing sites based on production volume, use the following calculation:

Nsites = UV/(C x K)
UV= PMN annual use volume, kg/yr
C= PMN concentration in paint, weight/volume
K= Liters of paint used per site, per year = 400 (default), 70 to 2000 (range), as calculated below. However, one shop reports using 500 liters of various paint products per month, including thinners, which is much greater than the default value (CCC, 1996). This data was not used below, but is only presented here for comparison. K= Monthly paint allowance x 12 months x % paint with PMN/paint cost. Monthly paint allowance, per shop: $1762 (default), 12 months/year. Shops spend from $644 (average of small shops) to $5,094 (average of large shops) on paint per month (BSB, 1995). The average of all shops is $1762/month.

Percentage of paint (dollar basis) that contains the PMN, used by a single shop: 67%. A typical shop uses 1.5 brands of paint (BSB, 1995). Assume no more than one brand of paint would contain the PMN, due to competitive barriers.

Paint cost: $35/L (default). The price of base coats ranges from $13 to $35/pint ($27 to $74/L), the price of clearcoats ranges from $100 to $175/gallon ($26 to $46/L), and the price of primers ranges from $75 to $150/gallon ($20 to $40/L) (Brown, 1996).

Occupational Exposure

Worker Activities

Worker activities in or near automobile OEM painting operations include robotics operation, paint mixing, paint booth cleaning, inspection, and manual "touch-up" painting. It is expected that manual touch-up painting operations would be conducted in spray booths, allowing minimal or no overspray to other sections of the plant.

Worker activities at automobile refinishing shops include wet sanding, car washing, stripping (paint removal), machine sanding, blowing, buffing, polishing, paint spraying, paint and primer mixing, and inspection (Pfanstiehl, 1992).

Days/year Potential Exposure

For default values, use 250 days per year for automobile OEM and 170 days per year for automobile refinishing.

Number of Workers/Site

For new automobile manufacturing: Default: 17/site (includes only those workers directly involved in manual "touch-up" spray painting).

Calculation: 166,000 x 0.2 / (250 * 8) Basis:
Number of cars assembled per site per year: 166,000 (range: 81,563 to 262,000 for 14 plants, with one outlier plant producing 1,071,000 not included) (USEPA, 1994b).
Number of cars requiring manual touchup: 2% to 20%. USEPA (1994b) states this as 2%, while a cost model study selected rates of 10 to 30 percent (Brooke, 1994).
Number of days/year manual painting is conducted: 250 (assumed)
Number of cars painted by one worker per day: 8 (assumed)
Additional information not used in calculations: Total number of workers in plant painting operations: 14 to 986, average 394, for 14 plants (USEPA, 1994b).

For automobile refinishing: Default: 3/site. Basis: a typical shop employs 4 employees in production (BSB, 1995); only some of these employees would paint (i.e. <4). The number of production employees ranges from 1.9 to 10.1, on average depending on shop size, and the overall average for all shops is 3.88.

Inhalation Exposure

The PMN will most frequently be a nonvolatile solid such as an additive, a pigment, or a resin. The inhalation exposure scenarios presented in this section of the report are based on exposure to the nonvolatile fraction of paint when applied by manual spraying. Worker exposure scenarios to polyisocyanate during the application of isocyanate based paint systems is presented in Appendix 1. Appendix 1 should be used if the PMN is a polyisocyanate, while the following calculation should be used for all other paint components:

"What if" Potential Inhalation Dose Rate (mg/d) = mist concentration (mg/m^3) * duration (hr) * 1.25 m^3/hr breathing rate * PMN fraction of solids

Mist concentration is selected from one of the four scenarios described below. The paragraph immediately prior to the first scenario provides guidance on selecting a scenario.

Duration = Default is 8 hours for either automobile OEM or refinishing. This duration is reasonable for OEM but is conservative for refinishing. A duration of 1-2 hours can be used as typical duration for automobile refinishing because other activities such as car preparation, paint mixing, and equipment cleaning take up most of the day (Maitre, 1996). However, in some shops up to seven cars are painted per day and exposure duration is extended (NIOSH, 1981).

PMN concentration of solids = see calculation in "Key Assumptions" Section of this generic scenario

A summary of available paint mist worker exposure data extracted from various documents is presented in Table 5. The samples were analyzed according to NIOSH Method 500 (Total Particulates). The worker exposure data is sorted by type of engineering control (e.g. crossdraft of downdraft paint spray booth) and type of spray gun (e.g. HVLP or conventional). Note that in some instances exposure results were presented as 8-hr time-weighted averages; preparation and other non spraying activities were included. In other instances, results were normalized to reflect exposures only while spraying paint. Consequently, a direct comparison of the data may be misleading.

The data in Table 5 show a significant lowering of worker exposure to paint mist in downdraft paint booths compared with crossdraft booths. No significant difference in worker exposure is apparent between the exposure data for conventional spray gun and the HVLP gun in the crossdraft booth data. Slight differences between the two spray gun types were apparent in the downdraft booth data.

The following scenarios present exposure estimates under different combinations of engineering control (i.e., crossdraft or downdraft spray booth) and spray gun (i.e., conventional or HVLP). The paint mist concentrations presented represent approximate midpoints in available data.

In automobile OEM, 93 percent of the spray booths in 15 surveyed plants were downdraft (USEPA, 1994b); consequently, data from "Scenario 3" should be used as default (no information on gun use is available, however it is likely that Scenario 4 can describe typical operations in OEM "touch-up" booths). In automobile refinishing, data from "Scenario 1" should be used as default. However, statistics on the likely occurrence of each scenario is as follows: the percentage of shops using crossdraft booths is 30 percent, the percentage of shops using downdraft booths is 50 percent, and the percentage of shops using HVLP guns is 64 percent (BSB, 1995). Therefore, Scenarios 3 and 4 are more likely than Scenarios 1 and 2, and Scenario 2 is more likely than Scenario 1.

Scenario 1. *Crossdraft booth and conventional spray gun* (booth with paint spray filters or waterfall, and air atomization paint-spray gun)

Paint mist concentration:	15 mg/m^3 (midpoint sampling period TWA) This represents an exposure estimate based on the midpoint of available data for this combination of control and spray gun. This estimate is considered to be a spray painting period TWA, applicable for the duration of spray painting. (NIOSH, 1981, and Heitbrink et al, 1995)

Scenario 2. *Crossdraft booth and HVLP spray gun.* No significant difference between conventional gun and HVLP gun in the crossdraft booth based on review of available exposure information.

Paint mist concentration:	15 mg/m^3 (midpoint sampling period TWA) (Rudzinski et al, 1995)

Scenario 3. *Downdraft booth and conventional spray gun*

Paint mist concentration:	2.3 mg/m^3 (midpoint sampling period TWA) (Heitbrink, 1995)

Scenario 4. *Downdraft booth and HVLP spray gun*

Paint mist concentration:	1.9 mg/m^3 (midpoint sampling period TWA) (Heitbrink, 1995)

Dermal Exposure

To estimate dermal exposure to the PMN during paint spraying, the dermal contact model presented in the CEB manual should be used with the following assumptions for routine 2-hand immersion (CEB, 1991). These assumptions apply to both automobile OEM and refinishing.

$$D = SQC$$

Where: D = Potential Dermal Dose Rate (mg/day)
S = Surface area of contact (cm^2) = 1300
Q = Quantity typically remaining on the skin (mg/cm^2) = 5-14
C = % PMN in formulation

Environmental Releases

In automotive OEM, the potential release points of a nonvolatile PMN are as follows: (1) water releases from blowdown (a purge stream of the circulating paint booth water, of continuous to intermittent frequency), (2) water releases from sludge processing (sludge may be removed continuously, or as infrequently as once/year which would correspond to the removal of the entire pit contents). The corresponding excess water from sludge processing is commonly returned to the pit for recirculation, but may potentially be released particularly if sludge is removed only once a year. A facility would either remove (skim) sludge continuously for processing, or let the sludge collect for a year and remove the sludge from the pit, but would not perform both operations (Patterson, 1996). (3) The generated sludge, which may be collected in containers for disposal or dumped to the facility's onsite wastewater treatment plant (Patterson, 1996), (4) stack air releases, with the PMN entrained as an aerosol.

In automotive refinishing, the potential release points of a nonvolatile PMN are as follows: (1) air filter waste from overspray, (2) PMN-containing mist entrained in the stack air.

<u>Water</u>

For new automobile manufacturing, releases may be continuous or as infrequently as once per year:

Release, kg/site/day= UV*0.35*0.96*0.10/(Nsites*Ndays) over Ndays per year from: continuous purge of paint booth wet scrubber to: onsite WWTP

OR

Release, kg/site/day= UV*0.35*0.10*0.96/Nsites over 1 day per year from: annual sludge pit cleaning

UV= Annual use quantity of PMN, kg/year
Nsites= number of use sites
Ndays=number of days painting
Assumptions: (1) A transfer efficiency of 65 percent (1-0.65=0.35)
(2) A solids removal efficiency of 90% (1-0.90=0.10), based on a pilot plant operation of paint solids removal in a water booth from a foundry (Sokolovic, 1996). This assumption is uncertain due to the absence of industry specific data and may be conservative.
(3) Releases to air of 4% (see below) (1-0.04=0.96)

For automobile refinishing: water releases are not expected. Based on hygiene surveys in literature and information from a spray booth manufacturer (Garcia, 1996), water controls in spray booths are seldom, if ever, used. Water releases for other operations (e.g., equipment cleaning) are not expected and discussed below under incineration and landfill releases.

<u>Air</u>

For new automobile manufacturing:

Release, kg/site/day= UV*0.35*0.04/(Nsites*Ndays) over Ndays per year
from: point source release from scrubber
UV= Annual use quantity of PMN, kg/year
Nsites= number of use sites
Ndays=number of days painting
0.35 is based on a transfer efficiency of 65 percent
0.04 is based on a midpoint paint booth removal efficiency of 96 percent (range 92.9-99.8) (Chan, 1986)

For automobile refinishing:

Release, kg/site/day= UV*0.75*0.10/(Nsites*Ndays)
from: fugitive release from spraying
UV= Annual use quantity of PMN, kg/year
Nsites= number of use sites
Ndays=number of days painting
0.75 is based on a midpoint transfer efficiency of 25 percent
0.10 is based on a midpoint paint booth removal efficiency of 90 percent for dry filters (range 87.0-99.8) (Rodriguez, 1987)

<u>Incineration or landfill</u> (assume the quantity calculated below goes to incineration OR landfill)

For new automobile manufacturing, releases will result from overspray, equipment cleanup, and container residue. Default: Release, kg/yr = 0.35 x UV (UV=use volume)

- Paint overspray will be collected as sludge in the water-controlled spray booth or will settle on the floor, robotic arms, equipment, etc. Paint sludge is assumed to be landfilled or incinerated based on site-specific waste management practices. Paint-covered surfaces in the booth are routinely cleaned by scraping, solvent washing, peelable coatings or protective covers, or high pressure water blasting (USEPA, 1994b). It is assumed that entrained solids in the water from water blasting would be collected in the sludge, while remaining wastes would be collected and disposed of by incineration or landfill. The estimated quantity from overspray is 35 percent of the use volume (based on Heitbrink, 1996, for HVLP guns). As discussed above, some of this overspray partitions to water and air, so the quantity of overspray landfilled/incinerated is 0.35*(1-0.1-0.04)=0.30.

- Equipment cleanup will be required when changing colors, etc. No information on cleanup wastes were found but practices are assumed to mirror those for cleaning spray booths. The estimated quantity from equipment cleanup is 1 percent of the use volume.

- Paint residue from drums or tanks are assumed to be landfilled or incinerated. The estimated quantity from container residue is 4 percent of the use volume (if the type of container is unknown), or 0.2 percent of the use volume if it is known that only very large containers such as tank cars are used.

For automobile refinishing, releases will result from overspray, equipment cleanup, and container residue. Default: Release, kg/yr = 0.8 x UV (UV=use volume).

.75 + .01 + .04

- Paint overspray will be collected in filters exit to the ambient air (as discussed in air releases), or will settle on the floor, etc. The filters are assumed to be landfilled or incinerated based on site-specific waste management practices. Assume that surfaces in the spray booth are cleaned by using peelable coatings or by solvent washing. The estimated quantity from overspray is 75 percent of the use volume (based on Heitbrink, 1996, for conventional guns).

- Equipment cleanup will be required after every paint application. Common methods of cleanup include rinsing with solvent, using a solvent wash station, and wiping clean (EPA, 1994a). It is assumed that such wastes would be incinerated or landfilled. The estimated quantity from equipment cleanup is 1 percent of the use volume.

- Paint residue from cans or drums are assumed to be landfilled or incinerated. The estimated quantity from container residue is 4 percent of the use volume (if the type of container is unknown), or 0.6 percent of the use volume if i is known that only small containers such as 1 gallon buckets are used.

C[illegible]

Table 5

SPRAY PAINT EXPOSURE SUMMARIES

Industry	Eng controls/ gun type	Activity Description	Exposure (mg/m^3)	Reference
Auto Refinishing	crossdraft/ conventional	7 cars per shift 40min/car various paints	4.0-16.1 (P)(#=7;geom mean=8.7) (8-hr twa=5.0) (65 mg/m^3 voc)	NIOSH Eval. of Eng. Control-Spray Painting, 1981
Kessler AFB	crossdraft/HVLP	Spray painting trucks	4-8 (P)(#=2)(sample period twa) 7-15.8 (A)(#=4)(sample period twa)	Rudzinski et. al., 1995
Langley AFB	crossdraft/HVLP	Spray painting aircraft ground equipment	28-34 (P)(#=2) 15-46.9(A)(#=4)	Rudzinski et. al., 1995
Auto Refinishing	downdraft/ conventional	Spray painting automobiles	0.26-18(P)(geom mean=2.3; #=7) (sample period twa)	Heitbrink et al, 1993
Auto Refinishing	downdraft/HVLP	Spray painting automobiles	1.9 (geom mean)(P)(#=23;GSD=3.0) (sample period twa)	Heitbrink et al, 1995
Auto Refinishing	crossdraft/ conventional	Spray painting automobiles	23 (geom mean)(P)(#=5;GSD=1.8) (sample period twa)	Heitbrink et al, 1995

P = personal sample
A = area sample
# = No. Samples collected

ATTACHMENT A

INHALATION EXPOSURE TO POLYISOCYANATE PMNs IN PAINT

A summary of available isocyanate exposure data and other related measured isocyanate concentrations extracted from various documents is presented in Table A-1. Both polyisocyanate and monomer isocyanate data is presented. The data is sorted by type of engineering control (e.g. crossdraft of downdraft paint spray booth) and type of spray gun (e.g. HVLP or conventional).

Note that in some instances results were presented as 8-hr time-weighted averages; preparation and other non spraying activities were included. In other instances, results were normalized to reflect exposures only while spraying paint. The samples were collected and analyzed according to various methods too numerous to describe. Consequently, a direct comparison of the data may be misleading.

The data in Table A-1 show a lowering of worker exposure to isocyanate in downdraft paint booths compared with crossdraft booths. The data also show a lowering of isocyanate exposure when using HVLP spray guns as compared to conventional spray guns.

The following scenarios present exposure estimates under different combinations of engineering control and spray gun. The concentrations presented represent approximate midpoints in available data. Guidance in selecting a scenario is presented in the main body of this report.

"What if" Potential Dose Rate (mg/d)= polyisocyanate concentration (mg/m^3) * duration (hr) * 1.25 m^3/hr breathing rate. Note that PMN concentration is not a variable. This is because the polyisocyanate concentration in the paint is unknown for the sampling data in Appendix A-1. The default duration is 8 hours, although shorter durations can be used as explained in the main body of this report.

Scenario 1. *Crossdraft booth and conventional spray gun*--(Crossdraft hood with paint spray filters or waterfall and air atomization paint-spray gun)

Measured concentration range during spraying operations <0.05-18.4 mg/m^3 (Janko, 1992 and Lesage, 1992)

Scenario 2. *Downdraft booth and conventional spray gun*

Measured concentration range during spraying operations 0.01-3.7 mg/m^3 (Goyer 1995 and Lesage, 1992). Goyer presented only mean values, so the range of actual measurements is unknown.

Scenario 3. *Crossdraft booth and HVLP spray gun*

Measured concentration range during spraying operations 1.0-5.2 mg/m^3 (Rudzinski 1995).

Scenario 4. *Downdraft booth and HVLP spray gun*

Estimated range of polyisocyanate concentration 0.6-1.4 during spraying operations. Based on paint mist data from Table II of Heitbrink (1995), 1.9-4.7 mg/m^3 during spraying operations, and the assumption that approximately 30% of particulate overspray is from a polyisocyanate for a typical HDI based paint system (Rudzinski, 1995).

Table A-1

ISOCYANATE CONCENTRATIONS

Industry	Isocyanate Sampled	Eng controls/ gun type	Activity Description	Airborne Concentration (mg/m^3)	Reference
Automobile painting (crash repair workshop)	Active isocyanate	none/NA	Paint mixing & Spray gun washing	0.001 (P) (# of samples not provided)	Pisaniello & Muriale, 1989 (#10)
Automobile painting (crash repair workshop)	Active isocyanate	none/NA	Dry rubbing with mechanical sander (when new coat is few hours old)	0.006- 0.02 (P) (#=2) sample periods were approx 18 min duration	Pisaniello & Muriale, 1989 (#10)
USAF Automobile & Miscellaneous parts	HDI	crossdraft/ HVLP	Spray painting of large vehicles and objects	0.017-0.22 (P) (#=2) 0.004-0.14 (A) (#=4) sample period not reported	Rudzinski et. al., 1995 (#12)
Keesler AFB	N-75 (aliphatic polyisocyantes)	crossdraft/ HVLP	Spray painting trucks	1.0-1.9 (P) (#=2) 1.6-4.1 (A) (#=4) sample period not reported	Rudzinski et. al., 1995 (#12)
Langley AFB	N-75 (aliphatic polyisocyantes)	crossdraft/ HVLP	Spray painting aircraft ground equipment	4.7-5.2 (P) (#=2) 4.9-13.9 (A) (#=4) sample period not reported	Rudzinski et. al., 1995 (#12)
Car Paint Shops	Oligomer HDI	downdraft/ conventional	Spray paint operations (measured at various heights above floor)	5 in. - 2.6 (A) 32 in. - 2.9 (A) 43 in. - 1.9 (A) 55 in. - 1.4 (A)	Lesage et al, 1992 (#53)
USAF vehicle painting	TDI	crossdraft/ conventional	Spray painting operations	3.0 (P) (#=3) sample period not reported	Dept. of the Army Medical Command, 1996 (#69)

Industry	Isocyanate Sampled	Eng controls/ gun type	Activity Description	Airborne Concentration (mg/m^3)	Reference
Paint Manufacturing & Application Operations using PUR coatings	HDI and HDI-based polyisocyanates	no information	Transportation Aftermarket	0.0006-0.015 (P) (geometric mean = 0.03) (# =35) sample period not reported	H.E. Myer et al, 1993 (#70)
Car Spray painting	HDI polyisocyanate	Downdraft/ no info	Spray painting	0.25 - 3.0 (P) (#=12) sample period not reported	Maitre et al, 1996 (#54)
Paint Manufacturing & Application Operations using PUR coatings	HDI	no information	Heavy Equipment/Military	0.04 (geom mean) (#=25)(P)	H.E. Myer et al, 1993 (#70)
Paint Manufacturing & Application Operations using PUR coatings	HDI	no information	Maintenance/Construction	0.05 (geom mean) (#=16) (P)	H.E. Myer et al, 1993 (#70)
Paint Manufacturing & Application Operations using PUR coatings	HDI	no information	Wood/Furniture	0.02 (geom mean) (#=11) (P)	H.E. Myer et al, 1993 (#70)
Industrial Spray Operations	HDI monomers & HDI polyisocyanates	crossdraft/ conventional	Spray Painting & Related Operations	HDI monomer 0.007 (P) (geom mean) (#=24) HDI polyisocyantes 0.70-12.2 (P) (geom mean =3.87) (#=24)	M. Janko et al, 1992 (#76)
Auto Body Shops	HDI monomers & HDI polyisocyanates	crossdraft/ conventional	Spray Painting & Related Operations	HDI monomer 0.014 (P) (geom mean) (#=55) HDI polyisocyantes ND-18.4 (P) (geom mean =1.60) (#=55)	M. Janko et al, 1992 (#76)

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Industry	Isocyanate Sampled	Eng controls/ gun type	Activity Description	Airborne Concentration (mg/m^3)	Reference
Spray Finishing of Large Objects	HDI monomers & HDI polyisocyanates	crossdraft/ conventional	Spray Painting & Related Operations	HDI monomer 0.007-0.11(P) (#=31) HDI polyisocyantes 2.09-15.9 (P) (#=31)	M. Janko et al, 1992 (#76)
Auto Refinishing	HDI Oligomer	downdraft/ no info		0.1-2.16 mg/m^3 sample period twa	(#91)

P = personal sample
A = area sample
# = No. Samples collected

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NEW CHEMICALS ENVIRONMENTAL TECHNOLOGY INITIATIVE

CONTROL TECHNOLOGIES IN THE AUTOMATIVE REFINISHING INDUSTRY

DRAFT REPORT

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CONTROL TECHNOLOGIES IN THE AUTOMATIVE REFINISHING INDUSTRY

Introduction

The objective of this report was to develop information on the innovative technologies and control methods used in automotive refinishing operations. This information will be used to prepare outreach materials for the subject industry. Technologies and control methods were evaluated on several merits such as minimizing worker exposure, controlling environmental releases, waste minimization, cost, and current industry use. The sections below detail information specific to background information, paint spray equipment, spray booths, low volatile organic compound (VOC) paint, computerized paint mixing, other related refinishing operations, and respirator protection. Summary tables have been included to summarize performance characteristics of both paint spray equipment and spray booths.

Background

Automotive refinishing includes operations in auto body repair/paint shops, production auto body paint shops, new car dealer repair/paint shops, fleet operator repair/paint shops, and custom-made car fabrication facilities. Refinishing work typically consists of structural repair, surface preparation and painting. Surface preparation includes grinding the paint off sheet metal, and applying, smoothing, shaping and sanding polyester resin body fillers. Painting involves matching paint colors, mixing paint formulations, and painting the repaired area using custom and conventional painting techniques. Workers involved in auto body repair, and refinishing can potentially be exposed to a wide range of air contaminants. During structural repair, activities such as sanding, grinding, and welding generate aerosols that are released into the worker's breathing zone. If the surface of the vehicle being repaired contains toxic metals such as lead, cadmium, or chromium, exposure to these metals is possible. Automobile painters can be exposed to organic solvents, hardeners that may contain isocyanate resins, and pigments that may contain toxic components. Within the automobile refinishing industry, the major air contaminant exposure appears to be to polyisocyanate (Heitbrink, 1995).

A range of control methods and technologies have been developed and are being widely used to control occupational exposures for spray painting in this industry. The most effective controls are engineering controls, particularly high volume low pressure spray guns and downdraft spray paint booths. New paint formulations have been developed to meet regulatory requirements in reducing solvent emissions in the industry. Other controls such as personal protective equipment including respiratory protection are also used to reduce employee exposures. The technologies and controls being used in the auto body refinishing industry are discussed in the following sections of this paper. This information can be used to prepare outreach materials and to try to leverage the available resources to improve the availability of these technologies.

Paint Spray Equipment

Spray painting in auto body shops is a manual process in which automotive painters use spray guns to apply successive coats of paint until the finish of the repaired sections of the vehicle matches that of the original undamaged portions. To speed drying between coats or for coatings which must be heated to cure, the painted vehicle surface is heated with heat lamps, in special infrared ovens, or in heated spray paint booths. After each coat of primer dries, the surface is sanded to remove any irregularities and to improve the adhesion of the next coat. Final sanding of primers may be done with a fine grade of sandpaper. A sealer is then applied and allowed to dry, followed by the final topcoat. When lacquer is used, the finished surface is usually polished after the final coat has dried, whereas enamel dries to a high gloss and is usually not polished.

Spray guns used in refinishing automobiles atomize paint with compressed air and project a paint mist onto the surface of the vehicle. The mechanism used in atomization and delivery of the paint directly affects the efficiency of the painting process. Transfer efficiency is the ratio of the amount of coating solids deposited onto the surface of the coated part to the total amount of coating solids that exit the spray gun nozzle. The waste paint directed outside the main spray pattern and not deposited onto the vehicle surface is referred to as overspray. In addition, atomized paint can be pulled away from the car surface by compressed air currents deflected by the car surface and the painting technician, and appears to "bounce back". The bounce back can account for 20% of the 60% of the paint which does not reach the car surface when conventional spray guns are used (Fettis, 1995).

Conventional Air Spray Guns

Conventional air spray guns have been the standard spray equipment used to apply coatings in the automotive refinishing industry. With this type of spray gun, a low volume (2 to 10 cfm) of air is pressurized and forced through a nozzle; the paint or coating is atomized in the air at the nozzle throat. Conventional spray guns are usually operated with air pressures of 30 to 90 pounds per square inch (psi) at a fluid pressure of 10 to 20 psi. Air is supplied by an air compressor during spraying operations. There are two basic types of conventional spray guns: syphon-feed and gravity feed. In syphon-feed guns the paint cup is attached below the spray gun, and the rapid flow of air through the gun creates a vacuum that siphons the coating out of the cup. Gravity-feed guns, have the paint cup above the gun and require less air pressure to move the coating through the gun (USEPA, 1994; Schrantz, 1992). The advantage of conventional spray guns is their capability to achieve very fine atomization. The disadvantages of this equipment is that it develops excessive spray mist and overspray fog. Conventional spray guns equipment has a transfer efficiency in the range of 20% to 40%, and therefore most of the paint becomes an overspray that may contaminate the air in the worker's breathing zone (Heitbrink, 1996).

High Volume Low Pressure Spray Guns

High Volume Low Pressure (HVLP) spray guns are systems which use a high volume (30 cfm to 200 cfm) of low pressure (pressure at the gun of between 0.1 and 10.0 psi) and at a fluid pressure of 50.0 psi. The lower velocity of the atomizing air stream results in a more controlled spray pattern, less bounce back, and enhanced transfer efficiency. HVLP guns are estimated to have a transfer efficiency of at least 65% (Heitbrink, 1996). Some disadvantages to this equipment are higher initial cost, inability to atomize coatings as finely as can be achieved with conventional spray guns, slower application speed, and the need for operator training. Conventional spray guns cost up to $350 while HVLP guns cost from $500 to $1000 (Brown, 1996). HVLP guns can be used with some existing air compressors, however capital costs for HVLP systems including compressors are about $1,000 to $22,000 (CARB, 1991). HVLP technology has become commonplace in auto body stops because of reduced paint usage and acceptable finish quality provided by the guns on the market (BAAQMD, 1995). In 1995, approximately 64% of U.S. auto body shops reported owning HVLP equipment. Approximately 49% of small auto body shops (<$124,999 annual sales) and approximately 68% of very large (>$1 million annual sales) owned HVLP spray painting equipment. In 1995, approximately 12% of auto body shops surveyed planned to purchase HVLP spray equipment (BSB, 1995).

Testing conducted by the National Institute for Occupational Safety and Health (NIOSH) in an equipment manufacturer's test facility, demonstrated that particulate overspray concentration was reduced by a factor of 2, and there was a 30% increase in the ratio of paint film thickness to mass of paint applied when a HVLP spray gun was used. These results indicate that using an HVLP spray-painting gun can reduce paint usage and overspray production, resulting in noticeably lower worker exposures (Heitbrink, 1996).

Low Volume Low Pressure Spray Guns

Other guns used in the industry include low volume, low pressure (LVLP) guns. LVLP spray guns, like HVLP guns atomize coatings at lower velocity (9.5 to 10 psi) and lower velocity than conventional spray guns but use an approximately 45 to 60 percent smaller volume of air than HVLP guns. Energy costs for air compression are reported to be less than with HVLP guns (USEPA, 1994).

Electrostatic Spray Guns

Electrostatic spraying systems, which have deposition efficiencies of between 60% and 90% are widely used in U.S. automotive assembly plants. Electrostatic spray systems are typically pressure-feed. A large amount of coating is contained in the hose that connects the spray guns to be paint pot, and the paint must be removed before the next coating can be applied with the spray gun. Because of this design and the prohibitively high cost of electrostatic spray systems, this type of equipment is impractical for the automotive refinishing industry. However, high technology manufacturing processes utilizing electrostatic spray painting equipment and robotics have eliminated or greatly reduced potential occupational exposures during spray application of OEM coating systems (USEPA, 1994).

Powder Coating Systems

Air-powered, electrostatic spray guns function in essentially the same way as electrostatic spray guns. Compressed air propels the power from the gun to the part. An electric field is generated between the spray gun and the workpiece. Powder is passing through the electric field picks up the charge and is directed by the field. When the operator moves the gun, the charged particles follow as they are carried forward by compressed air. When the powder particle strikes the oppositely charged workpiece, the charged particle adheres. Powder is delivered to the spray gun by compressed air. Typically, transfer efficiencies for powder spray guns are similar to wet paint spray guns. However, powder overspray can be reused, and powder systems can therefore operate with powder utilization rates of up to 98%. After the powder is applied, the workpiece must be cured in a curing oven.

Table 6 summarizes the information discussed on paint spray equipment.

Table 6

COMPARISON OF CHARACTERISTICS OF PAINT SPRAY EQUIPMENT FOR AUTOMOTIVE REFINISHERS

Type of Painting System	Performance Characteristics		System Transfer Efficiency (%)	Cost Range ($)	Population of Shops Using Equipment
	Advantages	Disadvantages			
Conventional	Low cost Low maintenance Excellent material atomization Excellent operator control Quick color change capabilities Coating can be applied by syphon or under pressure	Uses high volume of air Develops excessive spray dust and overspray fog Does not adapt to high volume material output (economies of scale) Low transfer efficiency Pressure fed systems require high volumes of coatings	20 to 40	up to 350	Specific population data is unknown. Some states have mandated the use of HVLP systems by automotive refinishers.
High Volume Low Pressure	Low blowback and spray fog Will apply high-viscosity high solid coatings (low VOC coatings) Relatively easy to clean Can be used for intricate parts Good operator controls	High initial cost Slower application speed with some coatings Does not fully atomize some coatings Higher maintenance costs Requires operator training Still relatively new to the market	at least 65	500-1000	64% of all shops

Table 6 (Cont'd)

COMPARISON OF CHARACTERISTICS OF PAINT SPRAY EQUIPMENT FOR AUTOMOTIVE REFINISHERS

Type of Painting System	Performance Characteristics		System Transfer Efficiency (%)	Cost Range ($)	Population of Shops Using Equipment
	Advantages	Disadvantages			
Low Volume Low Pressure	Low blowback and spray fog Will apply high-viscosity high solid coatings Easy to clean Can be used for intricate parts Good operator controls Needs less air compression then HVLP Lower energy requirements	High initial cost Slower application speed than HVLP Does not fully atomize some coatings Higher maintenance costs Requires operator training Still relatively new to the market	at least 65	500-1000	Population data is unknown
Electrostatic	Coating wrap on edges and parts Material savings through superior transfer High production output ideally adapts to automation Reduced manpower requirements Lower spray booth velocity Can be used with both solvent and water based coatings Can be used with a wide range of application processes	High equipment and maintenance costs Parts hangers hooks must be conductive and require frequent cleaning Automated lines must be adapted to long runs of similarly shaped parts Will not properly coat recessed areas Faraday Cage affects coating of corners, cavities, etc Electrical shock hazard Operator training is required	usually greater than 90	Unknown	Population data is unknown Electrostatic systems are more appropriate for OEM operations

Table 6 (Cont'd)

COMPARISON OF CHARACTERISTICS OF PAINT SPRAY EQUIPMENT FOR AUTOMOTIVE REFINISHERS

Type of Painting System	Performance Characteristics		System Transfer Efficiency (%)	Cost Range ($)	Population of Shops Using Equipment
	Advantages	Disadvantages			
Powder Coating	Almost zero VOC emissions Excess or waste powder can often be melted Powder can be applied to hot or cold parts Ideal for robotic application Applied in single coat system Economical for long runs of a few colors	Generally, capital equipment outlay is greater than for conventional coatings High energy usage due to high temperature ovens Some powders require temperatures as high as 500°F for curing Not suited for every application (parts that can not high temperature plastics, rubber, upholstery	Up to 95	5000-100000	Population data is unknown Powder coating systems are used primarily in OEM operations.

Sources: EPA, 1994 and BSB, 1995

Spray Booths

Automobile spray painting operations produce aerosols containing droplets and solvent vapors to which workers may be exposed. Spray booths, which are power-ventilated structures enclosing a spraying operation, can confine and limit the escape of spray, vapor, and residue, and safely conduct or direct overspray and vapors to an exhaust system. Automobile painting activities are usually performed inside a spray booth to ensure good finish, to reduce employee exposures to inhalation of solvent vapors and paint solids, and to reduce the hazards of fire and explosion arising from components used in paints and varnishes (Goyer, 1995). After painting, spray booths are used for ambient air drying or for drying at elevated temperatures. Evaluations of controls in the auto body refinishing industry, conducted by NIOSH, indicate that currently available spray-painting booths do not completely control worker exposure to paint overspray (Heitbrink, 1995).

Dry-type booths use filters to intercept and trap particles of overspray while water-wash booths use a flow of water over a solid surface to accomplish the same thing. Filters become clogged over time and must be replaced or the volume of air exhausted through the booth will diminish to the point where excessive amounts of overspray and solvent vapor or both reach the breathing zone of the worker and/or escape from the booth. Dry filters are commonly used for low to intermediate volume spray operations. (NFPA, 1981) Waterwash booths are spray booths equipped with a water-washing system designed to minimize concentrations of dusts or residues entering exhaust ducts and to permit the collection of dusts or residues. Where high volume spray coating operations are conducted for several hours a day, waterfall or cascade scrubbers are commonly used (NFPA, 1981). Either type can be used successfully in almost all applications, however in general dry-type booths are most often used in automotive refinishing shops. Water-wash booths are rarely used in auto body refinishing shops (Garcia, 1996).

Many spray-painting booths of the type used in the automobile refinishing industry have a painting cycle and a curing cycle. These booths are equipped with supply air fans and exhaust air fans. The supply air fan moves air from outside the shop through a heat exchanger or natural gas burners, through a bank of filters, and into the spray painting booth. The exhaust air moves out of the booth through filters and out of the building (Heitbrink, 1995). Many spray booths have painting and curing cycles. To cure paint and polyisocyanate hardeners, the booths are operated at temperatures as high as 79° C (175° F), although curing temperatures are typically 49°C to 60° C (120° to 140°F). Purchase costs of small basic spray paint booths range from $5,400 to $23,000 (Spray Systems, 1996). A medium-size repair shop in Maryland installed two booths in 1992 for a total cost of approximately $400,000. The purchase cost of each booth was approximately $60,000 but the installation of these booths required extensive foundation construction costs to accommodate the ventilation system for the booths (CCC, 1996).

Three types of commercially available spray-painting booths found in auto body shops include downdraft, semi-downdraft, and crossdraft spray painting booths. The characteristics of these booths are discussed in the following sections.

Crossdraft Spray Booths

In a crossdraft booth, the air enters through filters in the front of the booth and is exhausted through filters in the back of the booth (Heitbrink, 1995). Approximately 50% of U.S. auto body shops have cross draft booths. An industry profile study, which provides data for 1995, indicates that approximately 42% of small(<$124,999 annual sales) auto body shops had downdraft spray booths and approximately 25% of very large firms (>$1 million annual sales) owned cross draft spray booths (BSB, 1995).

Downdraft Spray Booths

Downdraft spray-painting booths are designed so air enters through filters in the ceiling of the booth and leaves through a metal grate in the floor of the book. In most U.S. automotive assembly plants, painting is done in a downdraft paint spray booth. During the painting process, conditioned ambient air is introduced to the paint spray booth through the roof. The air and paint pass downward over the parts to be painted. The paint overspray and solvent fumes exit with the exhaust air from the painting area through grates on the floor (Eklund, 1995).

Approximately 30% of U.S. auto body shops in 1995 reported having downdraft spray-painting booths, including approximately 8% of very small firms and 83% of very large shops. Approximately 19% of auto body shops planned to purchase downdraft booths (BSB, 1995).

Semi-Downdraft Spray Booths

In a semi-downdraft booth, air enters through filters in the ceiling of the booth and is exhausted through filters in the back of the booth. During the painting process, conditioned ambient air is introduced to the paint spray booth through the roof. The air and paint pass down and across over the parts to be painted. The paint overspray and solvent fumes exit with the exhaust air from the painting area through openings usually on a side of the booth (EPA, 1994).

Approximately 30% of U.S. auto body shops in 1995 reported having downdraft spray-painting booths, including approximately 8% of very small firms and 83% of very large shops. Approximately 19% of auto body shops planned to purchase downdraft booths (BSB, 1995). The BSB industry profile did not specify if the downdraft spray paint booth data represented semi-downdraft models.

Table 7 summarizes the information presented above on spray booths.

Table 7

COMPARISON OF CHARACTERISTICS OF PAINT SPRAY BOOTHS

Paint Booth System	Performance Characteristics [1]		Cost Range[2]	Population of Shops Using Equipment[3]
	Functional Advantages	Disadvantages		
Downdraft	State of the Art worker protection Air movement - enters the booth through the ceiling and passes out the floor of the unit Lowest air turbulence of the three systems available Best system for preventing paint deformities	May cost more than other systems May require extensive renovation at existing facilities Operator training necessary Extra energy needed for heated systems	\$12,000-\$60,000	30% of all body shops use downdraft or semi-downdraft paint booth systems Most common paint booth system in shops with sales greater than \$750,000 annually
Semi-Downdraft	Low air turbulence Air movement - enters the booth through the ceiling and passes out the back of the unit Installation may not require as much site renovation as downdraft	More air turbulence than downdraft May require extensive construction at existing facilities Operator training necessary Extra energy needed for heated systems	\$10,000-\$23,000	30% of all body shops use downdraft or semi-downdraft paint booth systems Most common paint booth system in shops with sales greater than \$750,000 annually
Crossdraft	Most affordable system Air movement - enters the booth through one side and passes out the other Installation may not require as much site renovation as semi-downdraft or downdraft	Highest air turbulence of three available models Least effective model for preventing paint deformities Operator safety Extra energy needed for heated systems	\$5,500-\$23,000	50% of all body shops have a cross draft paint booth system Most common paint booth in body shops with sales less than \$750,000 annually

Sources: 1 - EPA, 1994, 2 - Spray Systems and CCC, 1996, 3 - BSB, 1995)

Low VOC Coatings

This section of the report will detail the types of coatings used by auto body refinishers, the difference between OEM and refinisher coatings, some state regulatory trends for auto body refinishers, and alternative low volatile organic compound (VOC) coatings available. Low VOC coatings have two distinct advantages when compared to higher VOC coatings. These two advantages are reduced occupational exposures to and environmental releases of VOCs.

Conventional coatings are typically made up of three major components; a pigment for color, a polymer that acts as binder, and a liquid carrier-generally a solvent. In some coating formulations the solvent portion can account for two-thirds of the coating. VOCs are solvents that evaporate or volatilize during the painting process. Examples are thinners, reducers and cleaning solvents. Mixed in coatings, solvents provide proper viscosity, flow, and drying characteristics. For the automotive refinishing industry the paints can be set into distinct groups including primers, sealers, precoats, pretreatments, and specialty coatings.

Primers are base coats, sealers, or interim coats which are applied prior to colorant or aesthetics coats. In most cases, the primer is the most important coat upon which the remaining coats will adhere. Sealers are coatings that are formulated with resins, which when dried, are not readily soluble in solvents. These coats act as a shield for primers by resisting the penetration of solvents which are in the topcoat.

Automotive Precoats are any coating that is applied to bare metal to deactivate the metal surface for corrosion resistance to a subsequent water-based primer. This coating is applied to bare metal solely for the prevention of flash rusting caused by the water in water-based primers. Automotive pretreatments are any coating which contains a minimum of 0.5% acid by weight that is applied directly to bare metal surfaces to etch the metal surface for corrosion resistance and primer adhesion. Specialty coatings include coatings which are used to perform unusual job requirements such as helping to prevent surface defects and improve desired coating properties. Examples include coatings for plastic parts, anti-glare coatings, and gloss flatteners (Kirk-Othmer, 1992 and TNRCC, 1995).

The spray coatings applied by body shops differ from those applied by original equipment manufacturer's (OEM's). OEM facilities use coatings that require temperatures up to 400°F (204°C) to cure the coating. This is possible because no temperature-sensitive materials have yet been installed in the automobile. Body shops, on the other hand, must use coatings that cure at temperatures less than 150°F (66°C) to avoid damaging the vehicle's upholstery, glass, wiring or plastic components.

A driving force behind the automotive refinishing industry converting to the use of low VOC coatings has been the introduction of state regulatory requirements reducing the amount of VOCs in paints. Some states have regulated the auto body refinishing industry while others have not, so information is not representative. States like Texas, California, and Maryland have taken initiatives to require automotive refinishers to register for air permits and adopt new technologies within industry. Texas, for example, has specific guidelines established for the auto body coating industry. Table 8 details Texas VOC guidelines for coatings used in the auto body refinishing industry.

Table 8

TEXAS VOC GUIDELINES FOR COATINGS USED IN AUTOMOTIVE REFINISHING

Coating Type	VOC Allowance (Pounds/gallon) minus water and exempt solvents
Primers	5.0
Precoats	5.5
Pretreatment	6.5
Basecoat/Clearcoat	5.0
Specialty Coating	7.0
Sealers	6.0

(TNRCC, 1995)

The California Air Resources Board (CARB) has been developing low VOC coatings since the late 1980's. In 1989, California issued several rules which required coating manufactures to produce coatings with little or no VOCs. At that time however, industry was not effective in creating the new compounds to meet the required deadlines. Revisions to the regulations were made and consequently, today there are several paint vendors in California that offer a variety of low and no VOC coatings. In 1992, additional regulations were issued requiring auto body shops in most CARB districts to incorporate the low VOC coatings. CARB will be completing a comprehensive survey of the auto body industry in California in May of 1996. The data will be used to develop generic chemical formulations for different categories of automotive coatings. These generic formulation will be used to track and evaluate emissions from auto body shops state wide (Watkins, 1996).

The cost for low VOC coatings are slightly higher because of their higher solids content. Costs of paint can range significantly and are influenced by a number of factors. These can include percent solids in the paint mixture, coverage, or required coating thickness.

Base coats can range from \$13 to \$35 per pint. Clearcoats can range from \$100 to \$175 per gallon, and primers can range from \$75 to \$150 per gallon (Brown, 1996).

One manufacturer has developed a coating which utilizes low molecular weight volatile dimethysiloxanes as solvents in protective paint systems. The manufacturer claims that the product's lifetime in the atmosphere is 10 to 30 days, so there will be little chance of reactions with nitrous oxide and affecting the ozone. The new paint formulation can reduce VOCs by about ½ a lb /gal in some cases (Anon., 1995). Two other manufacturers, located in Rockville, Maryland and Exto, Pennsylvania, respectively, have teamed up to develop a new class of ultraviolet-cure coatings that requires no photo initiators. The manufacturers claim that these new coatings will be low cost alternatives for several large markets including the automotive market. The coatings polymerize in the presences of UV-light (Paint and Powder, 1996).

An example of new waterborne coatings applications includes a waterborne acrylic wash primer with a VOC content of 1.26 lbs/gallon. The wash can be used to wash and prime a variety of steel surfaces. The primer sets rapidly and reportedly is tack free after 15 minutes (Paint and Powder 1996). Current applicability of this material to the automotive refinishing industry is unknown.

Waterborne basecoats and primers have been developed and are currently being used at the OEM facilities. Many OEM facilities have switched to waterborne basecoats and primers to improve leveling and metallic/mica flake. One manufacturer has approximately 70% of the waterborne basecoat market.

Significant advances have been made in clearcoat chemistry. Clearcoats are specialty top coats and are used to provide improved gloss, durability and overall appearance to the basecoat. The ideal clearcoat will be able to resist environmental fallout (acid rain, bird droppings, and soot) for ten years and have VOC range comparable to waterborne primers and basecoats below 3.0 lbs per gallon VOC. (Anon., 1991a)

Computerized Mixing of Paints

During manual mixing operations to formulate a desired coating, workers and the environment may be exposed to the chemical constituents which make up the coatings. Most coatings are mixed with additional solvents and catalysts prior to application to ensure proper drying time, adhesion, appearance, and color-match. Topcoats in particular must be exactly mixed according to the manufacturer's instructions because even a slight deviation may result in unacceptable finish quality. The automobile refinishing industry is very concerned with color control. Of all appearance variables, color is the most noticeable, and, therefore extremely important. If a customer sees a subtle color variance in a repaired component of a vehicle, then this is perceived as poor quality.

Aside from offering precise formulations for coating, computerized mixing can decrease worker exposures, reduce environmental emissions, and minimize waste.

New car manufacturers (OEMs) are now using computerized equipment in an effort to standardize colors used in automotive finishing. One such system employing a spectrophotometer, operates by measuring the "reflectance of light beamed at a color sample placed in a measurement port" (Mueller, 1988). By adding the speed and accuracy of a computer to the color measurement instrument, formulas can be generated to match the target color. This formula specifies the mix of colorants, the closeness of the match, and the costs associated with producing the color formula. But the one drawback of this equipment is that "both finisher and coatings manufacturer must use the same color measurement scale" (Mueller, 1988). Currently, there are a number of color scales being used in the industry.

Another piece of equipment which has taken the number of scales currently on the market into consideration uses a spectrocolorimeter. It measures "light reflectance according to color and appearance" (Anon., 1988). It is used in measuring values of color standards, trouble-shooting finishing problems, and inspecting the final product prior to shipment. The system can calculate various color scales under a broad set of conditions and replicate measurements under different light sources. Although the readings are still adjusted by a technician for metamerism (the visual differences due to lighting variances), the system has the ability to include the observer and light source data into its final computations.

A paint manufacturer's representative indicated he was aware of two systems that the paint manufacturers used to help determine colors. The instruments are referred to as spectra-photometers. The first system uses light from a halogen bulb to detect the color scheme. The system can match colors to a 16 color spectrum wavelength. The other system uses light from a xenon bulb to detect the color scheme. This system can match colors to a 256 color spectrum wavelength. The representative stated that these instruments work better in theory than in the field, and that color flop (mica content and flatness) can drastically reduce the instruments effectiveness at creating correct color match. Not many shops have invested in these instruments because of the cost, which is above $20,000 per unit, and the lack of effectiveness (Brown, 1996).

Many shops order topcoats to match the automobile being refinished from local automotive paint distributors. Others mix their own colors using mixing stations. A mixing station typical consists of a microfiche viewer or a computer that contains the manufacturer's mixing instructions, a digital scale, and a mixing machine. Shops that use mixing stations typically stock only a few primary colors, from which almost any OEM color can be produced (USEPA, 1994).

A manufacturer developed a system that can be used in tinting paint. A carousel is provided that carries 80 different tints and a set of microfiche that provides the formulas. Once the correct car model and color are found, the necessary ingredients are added precisely by weight and proper amounts of hardener and reducer are added (Anon., 1986).

A shop visited for this project did not have any computerized mixing system on site, but relies on OEM paint codes, which are found on every model car, and then hand mixes the colors to match as closely as possible. True color matching is difficult, if not impossible and often auto body shops do what is known as blending. Blending is done when slight differences exist in colors and the painter covers area of the vehicle that may not need repainting in order to hide the color change. This allows the color difference to be spread out over a larger surface thus creating the illusion that the colors are the same (CCC, 1996).

Other Related Operations

Preparation Stations

Preparation of the surface for painting and application of primers or small spot painting is conducted in open areas of the body shops; however, in some shops these steps are performed in preparation stations. Preparation stations typically are ventilated and equipped with plastic curtains to control dust and coating overspray. Unlike spray-painting booths, preparation stations do not have walls and may involve recycled air. A study of engineering controls in auto body shops indicated that preparation stations evaluated did not appear to control worker exposure to air contaminants (Heitbrink, 1995). Many shops and preparation stations are equipped with portable infrared heating units to facilitate drying of primers during cool or humid shop conditions (USEPA, 1994 and Heitbrink 1995). In 1995, approximately 16% of U.S. auto body shops reported owning preparation stations, including approximately 7% of very small and 25% of very large shops. Approximately 19% of U.S. auto body shops planned to purchase preparation stations (BSB, 1995).

Local Exhaust Ventilation Systems

Rotary/orbital and straight line/reciprocating sanders are used during auto body repair operations to remove paint and to smooth body panels repaired with body filling compounds. Airborne dusts produced during these operations may contain a variety of hazardous substances including metal dusts, paint dusts, and abrasives from sanding media. Local exhaust ventilation for sanders, including High Velocity, Low Volume (HVLV) have been found to be effective in reducing total dust concentrations to one-tenth levels produced using unventilated sanders (NIOSH, 1996).

Respiratory Protection

Because potential occupational exposures can exceed OSHA PELs during spray painting operations, respiratory protection is normally required for spray operations. Many types of respirators are available for such operations. If properly selected and used respirators can reduce worker exposure significantly. However, data from a NIOSH study indicates that respirator usage at five of six auto body repair shops evaluated was inappropriate. (Heitbrink, 1996) The author reported that, respirators were in poor shape and not maintained properly. All of the shops included in the study were lacking a formal, written respiratory program. An Australian auto body study indicated that only 32% of the auto body repair workers had half-facepiece air purifying respirators that did not leak. (Heitbrink, 1996). As expected, surveys have found that breathing resistance and physical discomfort, such as pressure on the face and head, sweat on the face, and tightness of harness are often cited as the main reasons workers do not use respirators or use them properly. A trend toward increased use of airline respirators in the auto body repair shops has been reported (Janko, 1992). This type of respirators typically causes less physical discomfort and should offer better protection.

ATTACHMENT A

SITE VISIT REPORT

ATTACHMENTS A
Site Visit
Chevy Chase Chevrolet-Geo-Oldsmobile
7725 Wisconsin Ave.
Bethesda, Md 29814
April 26, 1996

On April 26, 1996, SAIC conducted a site visit to Chevy Chase Chevrolet-Geo-Oldsmobile. The facility is located directly off Wisconsin Ave two blocks north of East West Highway in Bethesda, Maryland. It is a new/used/auto body repair shop/ dealership that has been in the area for over 50 years. The auto body repair shop is located in the rear of the new car dealership and is split into several distinct areas. The purpose of the site visit was to gather information specifically concerning the painting and refinishing operations.

Information was obtained related to spray booths at the facility. The auto body shop has two floor drawing heated paint booths. Each spray booth is equipped with a separate air supply system for the painter and for overspray recovery. Outside air is drawn in from a vent on the west side of each booth. Air passes through heating coils and a series of filter and enters the paint booth at the ceiling level. The inside air is drawn toward the floor via a fan and is vented to an exhaust duct located outside and above the paint booth. Cars are driven into the booth and the garage door is lowered. The painters dons an air supplied protective hood and plastic like coveralls and begins painting. After the painting is completed the painter exits the booth and the coating is heated to 140-150° F and allowed to dry. Drying time varies from coating to coating, but on average the new low VOC coatings take anywhere from about 20 to 40 minutes to dry.

This shop had these booths installed three years ago at a cost of approximately $400,000. Each booth cost approximately $60,000 and the installation of these booths required extensive foundation construction due to the nature of the booth (Floor draw). The manager indicated the facility would install a third booth sometime in the future.

The manager also indicated that the booths use quite a bit of natural gas to maintain the curing heat at 140-150° F. All supplied air was drawn from the outside.

HVLP Spray Guns

This shop had 6 different models of HVLP spray guns. The manager confirmed that paint spray efficiency had increased to almost a 70% transfer rate, although some of the new low VOC paint formulations would not spray as well as some of the older lacquer paints. The high solid, low VOC paints often required more than 10 PSI nozzle pressure to atomize. A paint manufacture's vendor indicated that HVLP technology has come a long way in the last three years. He said that he could line up 6 HVLP guns, all with similar ratings and supply 40 PSI into each gun, but the nozzle spray would not be uniform. Often the output would range from 6 - 10

PSI. The representative indicated that true atomization of low VOC paint formulations often occurs at nozzle pressures higher than 10 PSI.

A closed container HVLP gun cleaner was seen on site. Both the shop manager and the paint vendor indicated that this equipment was purchased in response to a new regulation in Maryland.

LOW VOC Paint

Maryland State regulations concerning the use of low VOC paint began on April 15, 1996. These new regulations limited the types of paints shops like this can use. Specific VOC concentrations are spelled out for specific types of paint. The vendor indicated that there is a trend toward the use of low VOC paints. He stated that the new paints are not as easy to apply and have a slower drying time than some of the older lacquer paints. Many of the older paints have been regulated and cannot be used in Maryland.

The paint vendor stated that he would like to see uniform VOC regulations. At this time state regulation vary significantly and paint manufacturers have to run more batches of the same colors in order to meet state requirements. While some states have no regulations others have set standards which vary from coating to coating. This shop stated that they had moved to the low VOC paints over a year ago and the supplier has been very helpful for the shop. The supplier in this case even supplied monthly usage updates for the shop. This helps the body shop conform to the record keeping requirements.

The shop manager said the new paints work well, but the drying time has drastically reduced the amount of work that can be done. He said the old lacquer paints would dry at ambient temperatures in ten minutes, while the newer paints need to be heated and can take up to 30 minutes to dry.

Computerized Mixing

The paint vendor said he was aware of two systems that the paint manufacturers used to help determine colors. This shop did not have any computerized mixing system on site, rather they relied on OEM paint codes, which are on every model car, and hand mixed the colors to match as closely as possible. True color matching is difficult if not impossible, and often auto body shops do what is known as blending. Blending is done when slight differences exist in colors and the painter covers areas of the auto that may not need repainting in order to hide the color change. This allows for the color differences to be spread out over a larger surface thus creating the illusion that the colors are the same.

The paint vendor said that even at the OEM level hoods on cars painted with the same color on the same day in the same batch runs can not be exchanged because of the slight color differences. The vendor went on to say that one color standard can have up to 30 different variations and still be considered the same color standard.

There are two instruments available that act as a human eye to identify auto paint color. The instruments are referred to as spectra-photometers. One system uses light from a halogen bulb to detect the color scheme. It can match colors to a 16 color spectrum wavelength. The other system uses light from a xenon bulb to detect the color scheme. This system can match colors to a 256 color spectrum wavelength. The vendor stated these instruments work better in theory than in the field and that color flop (mica content and flatness) can drastically reduce the instruments effectiveness at creating correct color match.

Not many shops have invested in these instruments because of the cost, which may be above $20,000, and the lack of effectiveness.

Other Comments of Relevance

The shop manager presented his opinion about the insurance industry. Eighty-five percent of the work done at this shop is driven by insurance claims. The insurance companies have contractual rates which are established within various regions. The auto body shops therefore can only charge set rates for refinishing (work time and materials). These rates are established by the insurance companies and range significantly from locality to locality. This pricing drastically reduces the shops ability to pass along costs of capital such as spending $400,000 on new spray paint booths. When regulations are issued, shops have little choice but to comply and compliance becomes a real cost issue as in this case the shop can not just pass on the costs of major upgrades. For a shop of this size upgrades are possible, but for smaller shops who also rely on insurance claims for the majority of their work costly upgrades may not be possible because the volume of work may not be enough to recover the costs of capital improvement. The shop manager predicted that within a few years many of the medium size shops will go out of business because of non-compliance. He said real small shops will be ignored and the larger shops like his will expand to meet additional capacity. They can afford to make the upgrades and many medium sized shops will not be able to.

The shop manager said he would be converting over to all waterbased paint systems in a few years. He believes the industry will have no other choice. The waterbased paint systems can be sprayed just as the old solvent based systems, but the drying time is significantly longer. Areas in the country which have high humidity will have to make upgrades before they move to waterbased paints systems. The manager said he liked the paint booth upgrades primarily because of the added safety margins.

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