1995 National Pollution Prevention Center Case Study:

PAINT SPRAY BOOTH CLEANING PRACTICES IN THE AUTOMOTIVE INDUSTRY

Sponsored by:

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EXECUTIVE SUMMARY

Chrysler Corporation, Ford Motor Company, and General Motors Corporation, through their trade association, the American Automobile Manufacturers Association (AAMA), sponsored four internships for the summer of 1995 with the National Pollution Prevention Center (NPPC) at the University of Michigan. The primary assignment for the interns was to conduct a pollution prevention study on the paint spray booth cleaning process at three automotive assembly plants. This case study was prepared based on their evaluation.

The objectives of the study were to (1) determine the current practices for spray booth cleaning operations within the selected assembly plants, (2) recommend opportunities for reducing wastes and costs, (3) propose a potential best practice for paint booth cleaning based on observations at these plants, and (4) provide an automotive industry pollution prevention case study for use in curricula development by the NPPC.

Combined, the three automotive companies have 51 assembly plants in the U.S. where automobile bodies are painted. Each assembly plant thoroughly cleans paint spray booths in order to maintain very high quality painted surface and appearance. The paint booth cleaning process at three of these plants, one truck assembly plant, one full size vehicle assembly plant and one small vehicle assembly plant, (each located in southeast Michigan), was studied. Hydrocarbon based solvents used in the process generate volatile organic compounds (VOC) . Collection and abatement equipment typically reduces the emissions from the VOC generated by 80% or more.

It was found that three factors determined the cleaning practices and the material use. These are:

(1) type of paint used,
(2) spray booth design, and
(3) spray booth management procedures.

First, with regard to the type of paint used, plants 1 and 2 apply solvent-based paint while Plant 3 applies powder and water-based coatings. Spray booths where water-based paint is applied can be cleaned using a low-VOC (volatile organic compound) material and/or high-pressurized water blasting.

Second, booth design is an important factor in reducing paint overspray, there-by minimizing cleaning requirements. Optimal spray booth air flow balance reduces paint overspray and subsequent cleaning requirements. The booth balance is optimal when the water under the grates is flowing at the designed depth and rate. Plants 2 and 3 have excellent booth balance, but Plant 1 could improve air flow in the paint spray booth.

The third major factor in cleaning performance is the booth management. This includes implementing a best practice cleaning procedure, employee training and communication, and material accountability and quantity use limitations. Plant 2 uses significantly more solvent than

the other two plants and opportunity is available for use reduction. To better track material usage, booth management practices at Plant 1 could be enhanced by developing an improved communications process for engineers and suppliers.

Each of the three plants studied utilized different cleaning practices due to differences mentioned above. Although each of the plants provided valid reasons for their particular methodology, a best management practice may still be drawn from fusion of the cleaning practices at these three plants.

The Best Practice recommendations are:

(1) water blast the grates weekly,
(2) scrape the center track weekly and apply low-VOC barrier coat,
(3) change robot covers weekly and spray with tacky coat,
(4) limit the use of cleaning solvent to spray tips and bells,
(5) rinse walls, windows, silhouettes and hoses with water daily and spray low-VOC tacky coat,
(6) assure that spent/waste rags are dry and efficiently reclaimed or properly disposed,
(7) reclaim all solvent,
(8) optimize booth balance,
(9) establish a communications process for engineers, booth managers and booth cleaners, and
(10) establish booth cleaning metrics.

In addition to the recommended best management practices, other conclusions have been drawn from the study. Movement toward low-VOC coatings, such as powder coat technology and waterborne paint technology, will greatly decrease the amount of solvent required for cleaning paint spray booths. These technologies are being pursued by the Auto Companies through their consortia, USCAR and through ongoing vehicle and process redesign programs. Under USCAR, a Low Emissions Paint Cosortia was formed and a pilot plant has been constructed for material and equipment evaluations. Also, education regarding the proper use of booth cleaning technologies has potential to improve the efficiency of the cleaning process.

It is important to note that the descriptions of the plants presented in this case study are a snapshot of dynamic systems which are continually evolving and improving.

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PROJECT BACKGROUND

The American Automobile Manufacturers Association (AAMA), through its member companies - Chrysler Corporation, Ford Motor Company, and General Motors Corporation, is participating in an intern training program with the National Pollution Prevention Center (NPPC) at the University of Michigan. Under this intern program, four senior/graduate level engineering students worked at a respective auto company and the AAMA. Assignments were in the area of environmental management and waste prevention in manufacturing. The primary assignment was to jointly evaluate paint spray booth cleaning practices in automotive assembly plants and to develop a case study based on the observations.

This program was initiated by the AAMA member companies to support their efforts under the Automotive Pollution Prevention Project (Auto Project), a voluntary program to reduce the release of specific persistent toxic substances. An element in the Auto Project is technology and information transfer on pollution prevention. This information exchange is typically managed through case studies distributed by AAMA. The NPPC uses similar case studies to develop curricula for use by colleges and universities worldwide. Along with this case study, the interns developed other education materials, including an open-ended problem set, that may be tailored to a specific course.

The AAMA and each of its member companies selected an intern who studied activities related to the project, such as life cycle analysis, mass balancing, analysis of release data and implementation of various pollution prevention strategies. The four interns worked together on the paint spray booth project entitled “Paint Spray Booth Cleaning Practices In the Automotive Industry”. This project was suggested because it provides an opportunity to evaluate the processes, procedures, and practices of a typical automotive industry process.

There are 51 assembly plants operated by the three automotive companies in the U.S. One assembly plant from each company was selected as a representative plant for evaluation. The four interns worked as a team and utilized their various backgrounds - Chemical, Environmental, and Industrial and Operations Engineering - to identify current practices and potential opportunities for improvement. The interns worked in concert with plant personnel to gather material use and environmental and process data primarily in the areas of waste prevention and/or paint spray booth cleaning.

INTRODUCTION

The painting of vehicle bodies in a U. S. automobile assembly plant is a high volume painting process. In the plants studied, the number of vehicles painted per day ranged from about 850 to 1224 vehicles. This relates to nearly one vehicle painted/produced per minute of production time. During the painting process, air flow downdraft in the paint spray booth is maintained and is directed to a large water reservoir where most of the paint that misses the target vehicle body (paint overspray) is collected in the water and eventually treated and managed as paint sludge. Some of this paint overspray collects on the walls, windows, robots, fixtures, floor grates, and other components and areas of the spray booth. Since the paints used by most of the industry cure only when heated to temperatures in the 280 - 300°F +/- range, this overspray creates a sticky residue. To maintain high quality painted surface, the deposited paint overspray needs to be cleaned from the paint spray booth on a regular basis.

The transfer efficiency of the painting process is the ratio of the amount of paint material deposited on the vehicle to the amount sprayed. As the transfer efficiency increases, more paint stays on the target vehicle and less overspray adheres to the booth components; thus reducing cleaning requirements.

Traditionally, paint spray booths in the automotive industry have been cleaned with solvents (containing mostly volatile organic compounds). These solvents readily dissolve paint overspray. However, the evaporation of these solvents during the cleaning process releases volatile organic compound (VOC) as air emissions.

Objectives of the project were to:

- Identify opportunities to reduce wastes and costs
- Propose non-proprietary potential best practices for cleaning paint spray booths
- Provide an industrial pollution prevention case study for use in curricula development by the NPPC

PAINTING PROCESS OVERVIEW

The following section, an overview of the painting process, provides the necessary background for understanding the discussion on paint booth cleaning. The differences in the paint process that exist within the observed plants will be addressed individually in their specific section. See Appendix 1, Figure 1 for the general paint process layout.

First, the vehicle bodies, which are generally made of light-weight steel, (but certain models may include an aluminum component, such as the hood), undergo surface preparation and pre-paint treatment. This preparation involves thorough washing and wipe-cleaning. The pre-paint treatment process causes a chemical crystalization to occur on the vehicle surface that provides improved paint adhesion and anti-corrosion protection. Generally, this step includes the following:

(1) spray and/or dip wash and rinse, (2) spray or dip surface chemical conditioning, (3) immersion in a zinc phosphate bath, which chemically reacts with the metal surface where the crystals form, and (4) immersing or rinsing the vehicle bodies in a chromic acid or acid chromate followed by a deionized water rinse. (For a complete review of the pre-paint cleaning and coating treatment process, acquire the NPPC Open-Ended Problem: "Determining Mass Balances in Ford Wixom's Phosphate Coating System", available on CD ROM through the NPPC.)

The vehicle bodies are then conveyed directly from this phosphate pre-paint treatment process to the cathodic electrocoat process, which is typically a full immersion process.

The vehicle bodies are immersed in this prime coating (referred to as cathodic E-coat). The E-coat is electro-deposited on the vehicle bodies. That is, opposite charges are applied to the material and the vehicle, which causes the material to readily adhere to the surface of the vehicle.

After applying the E-coat, the vehicle bodies are conveyed to a curing oven (bake oven) where the coating is cured and dried prior to being conveyed to the prime-coat spray booth. As the vehicle moves toward and into the primecoat spray booth, sealers and other protective coatings, such as antichip, are applied.

After the sealers, anti-chip and primecoat applications, the basecoat and clearcoat paints are applied on the vehicle by (a) automated spray guns, such as reciprocating robots or stationary bells, or (b) by manually operated spray guns. Many times a combination of the two practices, automated and manual application, is used. The basecoat is the paint that provides color for the vehicle, while the clearcoat is a topcoat that adds luster and hardness to the paint finish while protecting the base coat from ultraviolet radiation. To prevent paint build-up on spray gun tips, each paint delivery hose and spray gun are purged with solvent between each change in color, which may be as often as every vehicle body. In some plants, this "purge solvent" is collected and recycled.

A flash-off zone is employed between the basecoat and the clearcoat zones to allow the basecoat to partially dry before the clearcoat is applied. It also gives the engineers an opportunity to monitor the quality of the basecoat paint. The clearcoat application is followed by an observation zone where the vehicle bodies are studied by quality control personnel and are labelled for either continuation down the line or for repair or paint touch-up if necessary. The vehicles then enter a series of ovens where the paint is cured, thus completing the painting process.

In some plants, a black paint (referred to as blackout) is also applied as accent to certain areas on the vehicle bodies, such as the wheel wells. This is usually completed along the conveyor line but not in one of the main paint spray booths.

GENERAL PAINT SPRAY BOOTH SETUP

The painting of vehicle bodies at a large assembly plant generally occurs in a series of large enclosures called paint spray booths (except as earlier mentioned, the cathodic E-coat is generally an immersion process). The antichip coat (or other types of protective coating), the primecoat, the basecoat, and the clearcoat are applied in the main color booths. Other booths are dedicated to touch-up or blackout, while some are dedicated to repair. Paint shops have either continuous or modular paint spray booth designs. (See Appendix 1, Figures 2 and 3).

Most paint shops have continuous spray booth design, where the vehicle bodies are painted in succession with basecoat and clearcoat in one long booth which consists of several zones.

Vehicles enter the color booths and continually proceed (by conveyor) through the basecoat, flash-off, clearcoat and observation zones and finally exit to the curing oven.

In modular booths, the vehicles are painted while stationary. The vehicles are indexed into each zone (basecoat, flash, clearcoat, and observation) where they remain for a set amount of time. While in the module, the vehicles do not move individually, but are indexed as a set. They continually stay the same distance apart. After passing through the zones, the vehicle body enters a “bake” oven where the paint is cured.

There are booth design features and operational practices that help reduce paint overspray, efficiently capture paint particles and dirt and, in turn, reduce cleaning requirements. Examples of such features are controlled downdraft waterwash systems and the use of masking agents. In booths with downdraft waterwash systems, a downward air flow forces paint particles and solvent, (primarily paint overspray, solvent and maintenance material wastes), down through the grates and into the eliminator. The eliminators are located below the basecoat and clearcoat zones in every paint booth.

The water recirculating systems are the large reservoirs of water beneath the booth (under the grates) that carry the paint overspray away from the booth. This circulation of water helps balance the air flow in the paint booth. The booth water discharges into a paint pit (usually located outside of the building) where it is treated with detackifiers, flocculants, and defoamers to remove the “stickiness” of the paint and to coagulate the very small paint particles into larger particles that form a paint sludge. Water is continously recirculated and returned to the spray booths. The paint sludge is eventually collected from the pit for further treatment and reclamation or disposal. (See Appendix 1, Figure 4 for booth layout).

“Masking” is used to cover the surface of booth components (e.g., robots, hoses) to protect them from a paint overspray build up. Two types of masking can be utilized: (1) protective covers and (2) chemical agents. Protective covers refer to a variety of shielding materials used to blanket or wrap booth components. The selection of protective covers depends on the component, the type of paint being applied and the anticipated amount of overspray. Protective covers include:

- polyethylene (plastic) sheeting and masking cling film
- plastic hose-wrappers
- robot socks and covers
- tar paper or roofing felt

Chemical masking agents are sprayed onto booth walls and windows to form a protective film. Several types of agents are used depending on the type of paint used, the extent of overspray, and the component being masked. The masking agent may form a dry film (peel coating) or it may remain in a tacky, semiliquid state (tacky coating).

Peel coatings are applied as a liquid and form a transparent film which covers the clean walls and windows. Accumulated overspray is periodically removed by peeling this film from the surfaces. Tacky coatings are sprayed onto clean walls and windows and provide a moist film where paint overspray accumulates. Tacky coatings can be washed from surfaces using low-pressurized water.

GENERAL PAINT SPRAY BOOTH CLEANING PRACTICES

Both the appearance and the quality of the painted surface of the vehicle body are the primary objectives of the painting process. Eliminating dirt and other paint particulates from the booth helps maintain a very clean paint spray booth which is essential to meeting these objectives, as dirt in the booth air and on the booth components is a source of contaminants that potentially can adhere to the wet paint on the vehicle and cause quality defects. To achieve a high quality level, both the operations personnel and the booth components are subject to strict cleanliness standards.

Components of spray booths that are cleaned on a regular basis include walls/silhouettes, windows, floor grates, floors, conveyors, hoses, robots and related equipment. The frequency of cleaning paint spray booths in a paint shop depends on the rate of paint accumulation and the degree of cleanliness required by the plant. Variations in cleaning practices are due to several factors:

- spray booth design
- paint type
- paint application method
- robot type
- paint application transfer efficiency
- time restrictions
- cleanliness requirements
- labor requirements
- safety concerns

Solvents are widely used to clean many spray booth components. Typically, solvent with a hydrocarbon base, (e.g., xylene, n-butyl acetate, methylisobutyl ketone, petroleum naphtha, etc.) is applied by wiping or spraying major booth components. Small items, like spray equipment tips, are often dipped into a solvent bath. A variety of alternative practices are also used to minimize the amount of solvent required, remove the dried paint or to protect the component from paint deposition so that cleaning is either not required or is minimized. These alternatives include mechanical methods and the use of water-based or low-VOC content cleaners.

Mechanical methods include water blasting and the use of small tools such as brushes, chisels, razor blades, putty knives, and other scrapers, squeegees, or rags. Often small tools are used in conjunction with other alternatives to reduce or eliminate the use of cleaning solvents.

Water blasting refers to spraying water at high pressure, such as 5,000 or 10,000 psi. In some plants the water is heated to enhance cleaning effectiveness. Two configurations of high pressure water blasting are commonly used. The first, used to “spin-jet” floor grates consists of a portable lawnmower-like unit with high pressure water. In the second system, high pressure water is supplied through a piping system to long-handled spray “lances” or other types of spray guns. Such spray guns may be used to clean almost all components of the spray booth.

A recent alternative to organic based cleaning solvents is the use of water-based or low-VOC cleaners. These are specially formulated to decrease the VOC content while maintaining the necessary cleaning standards. After these low VOC cleaners are applied and allowed to chemically react with the coatings on the booth components, the surfaces are rinsed with low pressure water (60-80 psi). Brushes may also be used to accelerate the paint removal. The waste residuals and paint sludge being removed are allowed to drop through the floor grates to the booth water below where they move with the water to the paint sludge pit.

INDIVIDUAL PLANT OPERATIONS AND DISCUSSION

PLANT 1

Background

Plant 1 is an assembly plant that produces a line of full-size pickup trucks with several options, such as standard or extended cabs, long or short boxes, and two or four wheel drive. While running production all three shifts, Plant 1 produces 1,224 vehicles per day. (at a rate of about 52 trucks per hour). The 2.4 million square foot plant employs 3,995 hourly and 332 salaried employees.

The trucks are painted continuously throughout the day through nine modular paint booths ("mods"). Six of the mods are used for production, while the other three are used for repair coats. Each shift is responsible for the daily cleaning of two production spray booths and one repair spray booth. The paint shop is set up in a modular fashion where the vehicles stop in each zone (as opposed to a continuous line). This allows the trucks to be painted while stationary.

Paint Spray Booth Process at Plant 1

Once the vehicle enters the main paint shop, or "clean room", it has already passed through the phosphate system and prime booths, and a sealer and full body primer surfacer have been applied. The vehicle carrier is moved by an indexer (conveyor chain) into a pattern that feeds one vehicle at a time into each one of the nine mods. Each mod has the same layout which includes four zones followed by a series of ovens. The zones consist of the basecoat, flash enclosure, clearcoat, and observation (see Appendix 1, Figure 3). There are four vehicles in each mod at one time, each in a different zone. Each vehicle remains in its respective zone the same length of time. Once in the mod, the vehicles do not move independently.

The indexer pulls the vehicle into the first zone of the mod which is the basecoat zone. The vehicle stops when the indexer hits a clamp which then holds it in place and the zone doors shut. The basecoat zone is completely automated with four robots. The robots paint the entire vehicle, both inside and outside, in three and a half minutes. The doors then open, allowing the vehicle to pass through to the next zone--the flash enclosure.

After drying briefly, the vehicle enters the clearcoat zone, which also has 4 robots. The final zone is the observation zone. Here, quality control personnel closely examine the vehicle, labeling it to either continue down the paint line or be re-routed to the repair booths. After the vehicle has passed through the four zones, it enters a series of ovens. The ovens dry and harden the paint, completing the paint process.

Paint Spray Booth Cleaning Practices at Plant 1

The majority of the paint is removed from the spray booths with highly-pressurized water. A solvent is used for detail work on the robots and in high priority areas in the booth. There are approximately eight cleaners per shift working within and around the booths. Six or seven booth cleaners work in the basecoat, flash, clearcoat, and observation zones, while the remaining cleaners clean the floors and other areas of the clean room. Each shift fulfills all of the daily cleaning practices on one of their three assigned mods, while touching up the other two booths (See Table 1).

Table 1: Plant 1 Cleaning Schedule

Shift	Mod Number	Mod Number	Repair Mod
First	2	5	8
Second	3	6	9
Third	1	4	7

Daily Cleaning

(1) The booth is prepared for cleaning by programming the robot spray guns to move to their highest position with the tips near the ceiling.

(2) The grates in the basecoat and clearcoat zones are cleaned with the spin-jet washer referred to as the "mower". The mower water blasts the grates at 8,000 psi, carrying the paint overspray down to the eliminator. The entire floor of the booth is gone over approximately twice, missing only the corners which are inaccessible to the mower. The grates are then flipped over and blasted on the other side. The mower is running approximately 25-30 minutes for each zone with water being sprayed through six nozzles on its underside. The size of the tip regulates the volume of water sprayed at a specific pressure. While running at 8,000 psi, the mower uses 25.2 gallons per minute. The mowing results in a consumption of approximately 1,400 gallons of water per mod.

(3) The cleaning lance is hooked up to the water supply at a pressure of approximately 5,000 psi. It is a hand-held, high-pressurized water spray gun. The cleaner blasts the center track, purge box, corner grates, indexer, holding clamps, and lower section of walls with the lance. The lance is run for approximately one hour in both topcoat paint zones. Its nozzle has a tip which allows 12 gallons per minute to pass through; this results in a consumption of 1,440 gallons of water per mod.

(4) The tip is then taken off of the lance to create a low-pressurized stream (approximately 1000 psi). The walls, upper windows, and lower robot covers, which had previously been covered with tacky coat, are sprayed. The tacky coat and overspray come off easily and

flow down through the grates and into the eliminator. When sprayed for ten minutes, the low-pressurized lance uses 860 gallons per mod.

(5) The silhouettes, doors, and ceiling are spot-checked for paint accumulation and paint scraps. The high-pressurized cleaning can deposit paint pieces all over the inside of the booth. This paint is then scraped off with a flat blade.

(6) The door windows, doors, and the door handles are cleaned with a rag and solvent.

(7) The robot arms are lowered, so that all parts are accessible to the cleaners. The dirty robot covers are ripped off and thrown into a plastic bag for disposal.

(8) Certain areas on the robots (where the paint had saturated and soaked through the covers) and the purge box are cleaned with a rag saturated with solvent. The spray gun tips and joints are also cleaned with a solvent. Solvent is used rather than water due to its fast evaporation rate which eliminates the possibility of water droplets falling on the vehicles as the robot passes over them during the painting.

(9) New robot covers are then put on and petroleum jelly is applied by hand to the joints on the robot arm. These areas are not tightly wrapped by covers due to their need for mobility. The petroleum jelly prevents the overspray from adhering to the sensitive joints.

(10) The solvent-filled rags and wet robot covers are disposed of in a non-hazardous waste bin.

(11) The tacky coat is reapplied through a spray gun to the walls, upper windows, and robot covers.

<u>Weekly Cleaning</u> - Plant 1

(1) The center track and ledge along lower wall is scraped with a spud, which is a long hoe-like tool. The paint-filled barrier coat scrapings fall down between the grates into the eliminator.

(2) A thick layer of barrier coat is applied to the center track.

<u>Bi-Annual Cleaning</u> - Plant 1 (occurs during the July and Winter Holiday shutdowns)

(1) The entire booth is cleaned in detail following daily cleaning procedure.

(2) The water is drained from the eliminator

(3) The walls of the eliminator are scrubbed and rinsed to remove all paint build up.

(4) The water is returned to its previous level.

The following table shows the booth cleaning material usage and VOC emissions:

Table 2: Plant 1 Paint Booth Cleaning Material Usage*

Material	**Usage per Month (gal/month)**	**VOC Content (lbs/gal)**	**VOC Emissions (lbs/year)**
Water	266,000	0	0
Tacky Coat	330	10	39,600
Barrier Coat	200	4	9,600
Purge Solvent	200	6.93	16,622

***** See "Sample Calculations" in the Appendix.

Recommendations for Plant 1

The following recommendations are based on our observations at Plant 1:

(1) Improve air flow in mods to reduce overspray. Since the topcoat zones are completely automated, the air flow could be adjusted specifically for the robots. Also, the robots could be programmed "tighter" to paint the edges of the vehicles body closer, minimizing the overspray. The reduction in overspray would reduce the amount of materials, time, money, and labor required to clean the booths. Most importantly, it would lengthen the interval between robot cover changes.

(2) Limit access to the solvents. Currently, all of the cleaners have access to the solvents. Even though solvent usage is discouraged for booth cleaning, it is not restrictively managed in the plant. When using solvents, the overspray comes off with a lot less effort. This makes the solvent very appealing to the cleaners.

(3) Create an accounting procedure to track the solvent usage for booth maintenance. Although Plant 1 prides itself in its low-solvent cleaning procedures, the exact amount used per cleaning is unknown. A flow meter could be placed at each solvent dispenser, allowing the maintenance management company to measure the gallons used for the booth cleaning. After an initial baseline is measured, efforts to reduce the solvent usage could begin.

(4) Supply cloth booth coveralls to all employees, instead of using disposable ones. The disposable coveralls were specifically for newly-employed cleaners who had not yet received their permanent uniform. Yet, many long-term employees wear disposable suits everyday. Although they may wear the same suit for an extended time, when they are

dirty, they throw them away. By investing in cloth coveralls, Plant 1 could reduce both their purchasing and disposal costs.

(5) Create a disposal system for the wet rags and robot covers. Currently, the cleaners use a general trash bin which is conveniently located beneath the floor at the end of a mod. They toss the rags, gloves, and robot covers down the chute into the open bin. Here, the solvents evaporate and are considered an internal discharge. A waste bin, that can be sealed shut, should be available for the cleaners to dispose the saturated solid wastes.

(6) Encourage communication between the maintenance management company, the cleaners, and the environmental engineers. The booth cleaners are employed by Plant 1, however, the maintenance managers are contracted by Plant 1. They were hired to oversee the cleaning of the paint booths, which seems to threaten the cleaners. The environmental engineers rely on the management company to handle many of the booth maintenance problems. Unfortunately, this reduces the environmental engineer input input in the decisions that are made and their expertise is not utilized. By encouraging communication and collaborating ideas, the cleaning practices and the waste material handling and disposal practices could be more efficient and effective.

PLANT 2

Background

Plant 2 assembles three full-size vehicles. The paint shop portion of the assembly plant has a production rate of 52 jobs/hr. It was constructed about seven years ago with the intent of producing “best in class” painted vehicles. It also included state of the art pollution control and abatement equipment (e.g., carbon absorbtion wheels, incinerators) to control and reduce release of VOCs and meet environmental requirements. This equipment typically reduces the quantity of emissions from the VOC generated in the booth cleaning process by 80% or more. The paint shop includes two enamel (color) booths and one prime booth, all which must be cleaned daily during the first shift (non-production morning shift), minimal cleaning during every break while production is in operation, and more intense cleaning over the weekends. The blackout paint booth requires cleaning only on the weekends. Plant 2 employs 14 booth maintenance cleaners and a maintenance manager. The booth maintenance team begins cleaning immediately after the last vehicle of that day’s production passes through the paint booth.

Paint Spray Booth Process at Plant 2

Plant 2 has three main spray booths (two enamel and one prime) and a blackout booth. The booth design promotes continuous line movement and excellent booth balance which involve air flow that sweeps paint overspray into the circulating water below. The two enamel booths are each used to apply acrylic enamel basecoat, two-component urethane clearcoat, and topcoat repair. The prime booth is used to apply one-component urethane antichip and modified-polyester taupe prime paint. All vehicle bodies pass through this booth, including those that will receive two-tone finishes. All first-run vehicles pass through No. 1 Enamel booth. No. 2 Enamel booth is used only for two-tone painted vehicles and repair.

The following details the movement of the vehicle through the painting process after E-coat paint and sealer application:

The vehicle enters the prime spray booth (185 ft long). The line begins with a feather duster to remove any dirt and residue on the exterior. Next, the vehicle passes through an entrance vestibule which blows off any remaining dirt and residue. The vehicle then enters the manual urethane antichip zone followed by a 2-robot urethane zone and buffer zone. The second half of the prime spray booth is the interior and exterior color prime. This section includes 12 stationary bells and 6 overhead bells followed by a buffer zone. Last is the manual touch-up zone and exit vestibule.

After a 30 minute prime paint cure through a “bake” oven, followed by an enamel “prep” (dry sanding, body wash and dry off oven), the vehicle enters an enamel spray booth entrance vestibule. The basecoat booth sections (175 ft long) have the following zone layout: blow-off, tack-off, manual spray for vehicle interior, 10 stationary and 3 overhead bells (auto), 2 reciprocators, 2 robots and flexible (manual touch-up). (In between the last robot zone and manual zone there is a section equiped for a potential future water-base reciprocator zone which will allow the use of water-based paint and low solvent cleaning practices.) The vehicle then enters a heated flash-off zone (100 ft long) for 5 minutes before entering the clearcoat section. The clearcoat booth floor plan (140 ft long) is the same as the base section: manual interior, 10 stationary bells, 6 overhead bells, 2 robots, and flex except that buffer zones are located between all sections to provide for the highest possible quality paint finish (See Appendix 1, Figure 2).

Following a 30 minute enamel oven cure/bake and inspection ,the vehicle is allowed to either continue down the line or is re-routed to enter No. 2 Enamel for two-tone painting or repair. After being polished and prepared for foam application, the vehicle is sent to a foam and blackout spray booth (40 ft long) or a touch-up & foam spray booth (80 ft. long). The blackout spray booth consists of only an automatic zone where the vehicle wheel wells are painted black for tri-coat and specific vehicles.

As earlier mentioned, booth air flow balance is critical to a quality painting process, and in solvent and water-borne application is reliant on recirculating water flow. Water enters the booth sub-floors from the outside walls and fills to the height of the dynatubes which carry the water into the eliminators below. As the water is circulating and draws air flow to it, vapor and paint overspray is picked up by the moving water and drawn into the dynatubes. In the eliminators, the vapor is collected by exhaust pipes, while the residual paint overspray and water are discharged to the very large paint water and sludge separation pits, which are open concrete structures located outside the building (approximately 800,000 gallons total volume). Chemical and physical treatment of this water causes the paint sludge to coagulate and eventually sink to the bottom of the pit after several days of floating on the surface of the water. These large pits are designed to allow about a 13 minute retention time so the now treated water and coagulating paint sludge will separate and the relatively clean water will pass over a weir and be returned (via pumping) back to the paint spray booths. Flow rates from the pits to and from the spray booths are in the 50,000 gallons per minute range. Due to evaporation loss of about 10,000 gal/day of spray booth water, fresh make-up water is added to the paint sludge pit water.

Paint Spray Booth Cleaning Practices at Plant 2

The paint overspray in these booths is cleaned using a combination of organic solvents and high pressure water blasting. The spray booth cleaning includes daily cleaning from midnight to 5 AM, weekend cleaning from midnight on Saturday to 5:30 Monday morning, and in-between shift cleaning (3 to 6 times a day) to wipe the applicator tips and bells.

<u>Daily Cleaning</u>

Three booth cleaning personnel work in the prime booth and five cleaners work in each enamel booth. Any cleaners not in the booths are busy cleaning the floors outside the booths or are on a different assignment in the plant.

(1) At the beginning of the shift, the maintenance manager unlocks and enters the paint kitchen/dock. He checks and records the purge solvent level, and then opens the valve to begin pumping the solvent to the paint booths. He closes the valve when the solvent level has dropped 30 inches in the tank, or 270 gallons (9 gals/inch). The cleaners in the prime and enamel booths fill as many 5 gallon buckets as they can while the pump is on -- 10 to 15 buckets of solvent per zone.

(2) In the prime and basecoat manual zones, the walls, windows and silhouettes are scrubbed with a mop (lint-free rag on the end of a stick). Each cleaner in the manual zones has an average of 12 buckets (3/4 full) of solvent. The mop is dipped into the bucket of solvent and the solvent is applied to the walls and windows with the solvent layden mop. (This method allows a fair amount of the solvent to drip / drain directly into the water below, where it would eventually evaporate either there in the plant or from the outside pit instead of through the booth vents.) The walls and windows are scrubbed with the mop and solvent until clean. The windows are squeegeed after being cleaned and the solvent

drips through the grates and into the water. The hoses, tips, and purge boxes are first scrubbed with brushes to loosen the paint and then wiped with rags or mops saturated with solvent. When time permits, or when needed, the robot covers are wiped down with mops to keep them clean until they are changed on the weekend.

(3) The prime automatic zone (bell zone), which does not collect a significant amount of overspray, is cleaned every night. Two cleaners, each with 6 buckets of solvent (one at each stationary bell), clean the hoses, overhead and stationary bells, walls, windows, and silhouettes.

(4) The last section of the prime booth is the manual touch-up. The cleaning includes scrubbing and wiping all the hoses, gun tips, walls and windows, while using 8 buckets of solvent.

(5) The basecoat automatic zone 1 (bell zone) is only used when zone 2 is not operating, but it still requires cleaning. The overspray is cleaned off the silhouette between zones 1 and 2 with a mop and the remaining buckets of solvent.

(6) In the basecoat robotic zone 2 (reciprocators), the walls and equipment collect a greater amount of overspray; therefore more cleaning is required. The cleaning procedure is similar to that for the manual zone, but the methods and solvent usage differ with the cleaner's discretion. Ten buckets of solvent are used in this zone. A brush and one bucket of solvent are used on each robot, with the remainder of the solvent being used on the other booth fixtures. The walls and windows are cleaned thoroughly, even when no overspray is visible. A mop is dipped into a bucket and used to apply the solvent on the sides of the booth. The windows are washed at least twice and the excess solvent is not squeegeed off.

(7) The last basecoat zone is the tri-coat manual, or flexible. The daily cleaning includes wiping all the gun hoses and tips with a rag or brush and wiping down the walls and windows with mops.

(8) The same cleaning procedures are used in the clearcoat manual, robot, automatic and flexible zones.

(9) At the end of the shift, the rags are wrung out over the remaining bucket of solvent. With this solvent, the cleaners scrub off their boots until they are paint-free. The spent solvent is then either disposed down through the grates into the recirculating water or left in the booth for the cleaning robot tips during production breaks. All of the brushes, mops, rags and buckets are collected and stored in the cleaner's locker until the next day. Dirty and contaminated rags that can no longer be used, are collected in a container and made available for disposal as non-hazardous wastes.

(10) The solvent used in the booth cleaning process appears to be either evaporated in the booth air flow and released as stack or internal fugitive emissions or it may be absorbed in the water and released over time within the booth or from the outside sludge separation pit. VOC collection and abatement equipment typically reduces emissions of the VOC generated in the cleaning process by 80% or more. Solvent reclamation boxes are accessible in the paint booths for unused and used purge solvent. Although currently these are used for purge solvent only during production, there may be opportunity to also use them to recover some booth cleaning solvent.

Weekly Cleaning - Plant 2

On Friday night after production ends, the weekend cleaning begins. One hundred and seventy gallons of purge solvent are used during this six hour shift. This cleaning was not observed for this study, but the information was obtained from the paint department and maintenance personnel.

(1) Walls, windows, silhouettes, hoses, and gun tips are cleaned following the daily cleaning procedure, but manual zones are not included in Saturday cleaning.

(2) The grates from the prime, enamel, and blackout booths are removed and transported downstairs to be water blasted at 10,000 psi. Clean grates are put back in place for the next weeks production. The blasting is completed in an enclosed area by a contracter. It lasts 5 hours, 5 days a week and the water flow rate is 24 gpm. Water usage is about 144,000 gal/month. The paint sludge is filtered and hauled away for disposal and the excess water is discharged via the process sewer to the plant's general water treatment facility.

(3) New robot covers are installed in each of the booths, while the used covers are disposed as non-hazardous waste (unless completely saturated with paint).

(4) The barrier coat is scraped off the center track with a spud (hoe-like tool) and allowed to drop to the recirculating water below.

(5) The cupboards and other details of the robots are opened and thoroughly scrubbed and wiped.

(6) The walls and windows in the blackout booths are scraped with a chisel or spud. The tar paper, which is laid out on the booth floors during the cleaning, catches the falling pieces of paint. Both the paper and the paint pieces are disposed in general refuge. The robot tips in the blackout booths are cleaned by wiping them with a rag saturated with solvent.

(7) The sub-floors are scrubbed to remove any large visible chunks of paint build-up.

On Sunday night, 130 gallons of purge solvent are used during the following cleaning procedures (not observed for this study):

(8) The manual zones are cleaned as described above, but in more detail.

(9) The barrier coat masking is applied to the center tracks with a brush. About 28 pounds of barrier coat are used each weekend.

(10) The sprayable tacky coat masking (which reduces the booth dirt by an estimated 20%) is applied to the new robot covers with a spray gun. Approximately 9 pounds of tacky coat are used each weekend.

Quarterly Cleaning - Plant 2 (not observed for this study)

When needed, the air flow filters are changed and disposed of as non-hazardous material. The sub-floor is cleaned by scraping large paint chunks off with a hoe. Lastly, the eliminator deck (back section) is scraped clean and the paint sludge is hauled away for disposal.

Bi-Annual Deep Cleaning - Plant 2 (not observed for this study)

During this cleaning, all booth components, fixtures and areas described above are cleaned in great detail and the center tracks in all the booths are water blasted at a pressure of 5000 psi.

Annual Cleaning - Plant 2 (not observed for this study)

Once a year, the tacky coat in the clearcoat (manual) zone, flash-off tunnel, and prime urethane zone is blasted off and reapplied.

Table 3 outlines the approximate paint booth cleaning material usage data and the calculated pounds of annual VOC generated. (NOTE: Collection and abatement equipment typically reduce VOC emissions from those generated during the spray booth cleaning process by 80% or more.)

Table 3. Plant 2 Paint Booth Cleaning Material Usage

Material	Usage in Booth Cleaning, gal/month	VOC Content, lb/gal	VOC Generated from Booth Cleaning, lb/year
Water @ 10,000 psi	145,000	0	0
Purge Solvent	5520	7.17	474,941
Barrier Coating	10	6.5	780
Tacky Coating	5.5	2.21	146

Recommendations for Plant 2

The following list of recommendations are based on observations of the cleaning practice that were identified as possibly costly or wasteful of resources or time, and/or could benefit from improved material handling practices:

(1) Since the amount of solvent used is limited by the maintenance manager, there is opportunity for further use reduction. The booth cleaners use the amount of solvent they receive. 270 gallons of solvent each night appeared sufficient to go over the components and fixtures two or three times. The amount of solvent pumped into the booths could be reduced to the point where there is no leftover solvent and booth component/fixtures are

only cleaned once. Based on our observation, this could reduce solvent costs and VOC emissions without jeopardizing the paint quality.

(2) Reclaim unused and/or dirty purge solvent by placing it into the purge reclamation boxes located in each spray booth. The reclamation system is designed to separate the two kinds of purge solvent (one used for cleaning and the other used to purge paint delivery lines). After separation, the solvent is filtered and sent back to the supply tank. Using the reclamation system has the potential to decrease solvent usage by up to 65 gallons per day (13 cleaners x one 5 gallon bucket each). This would also alleviate the problem of leaving full buckets of solvent in the booths for production shifts and allowing the additional release of VOC between shifts. The production shift painters should be allowed only a half of a bucket of solvent each to wipe their gun tips.

(3) The cleaners should be trained or instructed to wring out the rags and allow excess solvent to drip in to the buckets from the mops, rags and brushes before applying to booth components.

(4) Use tacky coat on walls, windows, silhouettes and robot covers in *all* zones to reduce purge solvent usage and daily cleaning time. The tacky coat contains 3.24 times less VOC per gallon than the solvent and can be rinsed off on a weekly basis due to excellent booth balance. It is estimated that solvent usage could decrease by at least one half (135 gallons) each day since the majority of the solvent is used to clean the walls, windows, and silhouettes.

(5) Assure that contaminated solid waste, such as rags and coverings are not saturated with paint and/or solvent when ready for disposal. Allow all moist or contaminated material to remain in a vented area prior to disposal so any VOC emissions pass through an incinerator or carbon absorbtion system.

(6) Collect and wash dirty nylon rags. This will reduce the amount of solid waste as well as costs for purchased material and waste disposal. Each cleaner uses a couple arm loads of rags each day. These spent rags could be easily placed in a specified bin and taken away to be cleaned and recycled.

(7) Have cleaners wipe their boots off in the standing water available by the booth doors and go directly to the locker rooms to change. Do not wear boots outside the paint facilities. This will eliminate the need to wash boots off with solvent.

PLANT 3

Background

Plant 3 assembles two models of small, four door sedans. It produces 985 vehicles per day, 5 days per week; operating on two shifts. The 3 million square feet facility sets on 310 acres of land. Although constructed in 1953, the plant has only been manufacturing vehicles since 1983. The paint shop was completely moderized in 1993 and utilizes state-of-the-art low-VOC painting technology.

The paint system uses a protective powder prime coat, followed by a water-borne basecoat and a solvent-based clearcoat paint. The use of the powder prime coat in conjunction with the water-borne basecoat significantly reduces solvent usage in both the painting and cleaning processes. There is one prime booth, two topcoat booths and one repair booth. In all booths, the air flow is maintained at a level high enough to direct the overspray downward into the wet collector, thus minimizing material settling on the surrounding walls and equipment.

Paint Spray Booth Process at Plant 3

The vehicles enter the powder prime booth where multiple robots, stationary bells and manual guns coat the vehicle with powder. Next, the vehicle passes through an oven which cures the powder coat creating a uniform protective film.

Next, the vehicles enter one of the topcoat booths, which are 233 feet long and contain a basecoat, flash off and clearcoat zone. In the basecoat zone, the paint is applied by six manual guns, six stationary verticals, three overhead bells, three robots and two touch-up manual guns. A flash off zone is located between the basecoat and clearcoat zones. In the clearcoat zone, multiple robots, stationary verticals and overhead bells and manual guns apply the clearcoat. Finally, the vehicles pass through the final bake oven to cure the basecoat and clearcoat coatings.

Vehicles entering the repair booth are masked with plastic and tape, leaving only the area requiring repair exposed for painting. The repair booth is 128 feet long and contains three robots used to apply the basecoat and two manual guns to apply the clearcoat. A small flash off zone is located between the basecoat and clearcoat zones.

Paint Spray Booth Cleaning Practices at Plant 3

The paint booths are cleaned daily during third shift while production is shut down. Thirteen employees can complete the cleaning in approximately two hours per booth. A deep clean is performed on the weekends and once a year during the model changeover.

Daily Cleaning - Plant 3

(1) The powder coat prime booth is cleaned using a vacuum, fitted with a brush at the tip. A dry, lint-free rag is used to dust off the booth walls and compressed air is used to blow out the powder nozzles. The majority of the powder overspray falls through the grates and is collected in a basin below the booth. In a powder system, water wash collectors are not required.

(2) In the water-borne basecoat section of the booth, the bell cups are removed and soaked in solvent while the booth cleaning is being completed. The exposed portion of the robot arms are scrubbed with a solvent soaked rag.

(3) The walls, windows, hoses, and purge boxes are sprayed with a low VOC cleaning material and allowed to soak. A material-soaked brillo pad is used to scrub the hoses to remove the heavy paint build up. After a few minutes, low pressure water (60 psi) is used to rinse the cleaning material and paint into the recirculating water paint sludge system below. A brush or a solvent soaked rag is used to remove any residual paint from the equipment or booth interior. The spent rags are disposed of as non-hazardous waste.

(4) Once the cleaning is complete, a tacky coat material is reapplied to the interior surfaces of the booth. It is sprayed onto all surfaces that have been cleaned, except the bells and robot arms.

(5) The same cleaning procedures are employed in the clearcoat booth, except that the bell cups are not removed. They are scrubbed in place with a solvent soaked rag. The flash off area is cleaned only when necessary.

Weekly Cleaning - Plant 3

(1) The center track is scraped and then washed with a cleaning material and water. After drying, a barrier coating is reapplied.

(2) The grates are removed twice per week and cleaned in a fluidized silica sand bed. In this unit, the grates are lowered into a hot (850 F) sand bath that is fluidized with air (10,000 cfm). The organic materials on the grates vaporize and combust in the bed or in the afterburners. The flue gas is drawn through a cyclone to remove the particles before being discharged to the atmosphere. The paint particles that remain in the sand are recovered and sold to a recycling facility. The fluidized sand operation contains 15,840 pounds of silicon dioxide sand and consumes 33 CFM of natural gas (1,800,000 BTU/hr) and 12 kWh/hr of electricity. Once clean, the grates are sprayed with a white grate coating to prevent the paint from adhering to the metal surface.

(3) The robot covers are changed once per week and disposed of with the rags. Tacky coat is applied to the outside of the new robot covers once they are in place.

The material usages are presented in the following table:

Table 4: Plant 3 Paint Booth Cleaning Material Usage

Material	Approximate Usage (per month)	VOC Content (lb./gal)	VOC Emissions (lbs / year)
Water @ 60 psi	6600 gal	0	0
Tacky Coating	250 gal	0.30	900
Grate Coating	6000 lbs.	0	0
Barrier Coating	3000 lbs.	0	0
Booth Detergent	700 gal	1.8	15,120
Booth Solvent	400 gal	7.06	33,888

Recommendations for Plant 3

(1) For applications that require solvents, use rags, rather than brushes to apply solvent and help prevent solvent dripping and waste by ringing out rags before using.

(2) Return unused solvent to an inplant reclamation site.

(3) The spent rags could be laundered rather than disposed of as waste. This would reduce purchase and disposal costs for the rags and eliminate this solid waste.

COMPARATIVE ANALYSIS OF THE THREE PLANTS

After gathering the data and information from each of the three plants, it was decided that there are three major criteria which determine cleaning practices and material use:

(1) type of paint being applied,
(2) booth design, and
(3) booth management practices.

Table 5 provides a comparison of material usage among the three plants.

Table 5: Average Material Usage (gal/month)

	Water	Purge Solvent	Tacky Coat	Barrier Coat	Booth Detergent	Grate Coating
Plant 1	266,000	200	330	200	0	0
Plant 2	144,000	5,520	5.5	10	0	0
Plant 3	6,600	400	250	3,000 lb/month	700	6,000 lb/month

NOTE: Plants 1 and 2 apply solvent-based paint while Plant 3 applies mostly powder and water-based coatings.

Significant differences in the amount of VOC generated during cleaning operations appear to be the result of the differences in (a) material use among the three plants, identified in Table 5, above, and (b) the specific cleaning practices employed, outlined in Table 7, on the following page. Table 6, below, displays the wide range in quantity of VOC generated among these three plants. VOC collection and abatement equipment typically reduces the emission of the VOC generated by 80% or more.

Table 6: Comparative Annual Pounds of VOC Generated from Booth Cleaning

	Purge Solvent	Tacky Coat	Barrier Coat	Booth Detergent		Total Pounds VOC Generated
Plant 1	16632	39600	9600	0		65,832
Plant 2	474941	146	780	0		475,867
Plant 3	33888	900	0	15120		49,908

Table 7: Comparison of Cleaning Practices

Paint Spray Booth Cleaning Methods, Equipment, and Materials								
		Booth Component						
Plant No.	**No. of Booths**	**Walls, Windows and Silhouettes**	**Ceilings**	**Grates**	**Robots/ equipment**	**Hoses**	**Spray equipment tips**	**Fixtures (center track, clamps)**
1	9	Lance with high-pressure water Windows wiped with solvent and rag Apply tacky coat to all	Spot-check for paint scraps and scrape with flat blade as needed	Scrape and spin jet grates	Wipe robots with rag when needed Change robot covers and spray tacky coat	N/A	Wipe with solvent and rag	Blast center track, purge box, indexer, and clamps daily & scrape weekly Spray barrier coat on center track
2	3	Scrub with solvent and brush, then wipe with mop; squeegee off excess solvent on windows Blast off tacky coat and re-apply in 3 zones annually	Wipe ceilings with mop as needed	Remove grates and clean using high-pressure water blasting	Some scrubbed with solvent & brush between cover changes Change robot covers and apply tacky coat Wipe down inside of cupboards	Scrub with solvent and brush, then wipe with mop	Wipe at end of production shifts, during breaks, and daily cleaning with solvent & rags	Scrape center track weekly Brush on barrier coat Water blast center track bi-annually
	1	**Blackout:** Overspray is scraped with chisel or hoe	**Blackout:** Overspray is scraped with chisel or hoe	**Blackout:** Remove and high-pressure water blast	**Blackout:** Change robot covers	**Blackout:** N/A	**Blackout:** Wipe tips with solvent and rags	**Blackout:** Overspray is scraped with chisel or hoe
3*	4	Spray on low VOC detergent, let stand, rinse with low pressure water Spray with tacky coat	Scrape as needed	Remove grates bi-weekly and clean in hot fluidized sand bed Coat with grate coating	Wipe arms with solvent and rag Change robot covers and spray tacky coat	Spray hoses with detergent, scrub with brillo pad, and rinse Spray with tacky coat	Remove and soak in solvent during cleaning	Spray center track and purge boxes with detergent, then scrub, rinse, and spray with tacky coat

***** Includes Enamel only. Plant #3 uses a powder prime coat, which requires only using a vacuum fitted with a brush at the tip to clean the booth. A dry rag is used to dust off the booth walls.

CONCLUSIONS

This study reviewed three distinctly different plants. It presents a snapshop of dynamic systems which are continually evolving and improving. Each of the three plants studied utilized different cleaning practices due to differences in the type of paint being applied, design of the spray booths and the booth cleaning management practices believed necessary for best-in-class paint quality. Although each of plants provided valid reasons for their particular practice, mostly to achieve the very best painted surface appearance and quality, a best management practice could still be drawn from fusion of the three cleaning practices.

The recommended best management practices in paint spray booth cleaning are as follows:

(1) water blast the grates weekly,
(2) scrape the center track weekly and apply low-VOC barrier coat,
(3) change robot covers weekly and spray with tacky coat,
(4) limit solvent use to spray tips and bells,
(5) rinse walls, windows, silhouettes and hoses with water daily and spray low-VOC tacky coat,
(6) assure that spent rags and coverings are dry and efficiently reclaimed or properly disposed,
(7) reclaim all solvent,
(8) maintain optimum booth balance,
(9) communicate effectively between engineers, booth managers and booth cleaners, and
(10) establish booth cleaning metrics.

In addition to the recommended best management practices, other conclusions have been drawn from this study. As the auto industry moves towards lower VOC materials, such as powder coatings and waterborne paint technology, the amount of solvent used for cleaning paint spray booths will continue to decrease. These technologies are being pursued jointly by the auto companies through U.S. CAR and a pilot plant has been constructed for evaluation of new technologies, materials and equipment. Additionally, education regarding the proper use of booth cleaning technologies will improve the efficiency of the cleaning process.

REFERENCES

BP Chemicals, N.J. Hazel, Life Cycle Assessment: OEM Car Paint Study

MVMA Information Bulletin, Plant Trip to Honda, Marysville, Ohio FEB 2-3, 1992, IF92-146, 7430 Second Avenue, Suite 300, Detroit, Michigan, March 16, 1992.

USCAR Low Emission Paint Consortium, A Unique Approach to Powder Painting Technology Development.

U.S. EPA Emission Standards Division, Alternative Control Techniques Document--Industrial Cleaning Solvents, EPA-453/R-94-015, Research Triangle Park, North Carolina, February, 1994.

U.S. EPA Emission Standards Division, Automobile Assembly Plant Spray Booth Cleaning Emission Reduction Technology Review, EPA-453/R-94-029, Research Triangle Park, North Carolina, March, 1994.

APPENDIX

Figure 1.

Paint Shop Process Layout

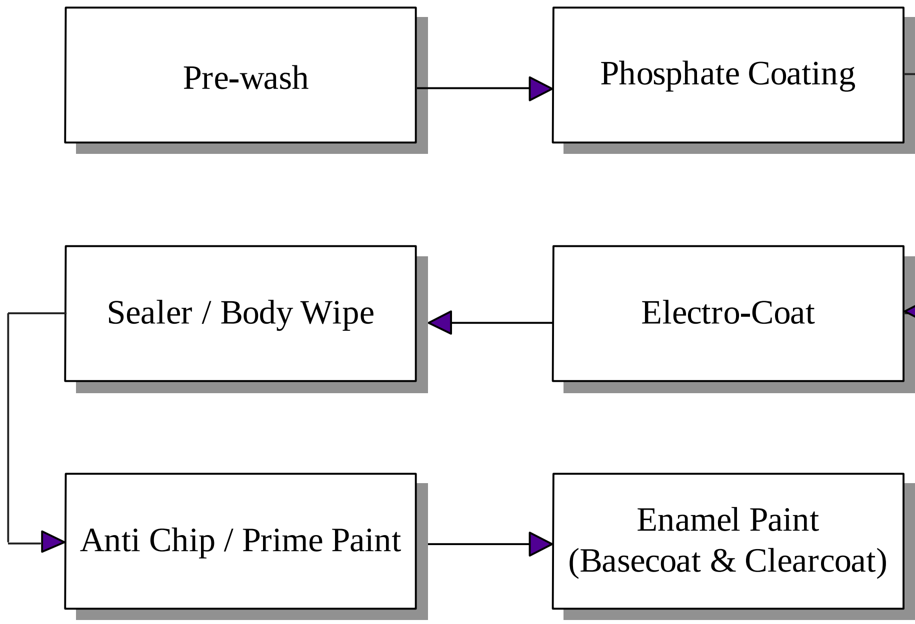


Figure 2.

Generic Enamel Paint Booth Layout (Continuous Line)

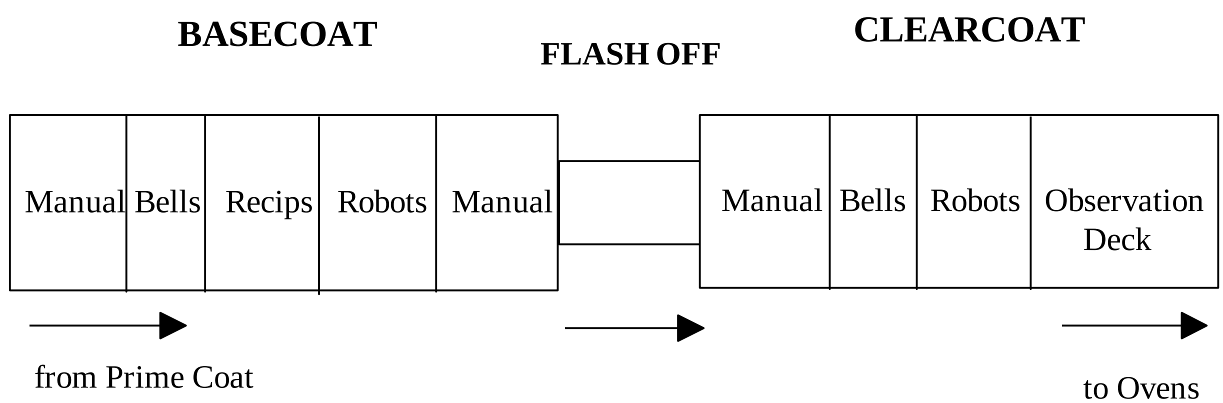


Figure 3.

Generic Enamel Paint Booth Layout (Modular Line)

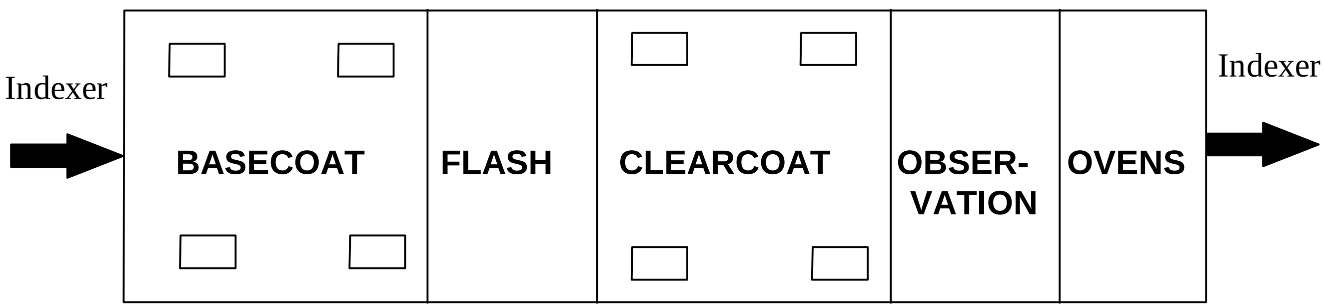
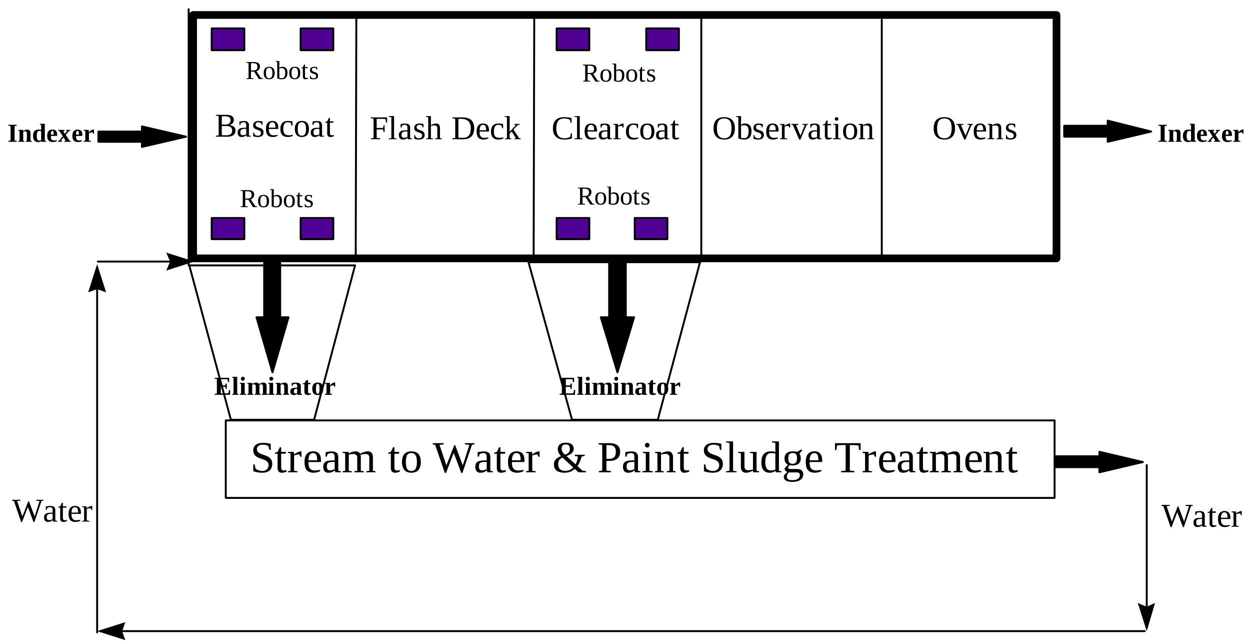


Figure 4.

Paint Booth Cross-Section



Sample Calculations

To calculate VOC content of cleaning products:

Density of product = specific gravity of product x density of water (lbs/gal)
= 0.883 x 8.34 lbs/gal
= 7.36 lbs/gal

VOC content (lb/gal) = % VOC/100 x density of product (lbs/gal)
= .30 x 7.36 lbs/gal
= 2.21 lbs/gal

To calculate VOC generated from booth cleaning (before entering control device):

VOC generated = product usage (gal/month) x VOC content (lbs/gal)
= 5.5 gals x 2.21 lbs/gal
= 12.15 lbs/month
= 146 lbs/year