4.2.2.8 Automobile And Light Duty Truck Surface Coating Operations[1-4]

4.2.2.8.1 General

Surface coating of an automobile body is a multistep operation carried out on an assembly line conveyor system. Such a line operates at a speed of 3 to 8 meters (9 to 25 feet) per minute and usually produces 30 to 70 units per hour. An assembly plant may operate up to 2 8-hour production shifts per day, with a third shift used for cleanup and maintenance. Plants may stop production for a vacation of one-and-a-half weeks at Christmas through New Year's Day and may stop for several weeks in summer for model changeover.

Although finishing processes vary from plant to plant, they have some common characteristics. Major steps of such processes are:

- Solvent[a] wipe
- Phosphating treatment
- Application of prime coat
- Curing of prime coat
- Application of guide coat
- Curing of guide coat
- Application of topcoat(s)
- Curing of topcoat(s)
- Final repair operations

A general diagram of these consecutive steps is presented in Figure 4.2.2.8-1. Application of a coating takes place in a dip tank or spray booth, and curing occurs in the flashoff area and bake oven. The typical structures for application and curing are contiguous, to prevent exposure of the wet body to the ambient environment before the coating is cured.

The automobile body is assembled from a number of welded metal sections. The body and the parts to be coated all pass through the same metal preparation process.

First, surfaces are wiped with solvent to eliminate traces of oil and grease. Second, a phosphating process prepares surfaces for the primer application. Since iron and steel rust readily, phosphate treatment is necessary to retard such. Phosphating also improves the adhesion of the primer and the metal. The phosphating process occurs in a multistage washer, with detergent cleaning, rinsing, and coating of the metal surface with zinc phosphate. The parts and bodies pass through a water spray cooling process. If solventborne primer is to be applied, they are then oven dried.

A primer is applied to protect the metal surface from corrosion and to ensure good adhesion of subsequent coatings. Approximately half of all assembly plants use solventborne primers with a combination of manual and automatic spray application. The rest use waterborne primers. As new plants are constructed and existing plants modernized, the use of waterborne primers is expected to increase.

Waterborne primer is most often applied in an electrodeposition (EDP) bath. The composition of the bath is about 5 to 15 volume percent solids, 2 to 10 percent solvent, and the rest water. The solvents used are typically organic compounds of higher molecular weight and low volatility, like ethylene glycol monobutyl ether.

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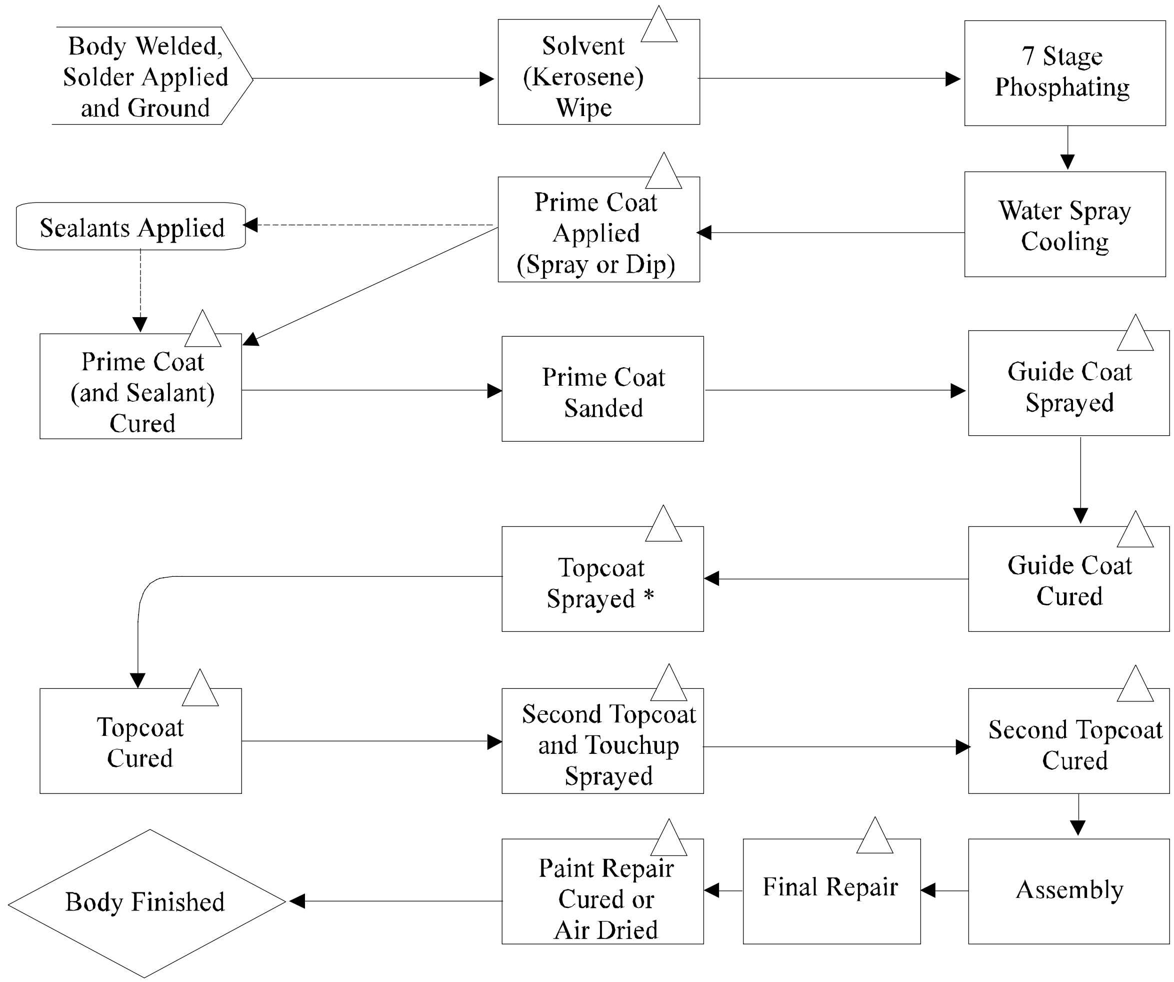
[a]The term "solvent" here means organic solvent.



*To get sufficient film build, for two colors or a base coat/clear coat, there may be multiple topcoats.

△ Potential Emmission Points

Figure 4.2.2.8-1. Typical automobile and light duty truck surface coating line.

When EDP is used, a guide coat (also called a primer surfacer) is applied between the primer and the topcoat to build film thickness, to fill in surface imperfections, and to permit sanding between the primer and topcoat. Guide coats are applied by a combination of manual and automatic spraying and can be solventborne or waterborne. Powder guide coat is used at one light duty truck plant.

The topcoat provides the variety of colors and surface appearance to meet customer demand. Topcoats are applied in 1 to 3 steps to ensure sufficient coating thickness. An oven bake may follow each topcoat application, or the coating may be applied wet on wet. At a minimum, the final topcoat is baked in a high-temperature oven.

Topcoats in the automobile industry traditionally have been solventborne lacquers and enamels. Recent trends have been to higher solids content. Powder topcoats have been tested at several plants.

The current trend in the industry is toward base coat/clear coat (BC/CC) topcoating systems, consisting of a relatively thin application of highly pigmented metallic base coat followed by a thicker clear coat. These BC/CC topcoats have more appealing appearance than do single coat metallic topcoats, and competitive pressures are expected to increase their use by U. S. manufacturers.

The VOC content of most BC/CC coatings in use today is higher than that of conventional enamel topcoats. Development and testing of lower VOC content (higher solids) BC/CC coatings are being done, however, by automobile manufacturers and coating suppliers.

Following the application of the topcoat, the body goes to the trim operation area, where vehicle assembly is completed. The final step of the surface coating operation is generally the final repair process, in which damaged coating is repaired in a spray booth and is air dried or baked in a low temperature oven to prevent damage of heat sensitive plastic parts added in the trim operation area.

4.2.2.8.2 Emissions And Controls

Volatile organic compounds (VOC) are the major pollutants from surface coating operations. Potential VOC emitting operations are shown in Figure 4.2.2.8-1. The application and curing of the prime coat, guide coat, and topcoat account for 50 to 80 percent of the VOC emitted from assembly plants. Final topcoat repair, cleanup, and miscellaneous sources such as the coating of small component parts and application of sealants, account for the remaining 20 percent. Approximately 75 to 90 percent of the VOC emitted during the application and curing process is emitted from the spray booth and flashoff area, and 10 to 25 percent from the bake oven. This emissions split is heavily dependent on the types of solvents used and on transfer efficiency. With improved transfer efficiencies and the newer coatings, it is expected that the percent of VOC emitted from the spray booth and the flashoff area will decrease, and the percent of VOC emitted from the bake oven will remain fairly constant. Higher solids coatings, with their slower solvents, will tend to have a greater fraction of emissions from the bake oven.

Several factors affect the mass of VOC emitted per vehicle from surface coating operations in the automotive industry. Among these are:

VOC content of coatings (pounds of coating, less water)
Volume solids content of coating
Area coated per vehicle

Film thickness
Transfer efficiency

The greater the quantity of VOC in the coating composition, the greater will be the emissions. Lacquers having 12 to 18 volume percent solids are higher in VOCs than enamels having 24 to 33 volume percent solids. Emissions are also influenced by the area of the parts being coated, the coating thickness, the configuration of the part, and the application technique.

The transfer efficiency (fraction of the solids in the total consumed coating that remains on the part) varies with the type of application technique. Transfer efficiency for typical air atomized spraying ranges from 30 to 50 percent. The range for electrostatic spraying, an application method that uses an electrical potential to increase transfer efficiency of the coating solids, is from 60 to 95 percent. Both air atomized and electrostatic spray equipment may be used in the same spray booth.

Several types of control techniques are available to reduce VOC emissions from automobile and light duty truck surface coating operations. These methods can be broadly categorized as either control devices or new coating and application systems. Control devices reduce emissions by either recovering or destroying VOC before it is discharged into the ambient air. Such techniques include thermal and catalytic incinerators on bake ovens, and carbon absorbers on spray booths. New coatings with relatively low VOC levels can be used in place of high-VOC-content coatings. Such coating systems include electrodeposition of waterborne prime coatings, and for top coats, air spray of waterborne enamels and air or electrostatic spray of high solids, solventborne enamels and powder coatings. Improvements in the transfer efficiency decrease the amount of coating which must be used to achieve a given film thickness, thereby reducing emissions of VOC to the ambient air.

Calculation of VOC emissions for representative conditions provides the emission factors in Table 4.2.2.8-1. The factors were calculated with the typical value of parameters present in Tables 4.2.2.8-2 and 4.2.2.8-3. The values for the various parameters for automobiles and light duty trucks represent average conditions existing in the automobile and light duty truck industry in 1980. A more accurate estimate of VOC emissions can be calculated with the equation in Table 4.2.2.8-1 and with site-specific values for the various parameters.

Emission factors are not available for final topcoat repair, cleanup, coating of small parts, and application of sealants.

Table 4.2.2.8-1 (Metric And English Units). EMISSION FACTORS FOR AUTOMOBILE AND LIGHT DUTY TRUCK SURFACE COATING OPERATIONS[a]

EMISSION FACTOR RATING: C

Coating	Automobile kg (lb) Of VOC		Light Duty Truck kg (lb) Of VOC	
	Per Vehicle	Per Hour[b]	Per Vehicle	Per Hour[c]
Prime Coat				
Solventborne spray	6.61 (14.54)	363 (799)	19.27 (42.39)	732 (1611)
Cathodic electrodeposition	0.21 (0.45)	12 (25)	0.27 (0.58)	10 (22)
Guide Coat				
Solventborne spray	1.89 (4.16)	104 (229)	6.38 (14.04)	243 (534)
Waterborne spray	0.68 (1.50)	38 (83)	2.3 (5.06)	87 (192)
Topcoat				
Lacquer	21.96 (48.31)	1208 (2657)	NA	NA
Dispersion lacquer	14.50 (31.90)	798 (1755)	NA	NA
Enamel	7.08 (15.58)	390 (857)	17.71 (38.96)	673 (1480)
Basecoat/clear coat	6.05 (13.32)	333 (732)	18.91 (41.59)	719 (1581)
Waterborne	2.25 (4.95)	124 (273)	7.03 (15.47)	267 (588)

[a] All nonmethane VOC. Factors are calculated using the following equation and the typical values of parameters presented in Tables 4.2.2.8-2 and 4.2.2.8-3. NA = not applicable.

$$E_v = \frac{A_v\ c_1\ T_f\ V_c\ c_2}{S_c\ e_T}$$

where:

- E_v = emission factor for VOC, mass per vehicle (lb/vehicle) (exclusive of any add-on control devices)
- A_v = area coated per vehicle (ft^2/vehicle)
- c_1 = conversion factor: 1 ft/12,000 mil
- T_f = thickness of the dry coating film (mil)
- V_c = VOC (organic solvent) content of coating as applied, less water (lb VOC/gal coating, less water)
- c_2 = conversion factor: 7.48 gal/ft^3
- S_c = solids in coating as applied, volume fraction (gal solids/gal coating)
- e_T = transfer efficiency fraction (fraction of total coating solids used that remains on coated parts)

Example: The VOC emissions per automobile from a cathodic electrodeposited prime coat.

$$E_v \text{ mass of VOC} = \frac{(850\ ft^2)\ (1/12000)\ (0.6\ mil)\ (1.2\ lb/gal{-}H_2O)\ (7.58\ gal/ft^3)}{(0.84\ gal/gal)\ (1.00)}$$

$$= 0.45\ lb\ VOC/vehicle\ (0.21\ kg\ VOC/vehicle)$$

[b] Based on an average line speed of 55 automobiles/hr.
[c] Based on an average line speed of 38 light duty trucks/hr.

Table 4.2.2.8-2 (English Units). PARAMETERS FOR THE AUTOMOBILE SURFACE COATING INDUSTRY[a]

Application	Area Coated Per Vehicle, ft^2	Film Thickness, mil	VOC Content, lb/gal-H_2O	Volume Fraction Solids, gal/gal-H_2O	Transfer Efficiency, %
Prime coat					
Solventborne spray	450 (220-570)	0.8 (0.3-2.5)	5.7 (4.2-6.0)	0.22 (0.20-0.35)	40 (35-50)
Cathodic electrodeposition	850 (660-1060)	0.6 (0.5-0.8)	1.2 (1.2-1.5)	0.84 (0.84-0.87)	100 (85-100)
Guide coat					
Solventborne spray	200 (170-280)	0.8 (0.5-1.5)	5.0 (3.0-5.6)	0.30 (0.25-0.55)	40 (35-65)
Waterborne spray	200 (170-280)	0.8 (0.5-2.0)	2.8 (2.6-3.0)	0.62 (0.60-0.65)	30 (25-40)
Topcoat					
Solventborne spray					
Lacquer	240 (170-280)	2.5 (1.0-3.0)	6.2 (5.8-6.6)	0.12 (0.10-0.13)	40 (30-65)
Dispersion lacquer	240 (170-280)	2.5 (1.0-3.0)	5.8 (4.9-5.8)	0.17 (0.17-0.27)	40 (30-65)
Enamel	240 (170-280)	2.5 (1.0-3.0)	5.0 (3.0-5.6)	0.30 (0.25-0.55)	40 (30-65)
Base coat/clear coat[b]	240	2.5	4.7	0.33	40
Base coat	240 (170-280)	1.0 (0.8-1.0)	5.6 (3.4-6.4)	0.20 (0.13-0.48)	40 (30-50)
Clear coat	240 (170-280)	1.5 (1.2-1.5)	4.0 (3.0-5.1)	0.42 (0.30-0.54)	40 (30-65)
Waterborne spray	240 (170-280)	2.2 (1.0-2.5)	2.8 (2.6-3.0)	0.62 (0.60-0.65)	30 (25-40)

[a] All values for coatings as applied except for VOC content and volume fraction solids that are for coatings as applied minus water. Ranges in parentheses. Low VOC content (high solids) base coat/clear coats are still undergoing testing and development.
[b] Composite of base coat and clear coat.

Table 4.2.2.8-3 (English Units). PARAMETERS FOR THE LIGHT DUTY TRUCK SURFACE COATING INDUSTRY[a]

Application	Area Coated Per Vehicle, ft^2	Film Thickness, mil	VOC Content, lb/gal-H_2O	Volume Fraction Solids, gal/gal-H_2O	Transfer Efficiency, %
Prime coat					
Solventborne spray	875 (300-1000)	1.2 (0.7-1.7)	5.7 (4.2-6.0)	0.22 (0.20-0.35)	40 (35-50)
Cathodic electrodeposition	1100 (850-1250)	0.6 (0.5-0.8)	1.2 (1.2-1.5)	0.84 (0.84-0.87)	100 (85-100)
Guide coat					
Solventborne spray	675 (180-740)	0.8 (0.7-1.7)	5.0 (3.0-5.6)	0.30 (0.25-0.55)	40 (35-65)
Waterborne spray	675 (180-740)	0.8 (0.5-2.0)	2.8 (2.6-3.0)	0.62 (0.60-0.65)	30 (25-40)
Topcoat					
Solventborne spray					
Enamel	750 (300-900)	2.0 (1.0-2.5)	5.0 (3.0-5.6)	0.30 (0.25-0.55)	40 (30-65)
Base coat/clear coat[b]	750	2.5	4.7	0.33	40
Base coat	750 (300-900)	1.0 (0.8-1.0)	5.6 (3.4-6.4)	0.20 (0.13-0.48)	40 (30-50)
Clear coat	750 (300-900)	1.5 (1.2-1.5)	4.0 (3.0-5.1)	0.42 (0.30-0.54)	40 (30-65)
Waterborne spray	750 (300-900)	2.2 (1.0-2.5)	2.8 (2.6-3.0)	0.62 (0.60-0.65)	30 (25-40)

[a] All values for coatings as applied, except for VOC content and volume fraction solids that are for coatings as applied minus water. Ranges in parentheses. Low VOC content (high solids) base coat/clear coats are still undergoing testing and development.
[b] Composite of typical base coat and clear coat.

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4. Written communication from D. A. Frank, General Motors Corporation, Warren, MI, to H. J. Modetz, Acurex Corporation, Morrisville, NC, April 14, 1981.