4.2.2.11 Large Appliance Surface Coating

4.2.2.11.1 General[1]

Large appliance surface coating is the application of protective or decorative organic coatings to preformed large appliance parts. For this discussion, large appliances are defined as any metal range, oven, microwave oven, refrigerator, freezer, washing machine, dryer, dishwasher, water heater, or trash compactor.

Regardless of the appliance, similar manufacturing operations are involved. Coiled or sheet metal is cut and stamped into the proper shapes, and the major parts are welded together. The welded parts are cleaned with organic degreasers or a caustic detergent (or both) to remove grease and mill scale accumulated during handling, and the parts are then rinsed in one or more water rinses. This is often followed by a process to improve the grain of the metal before treatment in a phosphate bath. Iron or zinc phosphate is commonly used to deposit a microscopic matrix of crystalline phosphate on the surface of the metal. This process provides corrosion resistance and increases the surface area of the part, thereby allowing superior coating adhesion. Often the highly reactive metal is protected with a rust inhibitor to prevent rusting prior to painting.

Two separate coatings have traditionally been applied to these prepared appliance parts: a protective prime coating that also covers surface imperfections and contributes to total coating thickness, and a final, decorative topcoat. Single-coat systems, where only a prime coat or only a topcoat is applied, are becoming more common. For parts not exposed to customer view, a prime coat alone may suffice. For exposed parts, a protective coating may be formulated and applied so as to act as the topcoat. There are many different application techniques in the large appliance industry, including manual, automatic, and electrostatic spray operations, and several dipping methods. Selection of a particular method depends largely upon the geometry and use of the part, the production rate, and the type of coating being used. Typical application of these coating methods is shown in Figure 4.2.2.11-1.

A wide variety of coating formulations is used by the large appliance industry. The prevalent coating types include epoxies, epoxy/acrylics, acrylics, and polyester enamels. Liquid coatings may use either an organic solvent or water as the main carrier for the paint solids.

Waterborne coatings are of 3 major classes: water solutions, water emulsions, and water dispersions. All of the waterborne coatings, however, contain a small amount (up to 20 volume percent) of organic solvent that acts as a stabilizing, dispersing or emulsifying agent. Waterborne systems offer some advantages over organic solvent systems. They do not exhibit as great an increase in viscosity with increasing molecular weight of solids, they are nonflammable, and they have limited toxicity. But because of the relatively slow evaporation rate of water, it is difficult to achieve a smooth finish with waterborne coatings. A bumpy "orange peel" surface often results. For this reason, their main use in the large appliance industry is as prime coats.

While conventional organic solventborne coatings also are used for prime coats, they predominate as topcoats. This is due in large part to the controllability of the finish and the amenability of these materials to application by electrostatic spray techniques. The most common organic solvents are ketones, esters, ethers, aromatics, and alcohols. To obtain or maintain certain application characteristics, solvents are often added to coatings at the plant. The use of powder

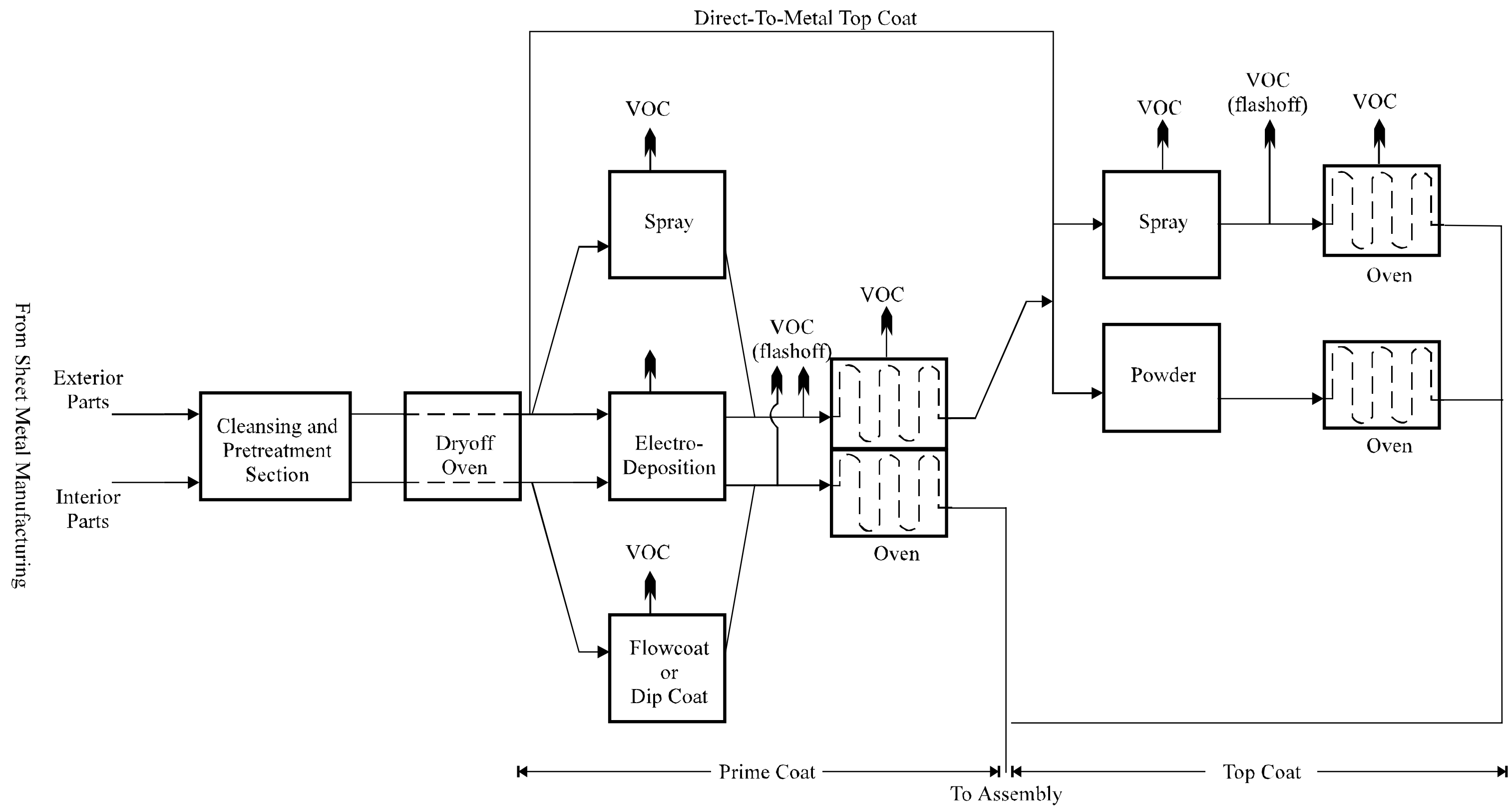

Figure 4.2.2.11-1. Typical coating application methods in the large appliance industry.

coatings for topcoats is gaining acceptance in the industry. These coatings, which are applied as a dry powder and then fused into a continuous coating film through the use of heat, yield negligible emissions.

4.2.2.11.2 Emissions And Controls[1-2]

Volatile organic compounds (VOC) are the major pollutants emitted from large appliance surface coating operations. VOC from evaporation of organic solvents contained in the coating are emitted in the application station, the flashoff area and the oven. An estimated 80 percent of total VOC emissions is given off in the application station and flashoff area. The remaining 20 percent occurs in the oven. Because the emissions are widely dispersed, the use of capture systems and control devices is not an economically attractive means of controlling emissions. While both incinerators and carbon adsorbers are technically feasible, none is known to be used in production, and none is expected. Improvements in coating formulation and application efficiency are the major means of reducing emissions.

Factors that affect the emission rate include the volume of coating used, the coating's solids content, the coating's VOC content, and the VOC density. The volume of coating used is a function of 3 additional variables: (1) the area coated, (2) the coating thickness, and (3) the application efficiency.

While a reduction in coating VOC content will reduce emissions, the transfer efficiency with which the coating is applied (i. e., the volume required to coat a given surface area) also has a direct bearing on the emissions. A transfer efficiency of 60 percent means that 60 percent of the coating solids consumed is deposited usefully onto appliance parts. The other 40 percent is wasted overspray. With a specified VOC content, an application system with a high transfer efficiency will have lower emission levels than will a system with a low transfer efficiency, because a smaller volume of coating will coat the same surface area. Since not every application method can be used with all parts and types of coating, transfer efficiencies in this industry range from 40 to over 95 percent.

Although waterborne prime coats are becoming common, the trend for topcoats appears to be toward use of "high solids" solventborne material, generally 60 volume percent or greater solids. As different types of coatings are required to meet different performance specifications, a combination of reduced coating VOC content and improved transfer efficiency is the most common means of emission reduction.

In the absence of control systems that remove or destroy a known fraction of the VOC prior to emission to the atmosphere, a material balance provides the quickest and most accurate emissions estimate. An equation to calculate emissions is presented below. To the extent that the parameters of this equation are known or can be determined, its use is encouraged. In the event that both a prime coat and a topcoat are used, the emissions from each must be calculated separately and added to estimate total emissions. Because of the diversity of product mix and plant sizes, it is difficult to provide emission factors for "typical" facilities. Approximate values for several of the variables in the equation are provided, however.

$$E = \frac{(6.234 \times 10^{-4})\ P\ A\ t\ V_o\ D_o}{V_s\ T} + L_d\ D_d$$

where:

E = mass of VOC emissions per unit time (lb/unit time)
P = units of production per unit time
A = area coated per unit of production (ft^2) (see Table 4.2.2.11-2)
t = dry coating thickness (mils) (see Table 4.2.2.11-2)
V_o = proportion of VOC in the coating (volume fraction), as received[a]
D_o = density of VOC solvent in the coating (lb/gal), as received[a]
V_s = proportion of solids in the coating (volume fraction), as received[a]
T = transfer efficiency (fraction: the ratio of coating solids deposited onto appliance parts to the total amount of coating solids used. See Table 4.2.2.11-1.)
L_d = volume of VOC solvent added to the coating per unit time (gal/unit time)
D_d = density of VOC solvent added (lb/gal)

The constant 6.234×10^{-4} is the product of 2 conversion factors:

$$\frac{8.333 \times 10^{-5} \text{ ft}}{\text{mil}} \quad \text{and} \quad \frac{7.481 \text{ gal}}{\text{ft}^3}$$

If all the data are not available to complete the above equation, the following may be used as approximations:

$V_o = 0.38$
$D_o = 7.36$ lb/gal
$V_s = 0.62$
$L_d = 0$ (assumes no solvent added at the plant)

In the absence of all operating data, an emission estimate of 49.9 Mg (55 tons) of VOC per year may be used for the average appliance plant. Because of the large variation in emissions among plants (from less than 10 to more than 225 Mg [10 to 250 tons] per year), caution is advised when this estimate is used for anything except approximations for a large geographical area. Most of the known large appliance plants are in localities considered nonattainment areas for achieving the national ambient air quality standard (NAAQS) for ozone. The 49.9-Mg-per-year (55-ton-per-year) average is based on an emission limit of 2.8 lb of VOC per gallon of coating (minus water), which is the limit recommended by the Control Techniques Guideline (CTG) applicable in those areas. For a plant operating in an area where there are no emission limits, the emissions may be 4 times greater than from an identical plant subject to the CTG-recommended limit.

[a] If known, V_o, D_o, and V_s for the coating as applied (i. e., diluted) may be used in lieu of the values for the coating as received, and the term L_d D_d deleted.

Table 4.2.2.11-1. TRANSFER EFFICIENCIES

Application Method	Transfer Efficiency (T)
Air atomized spray	0.40
Airless spray	0.45
Manual electrostatic spray	0.60
Flow coat	0.85
Dip coat	0.85
Nonrotational automatic electrostatic spray	0.85
Rotating head automatic electrostatic spray	0.90
Electrodeposition	0.95
Powder	0.95

Table 4.2.2.11-2 (Metric And English Units). AREAS COATED AND COATING THICKNESS[a]

Appliance	Prime Coat		Topcoat	
	A (ft^2)	t (mils)	A (ft^2)	t (mils)
Compactor	20	0.5	20	0.8
Dishwasher	10	0.5	10	0.8
Dryer	90	0.6	30	1.2
Freezer	75	0.5	75	0.8
Microwave oven	8	0.5	8	0.8
Range	20	0.5	30	0.8
Refrigerator	75	0.5	75	0.8
Washing machine	70	0.6	25	1.2
Water heater	20	0.5	20	0.8

[a] A = area coated per unit of production. t = dry coating thickness.

References For Section 4.2.2.11

1. *Industrial Surface Coating: Appliances—Background Information For Proposed Standards*, EPA-450/3-80-037a, U. S. Environmental Protection Agency, Research Triangle Park, NC, November 1980.

2. *Industrial Surface Coating: Large Appliances—Background Information For Promulgated Standards*, EPA 450/3-80-037b, U. S. Environmental Protection Agency, Research Triangle Park, NC, 27711, October 1982.