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NONINDUSTRIAL
SURFACE COATING
AP-42 Section 4.2.1
Reference Number
1

ENGINEERING MANUAL

SECOND EDITION



U.S. ENVIRONMENTAL PROTECTION AGENCY

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Incineration, if employed, must be capable of oxidizing at least 90 percent of the carbon in the organic material to carbon dioxide. This requirement is not waived by the 85 percent reduction above. Since temperatures of 1400° to 1500 °F are sometimes required, heat recovery for use elsewhere in the process or for preheating the incoming gases will reduce the costs of the afterburner operation. The determination of whether 90 percent of the carbon in the organic materials has been oxidized to carbon dioxide is made by chromatographic separation of the components in the incoming and exit streams to the afterburner and combustion and measurement of the resulting carbon dioxide in an infrared spectrophotometer.

Activated carbon adsorbers that can be regenerated by the use of steam, with the subsequent condensation and separation of solvent and water, are also possible alternatives. They are especially suitable where solvent recovery is desirable because of cost considerations or where incineration is impractical as with chlorinated solvents.

Generally, neither of these methods is feasible where large air volumes are involved, as in paint spraying operations. In such instances, it has proven more economical to reformulate the solvent systems to the extent of making them non-photochemically reactive and thereby removing the limitation on the quantity of organic material which may be emitted.

Various problems are encountered in this approach, such as cost considerations, relative solvency, evaporation rates, compatibilities, and partial solvation of undercoats to name a few. Nevertheless, since the inception of Rule 66, it has been proven that reformulation can almost invariably be accomplished. In the rare instance where a solution cannot be found, a change from one basic coating system to another may be required.

Research is underway to develop solventless coatings. Some of these coatings already have been developed, including powder coatings, plastisols, and electrocoating and radiation curing, which enable low viscosity monomers to be used.

SURFACE COATING OPERATIONS

INTRODUCTION

Many manufactured articles receive coatings for surface decoration and/or protection before being marketed. A number of basic coating operations are utilized for this purpose, including spraying, dipping, flowcoating, roller coating and electrocoating. There are variations and combinations

of these operations, each designed for a special task. For example, articles may be coated by spraying with either an air-atomized, airless, electrostatic, airless-electrostatic, or hot-spray method. The coatings applied in these operations vary widely as to composition and physical properties.

TYPES OF EQUIPMENT

Spray Booths

In spraying operations, a coating from a supply tank is forced, usually by compressed air, through a "gun" which is used to direct the coating as a spray upon the article to be coated. Many spraying operations are conducted in a booth or enclosure vented by a fan to protect the health and safety of the spray gun operator by ensuring that explosive and toxic concentration levels of solvent vapors do not develop. Table 231 shows threshold limit values of typical coating solvents. These values are average concentrations to which workers may be safely exposed for an 8-hour day without adverse effect to their health.

Booths used in spraying operations, for convenience, are referred to as paint spray booths, although the actual coating sprayed may be other than paint. Such booths are discussed in relation to particulate removal for ceramic and metal deposition equipment in Chapter 7.

Paint spray booths may have an independent air supply delivering heated, filtered, and/or humidified air. Booths not having a direct independent air supply may or may not be equipped to filter incoming plant air as well as to remove particulate matter from the exhausted air. Typical floor type paint spray booths are shown in Figures 650, 651, and 652.

Flowcoating Machines

In flowcoating operations, such as shown in Figures 653 and 654, a coating is fed through overhead nozzles so as to flow in a steady stream over the article to be coated, which is suspended from a conveyor line. Excess paint drains from the article to a catch basin from which it is recirculated by a pump back to the flow nozzles. Impinging heated air jets aid in the removal of superfluous coating and solvent from the coated article prior to its entering an oven for baking.

Flowcoating is used on articles which cannot be dipped because of their buoyancy, such as fuel-oil tanks, gas cylinders, pressure bottles, etc.

A new variation of the flowcoating process, electrophoretic flowcoating, has been developed and already has reached production scale in Europe.

Table 231. THRESHOLD LIMIT VALUES OF TYPICAL PAINT SOLVENTS

	Lower explosive limit (LEL) ^a		25% of LEL, ppm	Maximum allowance concentration, ^b ppm
	%	ppm		
Acetone	2.15	22,000	5,500	1,000
Amyl acetate	1.1	11,100	2,770	200
Methyl ethyl ketone	1.81	18,400	4,600	250
Butyl acetate	1.7	17,300	4,320	200
Cellosolve	2.6	26,700	6,670	200
Ethyl acetate	2.18	22,300	5,570	400
Cellosolve acetate	1.71	17,400	4,350	100
Ethanal	3.28	33,900	8,470	1,000
Naphtha (petroleum)	0.92 to 1.1	9,290	2,320	500
Toluene	1.27	12,600	3,150	200
Xylene	1.0	10,100	2,520	200
Mineral spirits	0.77	7,760	1,940	500
Trichloroethylene ^c	-	-	-	100 ^d

^a Adapted from: Factory Mutual Engineering Division, 1959.

^b Adapted from: American Medical Association, 1956, except as noted.

^c Nonexplosive at ordinary temperatures.

^d Adapted from: American Conference of Governmental Industrial Hygienists, 1960.

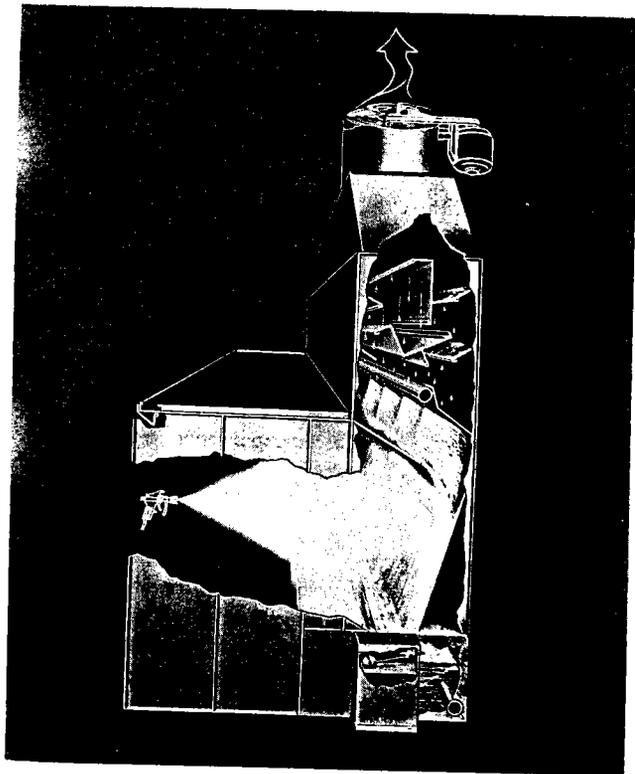


Figure 650. Water-wash spray booth (The Devilbiss Co., Toledo, Ohio).

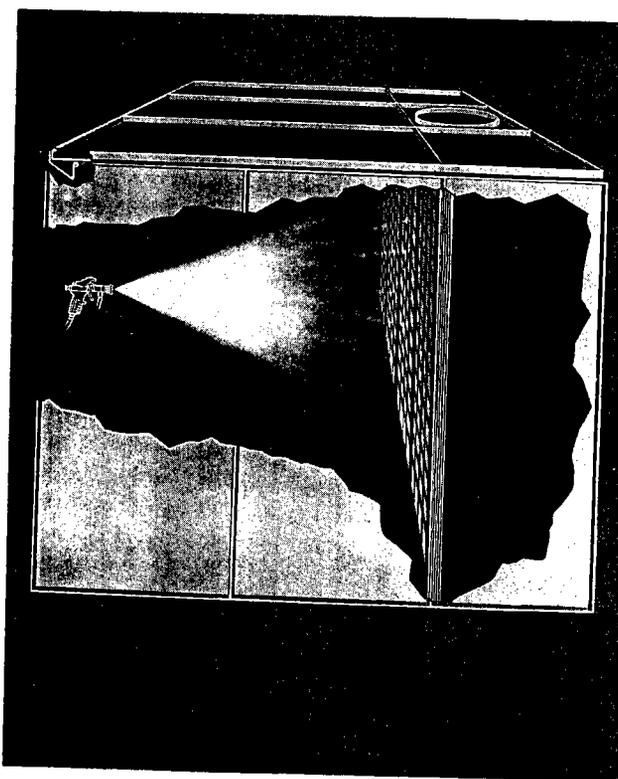


Figure 651. Paint arrester spray booth (The Devilbiss Co., Toledo, Ohio).

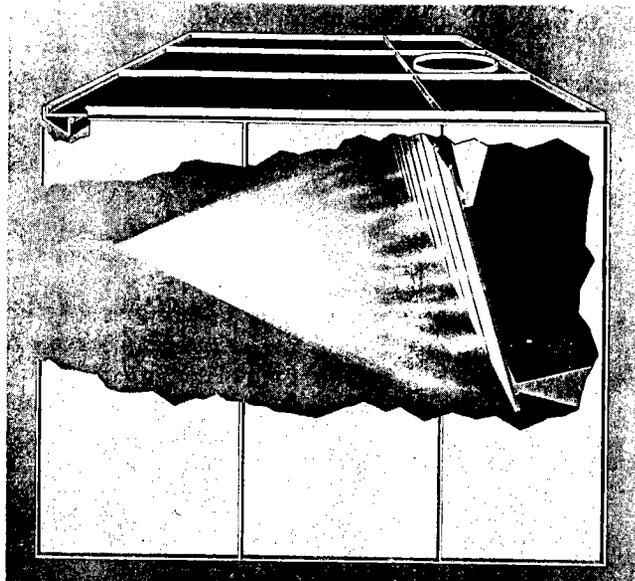


Figure 652. Dry baffle spray booth (The Devilbiss Co., Toledo, Ohio).



Figure 654. View of a flowcoating machine showing drain decks and enclosures (Industrial Systems, Inc., South Gate, Calif.).

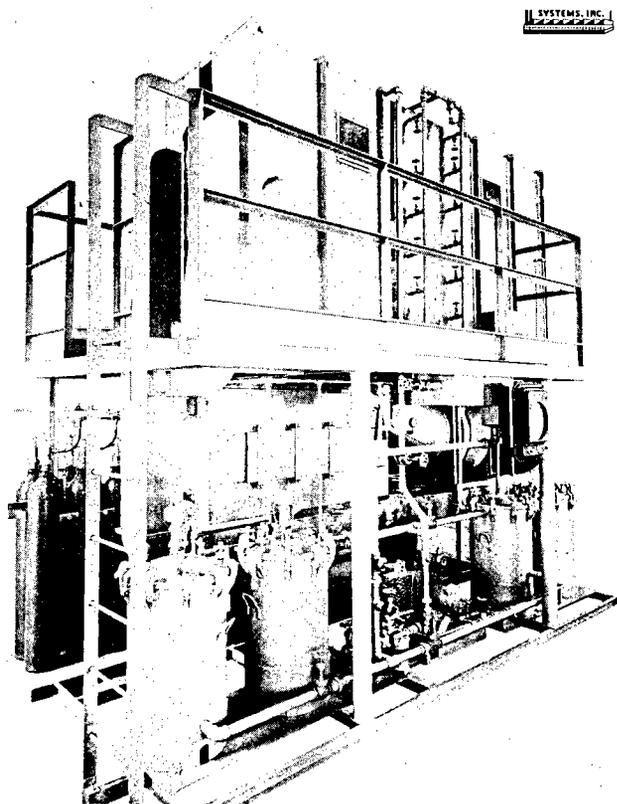


Figure 653. Side view of a flowcoating machine (Industrial Systems, Inc., South Gate, Calif.).

The item to be coated is made the anode and the flow nozzle is made the cathode. The same principles are applied in electrocoating, or electrophoretic deposition, which is described briefly under "Dip Tanks."

Dip Tanks

Dip tanks are simple vessels which contain a working supply of coating material. They usually are equipped with a close-off lid and a drainage reservoir, which are activated in case of fire. The object to be coated is immersed in the coating material long enough to be coated completely and then removed from the tank. Provision is made to drain the excess coating from the object back to the tank, either by suspending the work over the tank or by using drain boards that return the paint to the dip tank. Some method usually is provided for agitation of the coating material in the tank, in order to keep it uniformly mixed. The most frequently used method consists of withdrawing coating by a pump from the tank bottom and returning it to a point near the tank top but still under the liquid surface.

Electrocoating, a variation of the ordinary dip tank process of coating, is the electrodeposition of resinous materials on surfaces. This operation is sustained from water solutions, suspensions, or dispersions. In the electrocoating process, the object being coated is the anode and the tank containing the dilute solution, suspension or dispersion of film-forming materials usually is the cathode. The dilute coating system is converted from a water soluble or dispersible form to a dense, water insoluble film on the surface be-

ing coated. An advantage of electrocoating compared with dipping, flowcoating, or electrostatic spraying is its built-in property of producing uniform thickness on all solution-wetted surfaces, including sharp edges and remote areas.

Roller Coating Machines

Roller coating machines are similar to printing presses in principle. The machines usually have three or more power-driven rollers. One roller runs partially immersed in the coating and transfers the coating to a second, parallel roller. The strip or sheet to be coated is run between the second and third roller and is coated by transfer of coating from the second roller. The quantity of coating applied to the sheet or strip is established by the distance between the rollers.

THE AIR POLLUTION PROBLEM

Air Contaminants from Paint Spray Booths

The discharge from a paint spray booth consists of particulate matter and organic solvent vapors. The particulate matter, representing solids in the coating, derives from that portion of the coating which does not adhere to the target of the spraying, the inside of the booth, or its accessories. The organic solvent vapors derive from the organic solvent, diluent, or thinner which is used with the coating and evaporates from coating suspended in the airstream, on the target of the spraying, or on the inside surfaces of the booth and its accessories. The choice of the spraying method, air atomization, electrostatic, or other, is a factor in determining the amount of overspray, that is, the amount of sprayed coating which misses the article being coated. The configuration of the surface to be sprayed is another factor influencing the amount of overspray. Table 232 gives some typical overspray percentages.

The particulate matter consists of fine coating particles, whose concentration seldom exceeds 0.01 grain per scf of unfiltered exhaust. Despite this small concentration, the location of the exhaust stack must be carefully selected so as to prevent the coating from depositing or spotting on neighboring or company property.

Solvent concentrations in spray booth effluents vary from 100 to 200 ppm. Solvent emissions from the spray booth stacks vary widely with extent of operation, from less than 1 to over 3,000 pounds per day. Organic solvent vapors, in general, take part in atmospheric photochemical reactions leading to eye irritation and other photochemical smog effects. A more detailed discussion and listing of the principal photochemically reactive and nonphotochemically reactive solvents

Table 232. PERCENT OF OVERSPRAY AS A FUNCTION OF SPRAYING METHOD AND SPRAYED SURFACE

Method of spraying	Flat surfaces	Table leg surface	Bird cage surface
Air atomization	50	85	90
Airless	20 to 25	90	90
Electrostatic			
Disc	5	5 to 10	5 to 10
Airless	20	30	30
Air-atomized	25	35	35

are found in the section "Solvents and Their Uses." Solvent odors also may cause local public nuisances.

Essentially, all the solvent in or added to the coating mixture eventually is evaporated and emitted to the atmosphere. A notable exception, however, would be the styrene diluent in a polyester resin coating mixture. The styrene diluent is polymerized along with the polyester resin, thus classifying it as a reactant. Although organic solvents have different evaporation rates, solvent emissions by flash-off can be estimated at various times following the coating operation from the specific composite solvent formulation. Figure 655 relates solvent flash-off time with percent solvent emission for various classifications of coatings. Flash-off can be defined as that quantity (in terms of percent or weight) of solvent evaporated, under ambient or forced conditions, from the surfaces of coated parts during a specified time period.

The following examples show some factors to be considered in determining the solvent control measures required to operate the surface coating equipment in compliance with air pollution emission standards. Note that the solvent emission due to flash-off of solvent in the air space surrounding the coated article after it leaves a spray booth is added to other emissions because of the provisions of Rule 66(b) and (c).

Problem:

1. Calculate the weight of solvent emitted from a spray booth and associated oven.
2. Evaluate spray booth emissions with respect to Rule 66.

Given:

A conveyerized air-atomized electrostatic spray booth in which 15 gallons per day of reduced alkyd enamel (5 gallons of enamel plus 10 gallons of

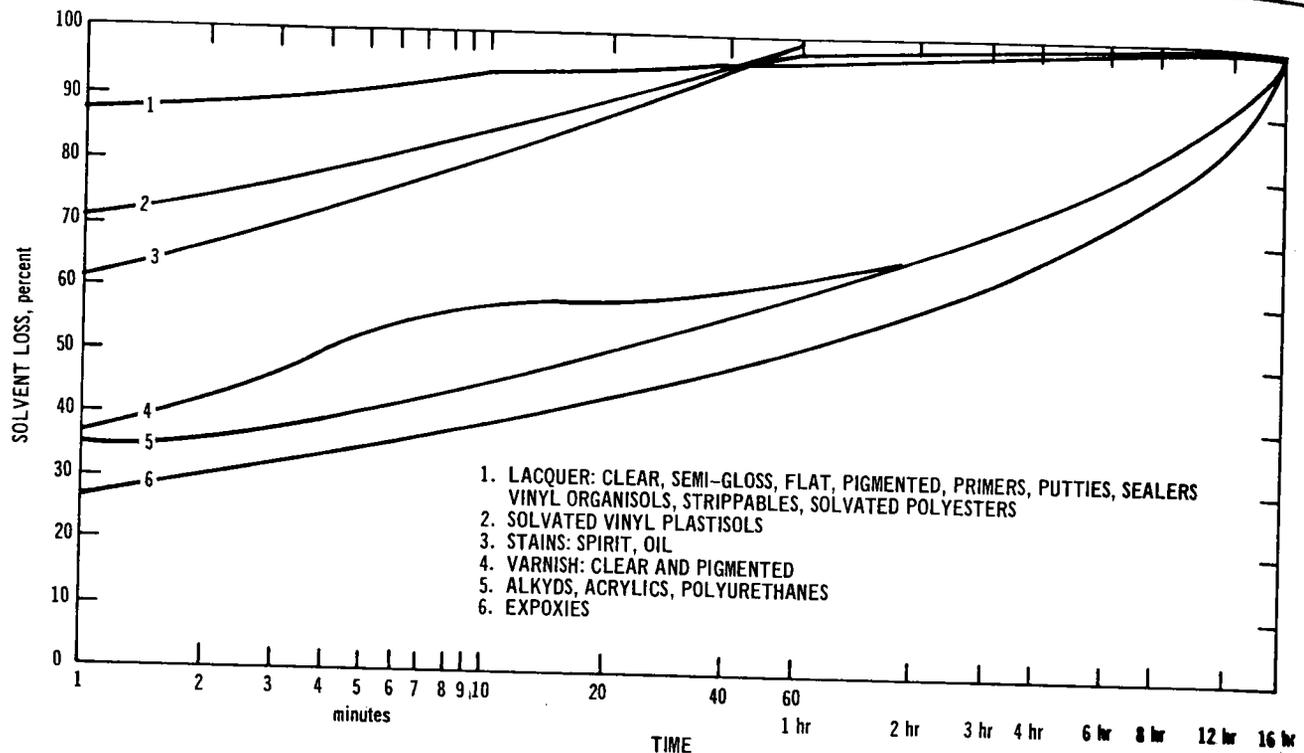


Figure 655. Evaporation curves relating percent solvent losses to solvent flash-off times.

toluene as thinner) are sprayed onto flat surfaces. After spraying, solvent is allowed to flash-off from the coated parts for 2 minutes before the parts enter the bake oven.

Alkyd enamel: Percent volatiles 53% by weight (fictitious) 50% by volume

Weight 9.7 lb/gal

Xylene 58% by volume of solvent in unthinned paint

Saturated aliphatic hydrocarbons 42% by volume of solvent in unthinned paint

Toluene thinner 7.2 lb/gal

Solution:

1. Solvent emissions from spray booth and oven:

Total solvent sprayed

$$S = (G)(\rho_1)(V) + T(\rho_2)$$

where

S = solvent sprayed, lb/day

V = volatile fraction = $\frac{\% \text{ volatiles by weight}}{100}$

G = unthinned paint sprayed, gal/day

ρ_1 = density of unthinned paint, lb/gal

T = thinner added, gal/day

ρ_2 = density of thinner, lb/gal.

$$S = (5)(9.7)(0.53) + (10)(7.2) = 25.6 + 72 = 97.6 \text{ lb/day}$$

Solvent emissions from spray booth and flash-off area

$$E = (S)(M) + (S)(1-M)(F)$$

where

S = solvent sprayed, lb/day

M = overspray fraction = $\frac{\% \text{ overspray}}{100}$
(from Table 232)

F = flash-off fraction = $\frac{\% \text{ flash-off}}{100}$
(from Figure 655).

Table 232 indicates an overspray factor of 25 percent for flat-surface, air-atomized electrostatic spraying. Figure 655, Curve 5, indicates a weight loss of 36 percent from the coating during a 2-minute flash-off period.

$$E = (97.6)(0.25) + (97.6)(1-0.25)(0.36) = 50.8 \text{ lb/day}$$

Solvent emissions from oven

Oven emission = solvent sprayed - spray booth and flash-off area emissions
 = $97.6 - 50.8 = 46.8$ lb/day

2. Spray booth compliance with Rule 66:

Rule 66b applies to the operation of coating equipment of this type and therefore solvent photochemical reactivity must be evaluated.

Solvent from unthinned paint

= (gal/day unthinned paint)(volatile fraction, by volume) = $(5)(0.5) = 2.5$ gal/day

Saturated hydrocarbons = $(2.5)(0.42)$
 = 1.05 gal/day

Xylene = $2.5 (0.58)$ = 1.45 gal/day

Toluene (added) = 10.00 gal/day

Total = 12.50 gal/day

Volume percent composition of composite solvent system

Saturated hydrocarbons	= $\frac{1.05}{12.50} \times 100 = 8.40\%$
Xylene	= $\frac{1.45}{12.50} \times 100 = 11.60\%$
Toluene	= $\frac{10.00}{12.50} \times 100 = 80.00\%$
Total	100.00%

The composite solvent system is classified photochemically reactive for the following reasons (see also "Solvents and Their Uses"):

1. Xylene exceeds the 8 percent by volume limitation of Rule 66k-2.
2. Toluene exceeds the 20 percent by volume limitation of Rule 66k-3.
3. The total of the volume percents of photochemically reactive solvents exceeds the 20 percent allowed by Rule 66k.

Since the composite solvent system is photochemically reactive, the solvent emissions from the spray booth may not exceed 40 lb/day under the provisions of Rule 66b. The calculations showed that the booth emits 50.8 lb/day, and therefore the unit exceeds the limits of Rule 66. Compliance with Rule 66 can be achieved by reducing or controlling the emissions to 40 lb/day or less, or by

reformulating the coating and solvent system to make it a nonphotochemically reactive system.

An alkyd enamel having the composition listed in Table 233 can be used to eliminate the photochemically reactive xylene nonconforming factor. However, the added toluene thinner would continue to cause the composite solvent system to exceed the limitation of 20 percent by volume total photochemically reactive solvents. A nonphotochemically reactive toluene replacement thinner, as listed in Table 233, can be used which, in conjunction with the conforming alkyd enamel, will result in a composite solvent system meeting regulatory requirements.

The emissions from the bake oven in the preceding example also violate the provisions of Rule 66. Such ovens and their relationship to Rule 66 are discussed in a later section.

Air Contaminants from Other Devices

Air contaminants from dipping, flowcoating, and roller coating exist only in the form of organic solvent vapors since no particulate matter is formed. Solvent emission rates from these operations may be estimated by the methods given in the spray booth example with the omission of the overspray factor.

HOODING AND VENTILATION REQUIREMENTS

Requirements for Paint Spray Booths

The usual spray booth ventilation rate is 100 to 150 fpm per square foot of booth opening. Insurance standards require that the enclosure for spraying operations be designed and maintained so that the average velocity over the face of the booth during spraying operations is not less than 100 fpm. Flow into the booth must be adequate to maintain capture velocity and overcome opposing air currents. Therefore, the booth should enclose the operation, and extraneous air motion near the booth should be eliminated or minimized.

Requirements for Other Devices

Dip tanks, flowcoaters, and roller coaters frequently are operated without ventilation hoods. When local ventilation at the unit is desirable, total enclosure or partial enclosure by a canopy hood may be installed. Hoods should encompass and be located close to the source of emissions. The flow into the hood must be sufficient to maintain capture velocity and overcome any opposing air currents.

Table 233. EXAMPLES OF SURFACE COATING AND ADDED THINNER FORMULAS ON AN AS-PURCHASED BASIS HAVING CONFORMING SOLVENT SYSTEMS (See section on "Solvents and Their Uses")

Type of surface coating	Weight, lb/gal	Composition of surface coatings, % vol						
		Nonvolatile portion	Hydrocarbon		Alcohols saturated	Ketones	Esters saturated	Ethers saturated
			Aliphatic saturated	Aromatic				
Enamel, air dry	7.6	39.6	93.5	6.5				
Enamel, baking	9.1	42.8	82.1	11.7	6.2			
Enamel, dipping	9.9	59.0	58.2	7.2	30.9		3.7	
Acrylic enamel	8.9	30.3		6.9		80.6	12.5	
Alkyd enamel	8.0	47.2	92.5	7.5				
Primer surfacer	9.4	49.0	18.0	8.9	21.8	16.5	16.8	18.0
Primer, epoxy	10.5	57.2	44.8	15.9	3.0		28.8	7.5
Primer, zinc chromate	10.3	37.8	80.0	7.2	12.8			
Primer, vinyl zinc chromate	8.4	34.0	17.5	7.9		60.0		14.6
Epoxy-polyamide	10.5	34.7		19.9	26.4	34.5	19.2	
Varnish, baking	6.6	35.3				97.0		3.0
Lacquer, spraying	7.9	26.1	7.0	1.7	21.3	23.2	45.1	1.7
Lacquer, hot spray	8.4	16.5	16.4	6.8	24.3	17.2	14.8	20.5
Lacquer, acrylic	8.4	38.2	10.0	18.5	3.5	42.0	26.0	
Vinyl, roller coat	7.7	12				43.5		56.5
Vinyl	8.9	22.00		18.9		81.1		
Vinyl acrylic	7.5	15.2				84.9	15.1	
Polyurethane	9.2	31.7		19.7		13.9	66.4	
Stain	7.3	21.6	80.6	14.0		0.1		5.3
Glaze	7.8	40.9	91.6	8.4				
Wash coat	7.1	12.4	40.6	14.7	10.8	13.7	15.7	4.5
Sealer	7.0	11.7	41.2	7.0	14.7	19.1	18.0	
Toluene replacement thinner	6.7		55.5	17.5 (Toluene)			9.0	18.0
Xylene replacement thinner	6.5		56.5	7.5	24.0		12.0	

AIR POLLUTION CONTROL EQUIPMENT

Control of Paint Spray Booth Particulates

A considerable quantity of particulate matter results from the use of the common air atomization spray gun. During coating of flat surfaces, a minimum of 50 percent of the coating sprayed is not deposited on the surfaces and is called overspray. During the spraying of other articles, the overspray may be as high as 90 percent, as shown in Table 232. Baffle plates, filters, or

water-spray curtains are used to reduce the emissions of particulate matter from paint spray booths. Reduction is further enhanced with electrostatic spraying, which decreases overspray.

Baffle plates control particulates from enamel spraying by adhesion, with removal efficiencies of 50 to 90 percent. Baffle plates have very low efficiencies in collecting lacquer spray particulates because of the rapid drying (solvent flash-off) of the lacquer and consequent slight adhesion

to the baffles. Figure 655, Curve 1, illustrates the rapid drying of lacquer coatings. Filter pads satisfactorily remove paint particulates with efficiencies as high as 98 percent. The filtering velocity should be less than 250 fpm.

Water curtains and sprays are satisfactory for removing paint particulates, and well-designed units have efficiencies up to 95 percent. A water circulation rate of 10 to 38 gallons per 1000 cubic feet of exhaust air is recommended. Surface active agents are added to the water to aid in the removal of paint from the circulating tank.

Control of Organic Vapors from Surface Coating Operations

Organic solvents used in coatings and thinners are not controllable by filters, baffles, or water curtains. Solvent vapors can be controlled or recovered by the application of condensation, compression, absorption, adsorption, or combustion principles, when necessary for either economic or regulatory requirements.

The composite solvent vapor emissions from coating operations are classified either as photochemically reactive or nonphotochemically reactive under Rule 66. If the composite emission is classified nonphotochemically reactive, its emission into the atmosphere is limited by regulatory requirements where large quantities are used. If the composite emission is classified as photochemically reactive, then its emission into the atmosphere is limited to small quantities. If it is desirable to recover the solvent for reuse, then, in view of the small solvent vapor concentration in the airstream from the spray booth, applicator hood, or enclosure, the only economically feasible solvent recovery method is adsorption.

Control efficiencies of 90 percent or greater are possible by adsorption using activated carbon, provided particulates are removed from the contaminated airstream by filtration before the airstream enters the carbon bed. An industrial illustration of this method is in the application of stain or soil repellent chemicals (fluorocarbons) to fabrics. The fluorocarbon is dissolved in a chlorinated solvent, and the solution is sprayed onto the surface of the fabric. The solvent then is evaporated from the cloth as it passes through a dryer. The effluent from the spray booth and dryer is collected and ducted to the activated carbon adsorbers for solvent recovery.

When the solvent emission is not to be recovered and the emission is deemed photochemically reactive, then incineration would be the practical method of control, provided the solvent system cannot be reformulated to a nonphotochemically reactive system. An industrial illustration of

this is the roller coater application of a vinyl topcoat coating to can body tin plate sheets. The roller coater and conveyor are tightly encased to capture the solvent emissions, which are in turn ducted to an associated oven-afterburner unit for incineration. Generally, the vinyl topcoat coatings contain isophorone, which is a highly photochemically reactive solvent. General design features of adsorption-type devices and afterburners are discussed in Chapter 5.

PAINT BAKING OVENS AND OTHER SOLVENT-EMITTING OVENS

INTRODUCTION

The term "paint baking," as used in this section, refers to both the process of drying and the process of baking, curing, or polymerizing coatings. In both instances, heat is used to remove residual solvents, but in baking, curing, or polymerizing, the heat also serves to produce desired chemical changes in the coatings. These changes result in a hardened, toughened, less penetrable coating.

A rough, not always conclusive, method to distinguish a baking process from a drying process in the field is to wipe the finished coating with the coating solvent or the liquid coating. If the coating on the product from the oven wipes off, not abrades off, the process was drying; if it does not wipe off, the process was baking.

In its simplest form, paint baking may result only in speeding the evaporation of solvents and thinners which would normally air-dry. In a complex system, the following factors may be critical:

1. There must be sufficient time before heating to permit the coated surface to "level" and allow highly volatile solvents to evaporate slowly to prevent the formation of bubbles in the coating.
2. The heated process must start with a low temperature to provide for continued slow evaporation of residual solvents without bubbling.
3. Sufficient time and temperature must be provided for full curing of the coating.
4. The heated process must be ended before damage to the coating occurs.
5. Volatilized curing products must be removed from the area of the coated surface to prevent interference with the curing process.