Spray Coatings in the Furniture Industry - Generic Scenario for Estimating Occupational Exposures and Environmental Releases

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Scope and Content

This document presents a standard approach for estimating worker exposures to and environmental releases of non-volatile chemicals used in spray coatings for the metal and wooden furniture manufacturing industry. It does not cover worker exposures or environmental releases from the formulation of the coatings. The scenario covers the application of liquid coatings to furniture via spray coating, and does not cover coatings applied via roll coating or electrostatic application (powder coatings). The formulation of latex/emulsion coatings, roll coating, and electrostatic application are covered under other generic scenarios.

Industry Sector Description:

The metal and wood furniture industry consists of companies that manufacture household, office, store, public building, and restaurant furniture and fixtures. Table 1 presents census data for the metal and wood furniture manufacturing industry sectors based on their North American Industrial Classification System (NAICS) Codes.

Table 1. Census Data for Metal and Wood Furniture Manufacturing Industry Sectors

NAICS Code	Description	Number of Sites	Number of Workers	Percent Production Workers	Average Number of Production Workers per Site
Metal					
337124	Metal household furniture	419	23,388	79.9	45
337214	Non-wood office furniture manufacturing	317	44,742	69.5	98
337127	Institutional furniture framing	912	36,978	73.2	30
337215	Show case, partitioning, shelving, and locker manufacturing	2,028	72,293	74.0	26
Total Metal Furniture		*3,676*	*177,401*	*73.5*	*35*
Wood					
337122	Non-upholstered wood household furniture mfg.	3,913	123,706	86.3	27
337129	Wood television, radio, and sewing machine cabinet manufacturing	152	3,546	87.9	21
337211	Wood office furniture manufacturing	603	29,255	80.8	39
337212	Custom architectural woodwork and mill work manufacturing	1,165	24,867	70.0	15
337110	Wood kitchen cabinet and counter top manufacturing	8,176	122,015	79.2	12
Total Wood Furniture		*14,009*	*303,389*	*81.6*	*18*

Sources:
U.S. Census Data. 2001 County Business Patterns, NAICS 337, Furniture and Related Product Manufacturing.

U.S. Census Data. 2001 Annual Survey of Manufacturers, NAICS 337, Furniture and Related Product Manufacturing.

Process Description:

Below is a description of metal furniture spraying operations, wood furniture spray operations, spray techniques, and coating compositions. This scenario covers the spray application of liquid coatings in the furniture manufacturing industry. Application of powder coatings is covered in the Electrostatic Application of Powder Coatings Generic Scenario.

Metal Furniture Spray Coating

Coatings may be used directly as received from the manufacturer or they may be mixed with a small amount of solvent to adjust the viscosity. Also, multiple components may be mixed to form a desired coating. Coatings, that are used as received, are typically mixed prior to use to ensure that all components in the received coating are uniformly distributed in the coating. Mixing may take place at the coating application operation or in a dedicated room for mixing. Dedicated mix rooms are employed for coatings used in large quantities and may serve multiple coating application operations. Coatings are mixed in tanks sized appropriate for the expected usage of the coating and each tank is continually mixed.

Before the metal furniture unit or component part can be coated, the surface must be thoroughly cleaned. The cleaning operation typically consists of alkaline or acidic cleaning, water rinse, phosphate treatment (typically iron phosphate), another water rinse, pretreatment (application of rust inhibitor or adhesion promotor) and/or water rinse, and finally drying. After the metal has been prepared, the coating is applied to the part followed by curing or drying. The most common application technique is spraying.

Sprayable liquid coatings are applied in a booth by manual or automated operations. Overspray is collected in the booth on dry filters that are subsequently disposed of as waste. Water curtains may also be used to collect overspray, although they are much less common. Alternatively, some facilities may collect overspray for reuse.

After coating operations, the furniture parts are passed through a flash-off area, then a curing oven. In the flash-off area and curing oven, all volatile components of the coating are expected to be released. Volatile components of coatings are outside the scope of this generic scenario and therefore are not assessed in this generic scenario. The end result is a hard, dry coated part.

Cleaning operations include spray gun cleaning, paint line cleaning, and touch-up cleaning at final assembly. Cleaning is typically performed with an organic solvent or an aqueous solution. The chemical of interest is expected to be present in the cleaning residual and cleaning waste could be incinerated or released to water.

Sources:

Preliminary Industry Characterization: Surface Coating of Metal Furniture. US EPA, Office of Air Quality Planning and Standards. September 1998.

Compilation of Air Pollutant Emission Factors, Chapter 4 Evaporation Loss Sources. US EPA Office of Air Quality Planning and Standards. AP-42. September 1985.

Wood Furniture Spray Coating

Two major coating application techniques are used by the wood furniture manufacturing industry: flatline finishing and spray application. Flatline finishing is performed on truly flat furniture parts and consists of roll coating or curtain coating. Curtain coating is performed by passing the furniture part through a cascade of coating. This generic scenario will not cover releases and exposures from flatline finishing applications. Spray applications are performed either manually or automatically with a variety of spray guns in enclosed spray

booths. Finishing methods include coating, drying, and sanding in a series of repeated steps until desired final appearance is achieved. Most facilities move pieces along mechanically with conveyor systems; however, small facilities generally move the furniture manually between finishing stations.

Coatings may be used directly as received from the manufacturer or they may be mixed with a small amount of solvent to adjust the viscosity. Also, multiple components may be mixed to form a desired coating. Coatings, that are used as received, are typically mixed prior to use to ensure that all components in the received coating are uniformly distributed in the coating. Mixing may take place at the coating application operation or in a dedicated room for mixing. Dedicated mix rooms are employed for coatings used in large quantities and may serve multiple coating application operations. Coatings are mixed in tanks sized appropriate for the expected usage of the coating and each tank is continually mixed.

Coatings are applied either manually or automatically in spray booths. Spray booths are typically equipped with dry filters to collect overspray. Water curtains may be used to collect particulates from overspray; however, spent water has to be disposed of as hazardous waste. Therefore, new and modified spray booths use dry filters.

Between coating applications, wooden furniture parts are passed through a flash-off area and/or a curing oven. The length of the flash-off area varies greatly depending of type of coating and oven curing. In the flash-off area and curing oven, all volatile components of the coating are expected to be released. Volatile components of coatings are outside the scope of this generic scenario and therefore are not assessed in this generic scenario. The wooden furniture part may be sent though the coating and drying process multiple times to apply various finishing coatings before the final wooden part is produced.

Finishing steps for interior furniture include staining or painting, wash coating, filling, and sealing. Staining involves the application of a semi-clear colorant which adds the initial color, evens out color, and accents without hiding the natural wood grain. An alternative to staining is painting. Washcoating is applied to aid in adhesion, assist in filling or color uniformity, partially seal the wood, and prepare wood for another sanding. Fillers are applied to the wood to produce a smooth uniform surface. One or more coatings of a sealer are applied to provide adhesion, make sanding more effective, seal the wood and establish a foundation for further coating applications.

Finishing steps for exterior furniture include priming, staining or painting, and finishing. Outdoor furniture is commonly primed with a fungicide and a water-repellent. Exterior staining, painting, and finishing steps are similar to those of interior coating steps.

After the furniture piece has been stained or painted, a topcoat such as varnish or shellac is applied. Four categories of topcoats are used: standard nitrocellulose topcoats, acrylic topcoats, catalyzed topcoats, and conversion varnishes. The chemical of interest can be a component of any of these coatings. Table 4 presents a summary of the materials used in wood furniture coatings by process, and the percent solids by process.

Cleaning operations include spray application equipment cleaning, pipe clean-out, booth cleaning, spray gun cleaning, feed line cleaning, and coating reservoir cleaning. Industrial solvents are typically used to clean equipment that has applied solvent-borne coatings. Hot

water is used to clean equipment that has been used to apply water-borne coatings. The chemical of interest is expected to be present in the equipment cleaning waste.

Sources:
EPA Office of Compliance Sector Notebook Project Profile of the Wood Furniture and Fixtures Industry. US EPA, Office of Enforcement and Compliance Assurance, Washington, DC 20460. September 1995. EPA/310-R-95-003.

Research and Development Case Study: Low VOC/HAP Wood Furniture Coatings. US EPA Office of Air Quality Planning and Standards. National Risk Management Research Laboratory. May 2000. EPA-600/R-00-043.

Spray Techniques

The types of spray applications used for liquid coatings in the furniture manufacturing industry are listed in Table 2. A further description of these techniques will be presented in the final scenario.

Table 2. Types of Spray Applications

Type of Application	Fluid Pressure (MPa)	Fluid Flowrate (cm^3/min)
Airless Atomization	5-35	150-1500
Air-assisted Airless Atomization	35-170	NA
Air Atomization	70-700	50-1000

NA - not available.

Source:
Kirk-Othmer Encyclopedia of Chemical Technology. Spray Coating. John Wiley & Sons, Inc, 2004.

Coating Compositions

Liquid coatings typically used in the metal furniture industry are solvent-borne (organic based) resins such as acrylics, amines, vinyls, and cellulosics. Other types of coatings used are water-borne and solvent-borne with high solids content. Table 3 presents information on the composition of different types of metal coatings.

Table 3. Metal Coating Composition by Type

Coating	Solids Percent by Volume	Solids Percent by Weight
Solvent based	30	estimated as 40
High solids solvent based (exterior)	58±3	70.5±4
High solids solvent based (interior)	52.5±3	66.5±4
Aqueous based	27±3	32±5

Note: Solids weight percent for solvent based was estimated based on the relative densities of typical components in solvent-based paints (Kirk-Othmer). All other data was presented in both solids percent by volume and solids percent by weight.

Wood coating consists of several processes involving different coatings. Table 4 presents typical materials associated with these processes and percent solids for these coatings.

Table 4. Typical Materials in Wood Furniture Spray Coatings

Process	Materials	Percent Solids
Staining	Mineral spirits, alcohol, solvents, pigments (e.g., iron oxides, lead chromate, calcium sulfate, cadmium selenide)	5
Painting	Toluene, pigments (e.g., titanium dioxide, iron oxides, lead chromate), epoxy ester, resins, aromatic hydrocarbons, glycol ether, halogenated hydrocarbons, vinyl acetate, acrylic	38-54
Washing coating	Nitrocellulose-based lacquers, acrylic lacquers, varnish, shellac, polyurethane, solvents	2-13
Filling	Pigments (e.g., iron oxides, lead chromate, calcium sulfate, cadmium selenide), stains, drying oils, synthetic resins, solvent-based thinners	75 10-45 (when reduced with stains or pigments)
Sealing	Nitrocellulose-based lacquers, acrylic lacquers, varnish, shellac, solvents, polyurethane	10-30
Priming	Fungicide, water-repellent	NA
Topcoat application	Denatured alcohols, resins, shellac, petroleum distillates, toluene, diisocyanate	13-30
Rubbing/polishing	Lubricants, detergents, petroleum-based this oils, pumice, tripoli, diamaceous earth	NA
Cleaning (brush and spray gun)	acetone, toluene, petroleum distillates, methanol, methylene chloride, isopropanol, mineral spirits, alcohols	NA

NA - not available.

Both metal and wood coatings are made up of several different additives, and the formulation concentrations greatly vary based on the solvent and purpose. Additives typically in metal and wooden furniture spray coatings include: solvents, pigments, binders, extenders, antiskinning agents, spreading agents, dispersants, thickeners, coalescents, in-can preservatives, drying catalysts, UV protective agents, film preservation agents, defoamers, antiblocking agents, and sanding agents. Table 5 presents ranges of concentrations of these additives in metal and wood coatings. Note that each coating will only contain a subset of these additives.

Table 5. Typical Concentrations of Additives in Furniture Coatings

Type of Additive	Weight Percent in Furniture Coating
Solvents	25 - 75
Pigments	7 - 47
Binders	15-30
Extenders	15-23
Antiskinning agents*	0.2-0.3
Spreading agents	0-0.1
Dispersants	0.5-2.0
Thickeners	2.0-3.0
Coalescents**	2.0-5.0
In-can preservatives**	0.1-0.3
Drying catalysts	0.01-0.1
UV protective agents	0.05-0.1
Film preservation agents	0.5-1.0
Defoamers**	0.2-0.3
Antiblocking agents	0.5-1.0
Sanding agents	0.2-1.0

* Only for or essentially in organic solvent based products

** Only for or essentially in water based products

Sources:

Preliminary Industry Characterization: Surface Coating of Metal Furniture. US EPA, Office of Air Quality Planning and Standards. September 1998.

Spectracron® 360 Series High Solids Urethane Enamel (Exterior Product), PPG

Spectracron® 360 Series High Solids Urethane Enamel (Interior Product), PPG

Aquacron® 880 Series Water Reducible Alkyd Enamel, PPG

Kirk-Othmer Encyclopedia of Chemical Technology. Paint, Architectural. John Wiley & Sons, Inc, 2004.

EPA Office of Compliance Sector Notebook Project Profile of the Wood Furniture and Fixtures Industry. US EPA, Office of Enforcement and Compliance Assurance, Washington, DC 20460. September 1995. EPA/310-R-95-003.

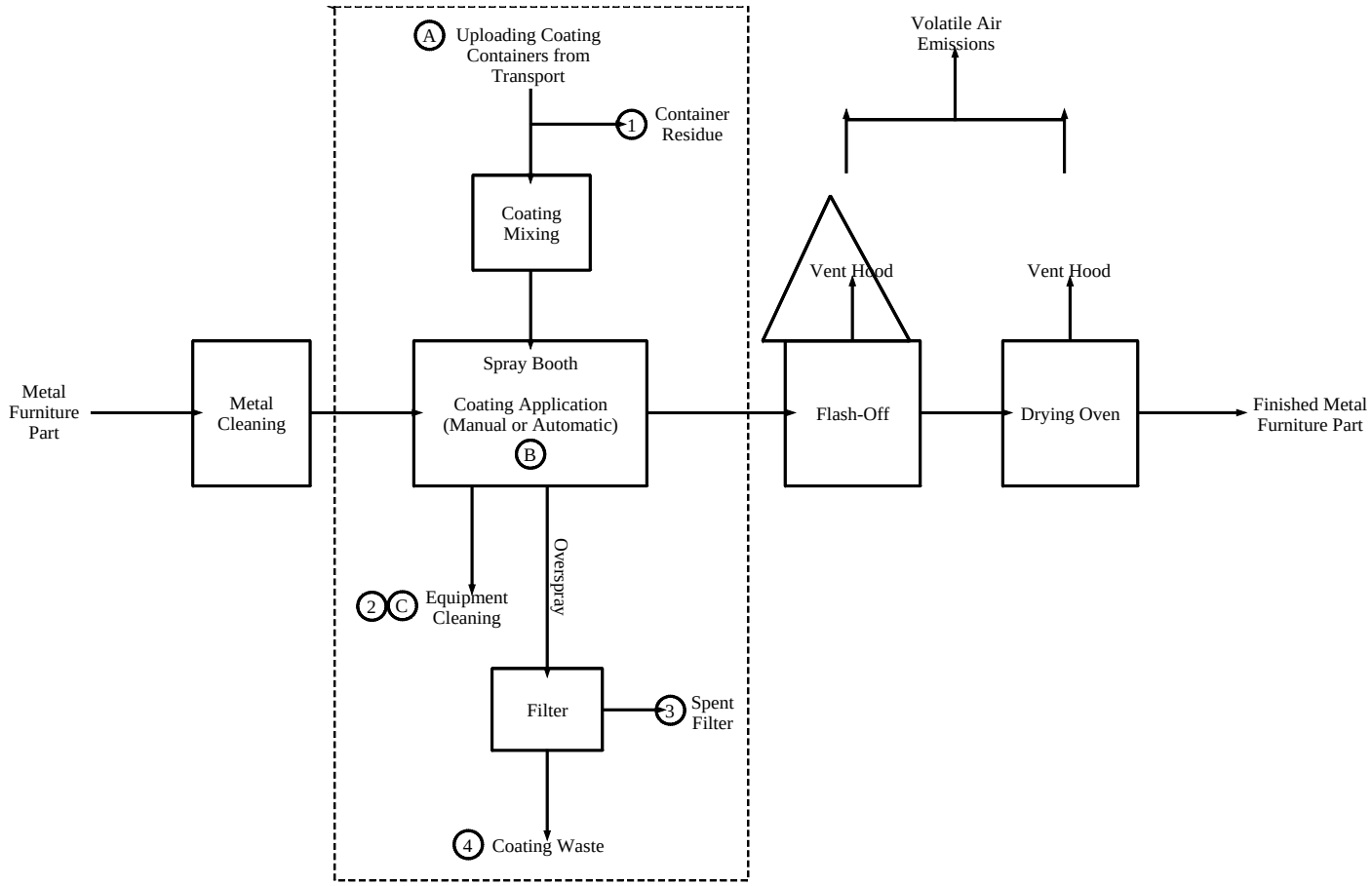
Research and Development Case Study: Low VOC/HAP Wood Furniture Coatings. US EPA Office of Air Quality Planning and Standards. National Risk Management Research Laboratory. May 2000. EPA-600/R-00-043.

European Commission, "Technical guidance document in support of Commission Directive 93/67/EEC on risk assessment for new notified substances and commission regulation (EC) No. 1488/94 on risk assessment for existing substances, " Part IV, Office for Official Publications of the European Communities, Luxembourg, 1996.

Northeast Waste Management Officials Association (NEWMOA). "Pollution Prevention in Metal Plating and Coating Operations," April 1998. http://www.p2pays.org/ref/01/00777/index.htm (last confirmed April 2004)

Process Flow Diagrams:

Process Flow Diagram for Metal Furniture Surface Coating

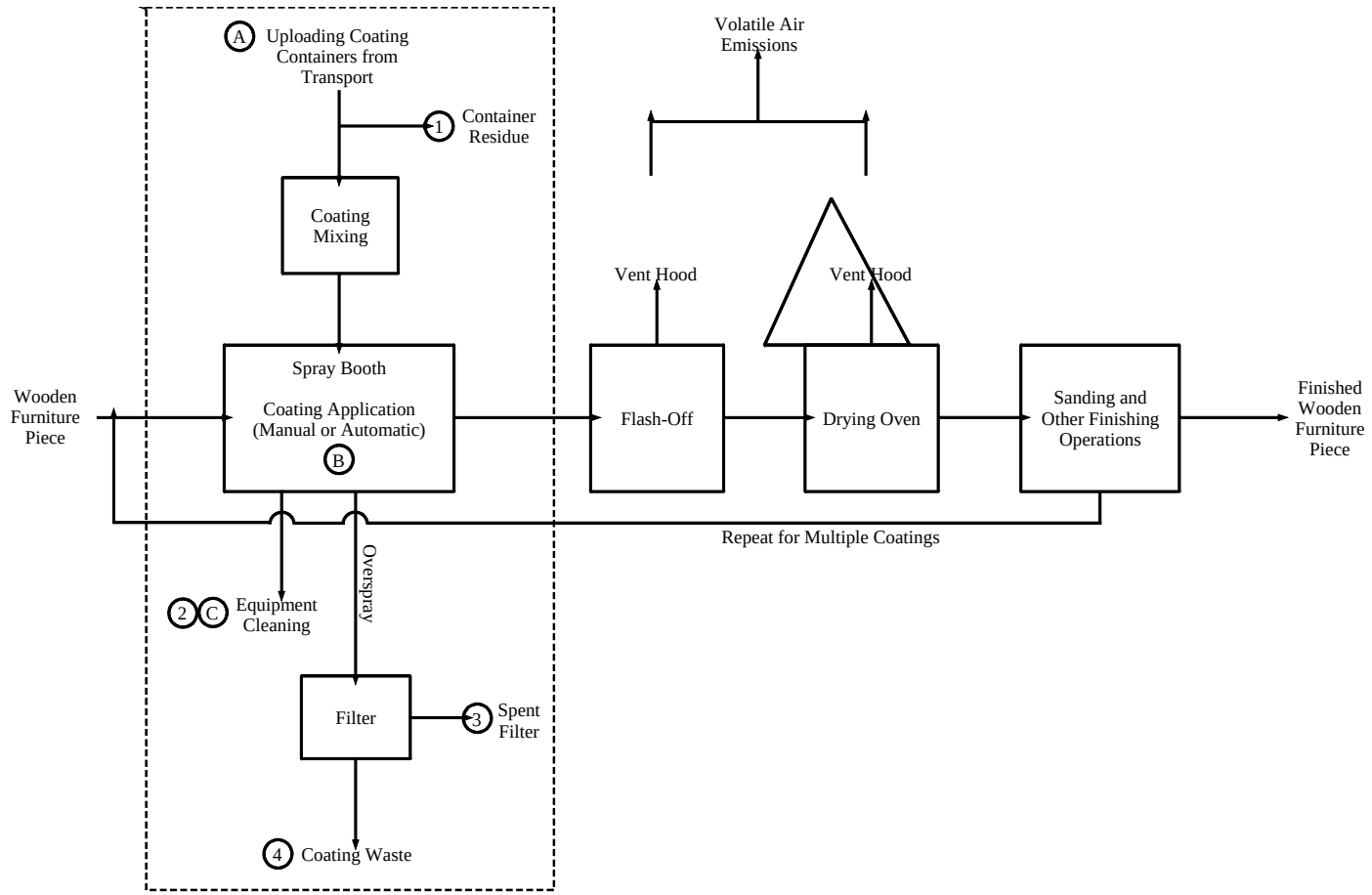


Releases:
1) Releases to water, incineration, or landfill from container residue.
2) Releases to water or incineration from equipment cleaning.
3) Releases to air from overspray.
4) Releases to landfill or incineration from overspay collected by filters.

Scope of the Scenario

Exposures:
A) Dermal exposure from unloading of the furniture coating.
B) Dermal exposure and inhalation exposure to mist from spraying operations.
C) Dermal exposure from equipment cleaning.

Process Flow Diagram for Wood Furniture Finishing



Releases:
1) Releases to water, incineration, or landfill from container residue.
2) Releases to water or incineration from equipment cleaning.
3) Releases to air from overspray.
4) Releases to landfill or incineration from overspray collecteted by filters.

Scope of the Scenario

Exposures:
A) Dermal exposure from unloading of the furniture coating.
B) Dermal exposure and inhalation exposure to mist from spraying operations.
C) Dermal exposure from equipment cleaning.

General Facility Estimates:

I. Daily Use Rate

Use the following available data and assumptions, if site-specific information is not provided. Table 6 presents coating usage data for the metal furniture industry. Table 7 presents coating usage data for wood furniture finishing industry.

Table 6. Metal Furniture Surface Coating Usage

Plant Size	Operating Schedule (hr/yr)	Number of Lines	Surface Area Coated (m^2/yr)	Liters of Coating Used per year (L/yr)	Liters of Coating Used per day (L/day)	Liters of Coating Used per Surface Area (L/m^2)
Small	2000	1 (1 spray booth)	45,000	5,000	20	0.11
Medium	2000	3 (3 booths/line)	780,000	87,100	348	0.11
Large	2000	10 (3 booths/line)	4,000,000	446,600	1786	0.11

a) 2,000 hours per year is equivalent to 250 days of operation and 8 hours per day.

Source: Compilation of Air Pollutant Emission Factors, Chapter 4 Evaporation Loss Sources. US EPA Office of Air Quality Planning and Standards. AP-42 September 1985.

Table 7. Wood Furniture Finishing Usage

Process	Materials Used (gal/yr)	Materials Used (L/yr)	Materials Used based on 250 days per year (L/day)	Materials Used per Surface Area (L/m^2)
Spray application of stain	1,143	4,326	17.3	0.133
Spray application of sealer	1,155	4,372	17.4	0.134
Spray application of clear lacquer	1,143	4,326	17.3	0.133
Average	1,147	4,341	17.4	0.134
Surface coated per year 350,000 ft2 (32,516 m^2)				

Based on information from two facilities in Georgia.

Source: An Analysis of Pollution Prevention Opportunities and Impediments in the Wood Products Manufacturing Sector in Georgia. Georgia Department of Natural Resources. April 1996.

With the data in Tables 6 and 7, use the following approach and assumptions to determine the daily use rate:

- For metal furniture surface coating, the daily use rate is determined by the size of the facility (see Table 6). The default daily use rate for metal furniture surface coating used in this scenario is the daily use rate for small shops. This value is used to ensure a conservative estimate for worker exposures.
- For wood furniture finishing, the daily use rate is estimated by the average amount of material used per day (see Table 7).
- If use on metal or wooden furniture is unknown, assume the coating is used on metal furniture. This assumption is the most conservative estimate for worker exposure.
- Table 5 presents typical additive concentrations to determine the weight fraction of the chemical of interest in the coating. Use the high end of the range as a conservative estimate.
- If the type of additive is unknown, assume the weight fraction of the additive is the percent solids in the coating. Default of 0.705 for metal coatings and 0.3 for wood coatings (see Tables 3 and 4). Assume metal coating if unknown.
- The densities of coatings range from less than 0.9 kg/L for some stains to greater than 1.4 kg/L for high solids coatings. If no other information is available, assume a density of 1 kg/L for the coating.

The following equation is used to calculate the daily use rate of the chemical of interest:

Daily Use Rate (kg/site-day) = Volume of Coating Used per Day (L/site-day) / Density of the Coating (kg/L) x Weight Fraction of Chemical in Coating

Example of coalescent in a metal furniture coating:
1 kg/site-day = 20 L/site-day / 1 kg/L x 0.05

If information is available about the surface area coated, the daily use rate of the chemical of interest can be calculated using the amount of coating required to cover a meter squared area. The following equation can be used to calculate the daily use rate of the chemical of interest if the surface area coated is known:

Daily Use Rate (kg/site-day) = Volume of Coating Used per Square Meter (L/m^2) / Density of the Coating (kg/L) x Surface Area of Furniture Coated per Day (m^2/site-day) x Weight Fraction of Chemical in Coating

Example of coalescent in a metal furniture coating used to coat 1,000 m^2/site-day:
5.5 kg/site-day = 0.11 L/m^2 / 1 kg/L x 1,000 m^2/site-day x 0.05

II. Days of Operation

Assume 250 days/yr. This is consistent with CEB standard estimate which assumes two weeks of down time per year and 5-day work weeks. This is also supported by the operating schedule for metal furniture manufacturing presented in Table 6.

III. Number of Sites

Calculated from the total production volume, daily use rate, and days of operation. According to 2001 County Business Pattern Data, a total of 3,676 metal furniture manufacturing facilities and 14,009 wood furniture manufacturing facilities operate in the U.S. The number of sites should not exceed these values.

Number of Sites (sites) = Production Volume (kg/yr) / Daily Use Rate (kg/site-day) / Days of Operation (days/yr)

Example of coalescent in a metal furniture coating (PV of 100,000 kg/yr assumed):

400 metal furniture sites = 100,000 kg/yr / 1 kg/site-day / 250 days/yr

Sources:

EPA Office of Compliance Sector Notebook Project Profile of the Wood Furniture and Fixtures Industry. US EPA, Office of Enforcement and Compliance Assurance, Washington, DC 20460. September 1995. EPA/310-R-95-003.

Compilation of Air Pollutant Emission Factors, Chapter 4 Evaporation Loss Sources. US EPA Office of Air Quality Planning and Standards. AP-42 September 1985.

An Analysis of Pollution Prevention Opportunities and Impediments in the Wood Products Manufacturing Sector in Georgia. Georgia Department of Natural Resources. April 1996.

U.S. Census Data. 2001 County Business Patterns, NAICS 337, Furniture and Related Product Manufacturing.

Environmental Release Assessments

1. Container Residue from Furniture Coating Transport Container (Release 1)

CEB standard assessments will be used depending on the size of the container and physical form. Coatings can be packaged in containers ranging in sizes. The most common found for furniture coatings are 1-gal, 5-gal, and 55-gal drums. These containers are received from the coating formulator or manufacturer and are expected to contain residual after unloading activities. Specific data describing transport container cleaning and waste disposal at furniture coating sites have not been found. The media of release for transport container residue is uncertain. Therefore, transport container residue disposal may be released to water, incineration or landfill. Assume 55-gallon (208 L) drums and density of 1 kg/L as defaults.

Number of Containers (containers/site-year) = Daily Use Rate (kg/site-day) x Days of Operation (days) / Fraction of Chemical in Coating / Container Volume (L/container) / Density (kg/L)

Example of coalescent in a metal furniture coating:

24 containers/site-yr = 1 kg/site-day x 250 days / 0.05 / 208 L/container / 1 kg/L

If the number of containers is less than the days of operation, the days of release is equal to the number of containers, and the daily release is calculated by the following equation:

Daily Release from Container Residue (kg/site-day) = Container Volume (L/container) x Density (kg/L) x Fraction of Chemical in Coating x Loss Fraction

Example of coalescent in a metal furniture coating:
6.24 kg/site-day = 208 L/container x 1 kg/L x 1 x 0.03

If the number of containers is greater than the days of operation, the days of release is equal to the days of operation, and the daily release is calculated based on the following equation:

Daily Release from Container Residue (kg/site-day) = Daily Use Rate (kg/site-day) x Loss Fraction

Example of coalescent in a metal furniture coating used at large plants:
2.7 kg/site-day = 89.3 kg/site-day x 0.03

2. Equipment Cleaning Releases to Water or Incineration (Release 2)

Release is based on CEB standard estimate for multiple vessels (2% loss of daily use rate). The chemical of interest may be released to water or incineration during the disposal of cleaning liquids generated during equipment cleaning activities. Spray guns, transfer lines, and spray booths "must be cleaned every time there is a color change and before the equipment is to be idle for a period of time (e.g., at the end of the day)." (U.S. EPA, 1995). Assume daily equipment cleaning. Equipment is expected to be rinsed out with a solvent or an aqueous solution on-site. A solvent wash is expected to be used in most cases for solvent-borne coatings and an aqueous wash is expected to be used for water-borne coatings (U.S. EPA, 2000). Solvent washes are expected to be incinerated. If site-specific information is not available, releases from equipment cleaning should be assessed to water or incineration.

Daily Release from Equipment Cleaning (kg/site-day) = Daily Use Rate (kg/site-day) x Loss Fraction

Example of coalescent in a metal furniture coating:
0.02 kg/site-day released = 1 kg/site-day x 0.02

3. Overspray Collected by Filters Released to Landfill or Incineration (Release 3)

During spraying operations, a significant amount of overspray is generated. Overspray is the sprayed coating that does not adhere to the substrate being painted. The amount of overspray generated depends on the type of spraying application, substrate, and spray gun. Transfer efficiency is the volume fraction of solids in the consumed coating that remains on the substrate. Transfer efficiencies can be used to determine the amount of chemical of interest released to the environment from overspray. Table 8 presents the transfer efficiencies for several spray techniques. As a conservative estimate, air-atomized is assumed if site-specific information is unknown.

Table 8. Transfer Efficiencies for Furniture Spray Techniques

Spray Technique	Wood	Wood Average	Wood Conservative	Metal	Metal Average	Metal Conservative
air-atomized	<0.50	<0.50	0.25	0.25	0.25	0.25
HVLP	0.4-0.65	0.525	0.4	0.40-0.65	0.525	0.40
airless	>0.50	>0.50	0.50	0.25	NA	NA

Spraying activities are typically performed in spray booths that are equipped with dry filters to collect overspray. Dry filters collect the solids portion (non-volatile) of the sprayed coating with a range of efficiencies from 90 to 99%. In the past, water curtains were used as a control technology to collect overspray, but now water curtains are no longer widely used. It is expected that at least 90% of the oversprayed, non-volatile chemical of interest in the coating is collected on the filter and is disposed of to incineration or landfill. The following equation calculates the annual amount of a non-volatile chemical of interest released to landfill or incineration from the spent filter.

Annual Release from Overspray Deposited on Filter (kg/yr) = Daily Use Rate (kg/site-day) x Number of Sites (sites) x Days of Operation (days) x (1 - Transfer Efficiency) x Collection Efficiency of Dry Filter

Example of coalescent in a metal furniture coating:
67,500 kg/yr = 1 kg/site-day x 400 sites x 250 days/yr x (1 - 0.25) x 0.9

4. Overspray Released to Air (Release 4)

A portion of the non-volatile coating components of the overspray is expected to pass through the filter and could be released to the atmosphere (Release 4). The following equation calculates the daily amount of chemical of interest released to air from overspray.

Daily Release to Air from Overspray (kg/site-day) = Daily Use Rate (kg/site-day) x (1 - Transfer Efficiency) x (1 - Collection Efficiency of Dry Filter)

Example of coalescent in a metal furniture coating:
0.075 kg/site-day = 1 kg/site-day x (1 - 0.25) x (1 - 0.9)

5. Volatile Air Emissions

The scope of this scenario is for non-volatile components in furniture coatings. If the chemical of interest is a volatile chemical, it is expected that 100% of the chemical of interest will be released to the atmosphere at three points during the furniture manufacturing process: 1) during spraying operations; 2) at the flash-off area; and 3) in the drying oven. The CEB standard assumption is that a chemical of interest is volatile if the pure component vapor pressure is greater than or equal to 0.01 torr.

On-Site Control Technologies:

Much information exists on the control of VOC emissions from spray coating operations. However, volatile components are outside the scope of this scenario. Wastewater from cleaning operations is typically adjusted for pH and discharged to a POTW. Additional treatment may be required depending on contamination levels (Office of Air Quality Planning and Standards, 1998).

Sources:

PEI Associates, Inc. 1986. Releases During Cleaning of Equipment. Washington, DC. Office of Toxics Substances. US Environmental Protection Agency. Contract 68-02-4248.

Spectracron® 360 Series High Solids Urethane Enamel (Exterior Product), PPG

Spectracron® 360 Series High Solids Urethane Enamel (Interior Product), PPG

Aquacron® 880 Series Water Reducible Alkyd Enamel, PPG

Research and Development Case Study: Low VOC/HAP Wood Furniture Coatings. US EPA Office of Air Quality Planning and Standards. National Risk Management Research Laboratory. May 2000. EPA-600/R-00-043.

EPA Office of Compliance Sector Notebook Project Profile of the Wood Furniture and Fixtures Industry. US EPA, Office of Enforcement and Compliance Assurance, Washington, DC 20460. September 1995. EPA/310-R-95-003.

Preliminary Industry Characterization: Surface Coating of Metal Furniture. US EPA, Office of Air Quality Planning and Standards. September 1998.

Compilation of Air Pollutant Emission Factors, Chapter 4 Evaporation Loss Sources. US EPA Office of Air Quality Planning and Standards. AP-42. September 1985.

Gupta, Ravila. Techniques for Pollution Prevention in Furniture Coating Operations. NC Office of Waste Reduction. June 21, 1994.

Preferred and Alternative Methods for Estimating Air Emissions from Surface Coating Operations Volume II Chapter 7. July 2001. US EPA Emission Inventory Improvement Program.

Occupational Exposure Assessments

Number of Workers per Site

Table 1 presents the number of establishments for each NAICS code, the total number of workers, the percentage of workers that are production workers and the average number of production workers per site. The average number of workers was determined by the total number of workers in the industry sector divided by the total number of facilities for that industry sector times the percentage of production workers. Assume 35 workers are exposed per site for metal furniture and 18 workers are exposed per site for wood furniture. If specific data is

not available, assume metal furniture as a conservative estimate. No specific data was found on the breakdown of workers by activity.

Occupational Exposures

C. Exposure During Unloading Coating Materials (Exposure A)

Workers unload chemicals from transport containers into a mixing vessel or coating reservoir connected to the spray-guns. The coatings are well mixed before application to ensure uniform distribution.

Inhalation: The scope of this scenario covers non-volatile components in furniture coatings. If the chemical of interest is a volatile chemical, then worker exposure during transfer would be expected. However, worker exposure to the non-volatile components in furniture coatings during transfer would be negligible. The CEB standard assumption is that a chemical of interest is volatile if the pure component vapor pressure is greater than or equal to 0.001 torr.

Dermal: CEB standard estimate for routine contact with liquids, 2 hands.

Dermal Exposure (mg/day) = Liquid Amount on Skin (mg/cm^2) x Surface Area of Skin (cm^2) x Number of Incidents x Fraction of Chemical in Coating

Example of coalescent in a metal furniture coating:
88 mg/day = 2.1 mg/cm^2-incident x 840 cm^2 x 1 incident/day x 0.05

B. Exposure During Spraying Operations (Exposure B)

Worker exposure to the chemical of interest is due to mist formed during spraying operations. Workers that are expected to be exposed to mist containing the chemical of interest are operators of manual spray booths or to a lesser extent workers that may enter an automated spray booth.

Inhalation: Worker inhalation exposures to mist are expected during manual spraying activities of the non-volatile chemical of interest. If site-specific information is not available, assume that spraying activities are performed manually. Table 9 presents a range of mist concentrations. These airborne concentrations are based on exposure monitoring data from metal and wood furniture manufacturing facilities. The data are presented in Appendix A.

Table 9. Airborne Levels of Paint Spray Mist

Industry	Paint Mist Concentration (mg/m^3) TWA	
	Low	High
Metal Furniture Finishing	3.7	23.5
Wood Furniture Finishing	0.1	2.5

If the substrate is not known, assume that the spraying of the unknown substrate would be characterized by the values for metal, since these are more conservative. Because these mist concentrations are for the non-volatile components of the coatings, the fraction of the chemical of interest in the non-solvent component of the coating must first be determined. Table 5 presents typical fractions of additives in coating formulations. Table 3 and 4 present typical fraction of solids in the coating formulation. Use the following methodology to determine the fraction of the solids in the coating.

- If the type of additive and weight fraction in the coating are unknown, assume the weight fraction of the additive in the coating and the weight fraction of solids in the coating is 0.705 for metal coatings and 0.3 for wood coatings (see Tables 3 and 4). Assume metal coating if unknown. This is consistent with the assumptions for calculating the daily use rate, and is the most conservative for estimating the inhalation exposure.
- If the type of additive or weight fraction in the coating is known, assume the coating is an aqueous based metal furniture coating as a conservative estimate. (Fraction of solids in the coating is 0.32.)

Note that 8 hrs/day must be used because concentrations are based on 8 hour TWAs.

Fraction of the Chemical in the Non-Solvent Component of the Coating = Fraction of the Chemical in the Coating / Fraction of Solids in the Coating

Example of coalescent in a water-based metal furniture coating:
0.16 = 0.05 / 0.32

Using this fraction and the concentrations in Table 9, the inhalation exposure from spray painting can be calculated using the following formula.

Inhalation Exposure (mg/day) = Concentration of Mist in the Air Due to Spraying Operations (mg/m3) x Breathing Rate (m^3/hr) x Hours per Day (hrs/day) x Fraction of Chemical in the Non-Solvent Component of the Coating

Example of coalescent in a water-based metal furniture coating:
5.9 to 38 mg/day = 3.7 to 23.5 (mg/m^3) x 1.25 (m^3/hr) x 8 (hrs/day) x 0.16

Dermal: CEB standard estimate for routine immersion in liquids, 2 hands. Operators of the spray guns in manual spray booths are expected to have the highest dermal contact.

Dermal Exposure (mg/day) = Liquid Amount on Skin (mg/cm^2) x Surface Area of Skin (cm^2) x Number of Incidents x Fraction of Chemical in Coating

Example of coalescent in a metal furniture coating:
433 mg/day = 10.3 mg/cm^2-incident x 840 cm^2 x 1 incident/day x 0.05

C. Exposure During Equipment Cleaning (Exposure C)

Workers may be exposed while cleaning the spray application equipment, pipes, booths, spray guns, feed lines, and coating reservoirs with water or organic solvents.

Inhalation: The scope of this scenario covers non-volatile components in furniture coatings. If the chemical of interest is a volatile chemical, then worker exposure equipment

cleaning would be expected. However, worker exposure to the non-volatile components in furniture coatings during cleaning would be negligible. The CEB standard assumption is that a chemical of interest is volatile if the pure component vapor pressure is greater than or equal to 0.001 torr.

Dermal: CEB standard estimate for routine contact with liquids, 2 hands. Assume concentration of chemical in the cleaning solution is 100% the concentration of chemical in the coating as a conservative estimate.

Dermal Exposure (mg/day) = Liquid Amount on Skin (mg/cm^2) x Surface Area of Skin (cm^2) x Number of Incidents x Fraction of Chemical in Coating x Fraction of Coating in Cleaning Solution

Example of coalescent in a metal furniture coating:
88 mg/day = 2.1 mg/cm^2-incident x 840 cm^2 x 1 incident/day x 0.05

Personal Protective Equipment (PPE):

Recommended PPE for workers in a spray booths includes:

- Air-supplied full face piece respirator;
- Disposable overalls and head covering;
- Gloves specific to the chemicals used; and
- boots and boot coverings. (DETIR)

Note that these are only PPE recommendations. Actual usage of PPE may be different.

Sources:

NIOSH, An Evaluation of Engineering Control Technology for Spray Painting. O'Brien, DM and Hurley, DE. NIOSH Pub. 81-121. 1981.

Rodriguez, V.E. Generic Engineering Assessment. Spray Coating Occupational Exposure and Environmental Releases. EPA/OTS/CEB. Revised October 1987.

DETIR. Spray Painting Guide for Employers and Operators. Queensland Government Department Employment, Training, and Industrial Relations.
http://www.whs.qld.gov.au/guide/gde43v3.pdf (Last confirmed April 2004)

Appendix A

PAINT MIST CONCENTRATION DATA

Table A-1. Airborne Levels of Paint Spray Mist in Metal Furniture Finishing

Painter	Paint Mist Concentration (mg/m^3) 8-hr TWA	
	Geometric Mean	Geometric Standard Deviation
U	27.6	1.9
V	<12.9	2.0
W	<18.9	2.0
X	3.7	1.8
Y	23.5	1.4
Z	7.0	1.1

Application Method: Compressed air; manual and reciprocator

NIOSH, An Evaluation of Engineering Control Technology for Spray Painting. O'Brien, DM and Hurley, DE. NIOSH Pub. 81-121. 1981.

Table A-2. Airborne Levels of Paint Spray Mist in Wood Furniture Finishing

Operation	Paint Mist Concentration (mg/m^3) TWA	
	Geometric Mean	Geometric Standard Deviation
Heavy coat of barrier finish	0.8	1.4
Second coat of barrier finish to top and sides	0.4	1.6
Manual coat of glaze to top and sides	1.0	1.2
Robot application of heavy coat of glaze (area sample)	0.1	2.0
Heavy coat of lacquer	0.5	1.2
Second coat of lacquer to top and sides	0.4	1.8
Light coat of glaze	0.1	5.0

Barrier coating of interior surfaces	0.5	1.1
Veil lacquer applied to interior	0.1	1.5
Final heavy coat of lacquer	2.5	1.0

Application Method: Airless; Compressed Air; Robot

NIOSH, An Evaluation of Engineering Control Technology for Spray Painting. O'Brien, DM and Hurley, DE. NIOSH Pub. 81-121. 1981.