

EPA-450/3-78-006

April 1978

**STUDY TO SUPPORT
NEW SOURCE PERFORMANCE
STANDARDS FOR SURFACE
COATING OF METAL
FURNITURE**



**U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711**

**STUDY TO SUPPORT
NEW SOURCE PERFORMANCE
STANDARDS FOR SURFACE COATING
OF METAL FURNITURE**

by

**Springborn Laboratories, Inc.
Enfield, Connecticut 06082**

Contract No. 68-02-2075

EPA Project Officer: Vera N. Gallagher

Prepared for

**U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711**

April 1978

This report is issued by the Environmental Protection Agency to report technical data of interest to a limited number of readers. Copies are available free of charge to Federal employees, current contractors and grantees, and nonprofit organizations - in limited quantities - from the Library Services Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711; or, for a fee, from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

This report was furnished to the Environmental Protection Agency by Springborn Laboratories, Inc., Enfield, Connecticut, in fulfillment of Contract No. 68-02-2075. The contents of this report are reproduced herein as received from Springborn Laboratories, Inc. The opinions, findings, and conclusions expressed are those of the author and not necessarily those of the Environmental Protection Agency. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

Publication No. EPA-450/3-78-006

CONTENTS

	<u>Page</u>
2. INTRODUCTION	2-1
2.1. AUTHORITY FOR THE STANDARDS	2-1
2.2. SELECTION OF CATEGORIES OF STATIONARY SOURCES	2-4
2.3. PROCEDURE FOR DEVELOPMENT OF STANDARDS PERFORMANCE	2-6
2.4. CONSIDERATION OF COSTS	2-8
2.5. CONSIDERATION OF ENVIRONMENTAL IMPACTS	2-9
2.6. IMPACT ON EXISTING SOURCES	2-10
3. THE METAL FURNITURE INDUSTRY	3-1
3.1. GENERAL DESCRIPTION	3-1
3.2. PROCESSES OR FACILITIES AND THEIR EMISSIONS	3-5
3.2.1. The Basic Processes	3-5
3.2.1.1. Spray Coating	3-5
3.2.1.2. Dip Coating	3-10
3.2.1.3. Flow Coating	3-13
3.2.2. Equipment Characteristics	3-14
3.2.3. Emission Characteristics	3-15
3.2.4. Parameters Affecting Emissions	3-17
3.3. REFERENCES	3-19
4. EMISSION CONTROL TECHNIQUES	4-1
4.1. THE ALTERNATIVE EMISSION CONTROL TECHNIQUES	4-1
4.1.1. Powder Coating	4-1
4.1.1.1. Electrostatic Spray	4-3
4.1.1.2. Fluidized Bed	4-12

CONTENTS (Continued - 2)

	<u>Page</u>
4.1.2. Water-Borne Coatings	4-14
4.1.2.1. Electrodeposition	4-15
4.1.2.2. Water-Borne Spray	4-22
4.1.2.3. Water-Borne Dip	4-24
4.1.2.4. Water-Borne Flow Coating	4-24
4.1.3. Higher Solids Coating	4-25
4.1.4. Carbon Adsorption	4-27
4.1.5. Incineration	4-34
4.1.5.1. Thermal Incinerators	4-34
4.1.5.2. Catalytic Incineration	4-39
4.2. EMISSION REDUCTION PERFORMANCE OF CONTROL TECHNIQUES	4-42
4.2.1. Powder Coating - Electrostatic Spray	4-43
4.2.2. Powder Coating - Fluidized Bed	4-43
4.2.3. Electrodeposition of Water-Bornes	4-43
4.2.4. Water-Borne Spray	4-44
4.2.5. Water-Borne Dip and Flow Coatings	4-46
4.2.6. Higher Solids Coatings	4-47
4.2.7. Incineration	4-49
4.2.8. Carbon Adsorption	4-49
4.3. REFERENCES	4-50
5. MODIFICATION AND RECONSTRUCTION	5-1
5.1. POTENTIAL MODIFICATIONS	5-2
5.2. RECONSTRUCTION	5-5
5.3. CONSTRAINTS	5-5

CONTENTS (Continued -3)

	<u>Page</u>
5.4. REFERENCES	5-7
6. EMISSION CONTROL SYSTEMS	6-1
6.1. ALTERNATIVE A-2	6-4
6.2. ALTERNATIVE A-3	6-4
6.3. ALTERNATIVE A-4	6-4
6.4. ALTERNATIVE A-5	6-7
6.5. ALTERNATIVE B-2	6-7
6.6. ALTERNATIVE B-3	6-11
6.7. ALTERNATIVE B-4	6-11
6.8. ALTERNATIVE B-5	6-11
6.9. ALTERNATIVE B-6	6-11
6.10. REFERENCES	6-14
7. ENVIRONMENTAL IMPACT	7-1
7.1. AIR POLLUTION IMPACT	7-1
7.1.1. State Regulations and Controlled Emissions	7-3
7.1.2. Uncontrolled and Controlled Emissions (Alternatives)	7-5
7.1.2.1. Spray Coating	7-5
7.1.2.2. Dip Coating	7-6
7.1.2.3. Estimated Hydrocarbon Emission Reduction in Future Years	7-10
7.2. WATER POLLUTION IMPACT	7-17
7.3. SOLID WASTE DISPOSAL IMPACT	7-18
7.4. ENERGY IMPACT	7-20
7.5. OTHER ENVIRONMENTAL IMPACTS	7-23
7.6. OTHER ENVIRONMENTAL CONCERNS	7-23
7.6.1. Irreversible and Irretrievable Commitment of Resources	7-23

CONTENTS (Continued -4)

	<u>Page</u>
7.6.2. Environmental Impact of Delayed Standards	7-23
7.6.3. Environmental Impact of No Standards	7-24
7.7. REFERENCES	7-25
8. ECONOMIC IMPACT	8-1
8.1. INDUSTRY ECONOMIC PROFILE	8-1
8.1.1. Introduction	8-1
8.1.2. Industry Size	8-1
8.1.3. Industry Growth: Past and Projected	8-7
8.1.4. Industry Structure	8-12
8.1.5. Channels of Distribution	8-16
8.1.6. Industry Markets	8-17
8.1.7. Labor and Materials Costs	8-17
8.1.8. Financial Performance	8-21
8.1.9. Imports and Exports	8-21
8.1.10. Geographic Distribution	8-24
8.2. COST ANALYSIS OF ALTERNATIVE EMISSION CONTROL SYSTEMS	8-27
8.2.1. Cost Effectiveness Summarized - New Facilities	8-29
8.2.2. Reconstructed Facilities	8-35
8.2.3. Water Pollution and Solid Waste Disposal	8-38
8.3. REFERENCES	8-39
9. RATIONALE FOR THE PROPOSED STANDARDS	9-1
9.1. SELECTION OF SOURCE FOR CONTROL	9-1
9.2. SELECTION OF POLLUTANTS AND AFFECTED FACILITIES	9-2
9.3. SELECTION OF THE BEST SYSTEM OF EMISSION REDUCTION CONSIDERING COSTS	9-9

CONTENTS (Continued 5)

	<u>Page</u>
9.4. SELECTION OF THE FORMAT OF THE PROPOSED STANDARD	9-10
9.4.1. Concentration - Airborne Emissions	9-10
9.4.2. Mass/Time - Airborne Emissions	9-10
9.4.3. Equipment Standard - Airborne Emissions	9-11
9.4.4. Mass of Emissions/Unit of Coating Material Consumed	9-11
9.5. SELECTION OF EMISSION LIMITS (To be prepared by EPA)	
9.6. VISIBLE EMISSION STANDARDS (To be prepared by EPA)	
9.7. MODIFICATION/RECONSTRUCTION CONSIDERATION	9-14
9.7.1. Potential Modifications	9-15
9.7.2. Substitution of Equipment	9-17
9.7.3. Reconstruction	9-18
9.7.4. Constraints	9-18
9.8. SELECTION OF MONITORING REQUIREMENTS (To be prepared by EPA)	
9.9. SELECTION OF PERFORMANCE TEST METHODS (To be prepared by EPA)	
APPENDIX A. - EVOLUTION OF PROPOSED STANDARDS	A-1
APPENDIX B. - INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS	B-1

Listing of Tables and Figures follows.

LIST OF TABLES AND FIGURES

TABLES

3-2.	Metal Furniture Trends and Projections in Thousand Dollars at Constant Price (1972)	3-3
3-3.	Metal Furniture Establishments	3-4
3-4.	Material Balance Metal Furniture Electrostatic Spray Coating	3-8
3-5.	Energy Balance Metal Furniture Coating Process	3-10
3-6.	Material Balance Metal Furniture Dip Coating	3-11
3-7.	Energy Balance Dip Coating Metal Furniture	3-13
3-8.	Average Emissions for the Metal Furniture Finishing Process Liters of Solvent Per 1000 Square Meters (Gallons of Solvent Per Square Foot)	3-16
4-1.	Examples of Metal Furniture Finishing with Powder Coatings	4-5
4-2.	Overall Weight Percent of Powder Utilized	4-9
4-3.	Water-Borne Coatings	4-16
4-4.	Electrodeposition in the Metal Furniture Industry	4-17
4-5.	Problem Solvents for Carbon Adsorption	4-30
4-6.	Percent Emission Reduction for Water-Borne Coatings Applied by Spray Techniques	4-45
4-7.	Reduction of Organic Solvent Emissions 92,400 Square Meters (1,000,000 Square Feet) Sprayed at 65 Percent Efficiency Approximately 30 Percent Volume Solids	4-46
4-8.	Percent Emission Reduction for Water-Borne Coatings Applied by Dip and Flow Coating	4-47
6-1.	Metal Furniture Emission Control Systems Size of Line: 3,000,000 Square Feet Coated Area Per Year	6-2
6-2.	Metal Furniture Emission Control Systems Size of Line: 22,464,000 Square Feet Coated Area Per Year	6-3

LIST OF TABLES AND FIGURES (Continued -2)

TABLES	<u>Page</u>
7-1. Metal Furniture Painting Operation Spray Coating Hydrocarbon Emission Factors and Controlled and Uncontrolled Model Plants	7-7
7-2. Metal Furniture Painting Operation Dip Coating Hydrocarbon Emission Factors and Control Efficiency Controlled and Uncontrolled Model Plants	7-9
7-3. Comparative Effectiveness of Alternate Control Systems Expressed in Annual Organic Emissions Controls on a Spray Coating Operation Assumed Annual Penetration: 5 Percent	7-11
7-4. Comparative Effectiveness of Alternate Control Systems Expressed in Annual Organic Emissions Controls on a Dip Coating Operation Assumed Annual Penetration: 5 Percent	7-12
7-5. Comparative Effectiveness of Alternate Control Systems Expressed in Annual Organic Emission Controls on a Spray Coating Operation Assumed Annual Penetration: 10 Percent	7-13
7-6. Comparative Effectiveness of Alternate Control Systems Expressed in Annual Organic Emissions Controls on a Dip Coating Operation Assumed Annual Penetration: 10 Percent	7-14
7-7. Effectiveness of Alternate Control Systems - Year 1985 Expressed in Annual Organic Emissions Controls on a Dip Coating Operation Comparative Annual Penetration: 5 and 10 Percent	7-15
7-8. Effectiveness of Alternative Control Systems - Year 1985 Expressed in Annual Organic Emission Controls on a Spray Coating Operation Comparative Annual Penetration: 5 and 10 Percent	7-16
7-9. Energy Balance - On a Spray Coating Operation	7-21
7-10. Energy Balance on a Dip Coating Operation	7-22
8.1-1. Basic Industry Statistics Metal Household Furniture (SIC 2514)	8-2
8.1-2. Basic Industry Statistics Metal Office Furniture (SIC 2522)	8-3
8.1-3. Basic Industry Statistics Public Building and Related Furniture (SIC 2531)	8-4

LIST OF TABLES AND FIGURES (Continued -3)

TABLES	<u>Page</u>
8.1-4. Basic Industry Statistics Metal Partitions and Fixtures (SIC 2542)	8-5
8.1-5. Basic Industry Statistics Metal Furniture Industry (Total Figures for SIC 2514, 2522, 2531, 2542)	8-6
8.1-6. Value of Metal Furniture Industry Shipments in Current and Constant Dollars, 1967, 1975	8-8
8.1-7. Concentration Ratios in Metal Furniture Manufacturing	8-13
8.1-8. Percent of Value Added in Metal Furniture Manufacturing by Multiunit and Single Unit Companies, 1972	8-14
8.1-9. Distribution by Firm Size in the Metal Furniture Industry of Establishments, Production Workers and Value Added by Manufacture, 1972 (Share of Total, Percent)	8-15
8.1-10. Metal Furniture Product Mix, 1963 - 1975 (As Percent of Value of Total Industry Shipments)	8-18
8.1-11. Labor and Materials Costs in Metal Furniture Manufacturing Relative to Value of Industry Shipments	8-19
8.1-12. Trends in Wages and Productivity in the Metal Furniture Industry 1958 - 1975	8-20
8.1-13. Metal Furniture Coating Materials Cost vs. Total Materials Cost and Value of Shipments, 1972 and 1967	8-22
8.1-14. Financial Ratios for Selected Metal Furniture Manufacturers	8-23
8.1-15. Geographical Distribution of Establishments and Value Added by Manufacture, Metal Furniture Industry, 1972	8-25
8.1-16. Geographical Distribution of Metal Furniture Industry Establishments, 1972 (In Percent of Number of Establishments)	8-26
8.2-1. Case Codes A-1 - A-7	8-28
8.2-2. Case Codes B-1 - B-6	8-29
8.2-3. Alternative Cases - New Facilities Metal Furniture - Part I	8-31
8.2-4. Alternative Cases - New Facilities Metal Furniture - Part II	8-32
8.2-5. Metal Furniture Coating Solvent Emissions from Affected Facilities	8-34

LIST OF TABLES AND FIGURES (Continued 4)

TABLES		<u>Page</u>
8.2-6.	Codes A.1-1 - A.1-3	8-35
8.2-7.	Codes B.1-1 - B.1-3	8-35
8.2-8.	Alternative Cases - Reconstructed Facilities Metal Furniture Part I	8-36
8.2-9.	Alternative Cases - Reconstructed Facilities Metal Furniture Part II	8-37

FIGURES

3-1.	Electrostatic Solvent Spray Costing System	3-6
3-2.	Flow Diagram - Material for Electrostatic Spray Solvent-Borne Coating	3-9
3-3.	Flow Diagram - Material for Solvent-Borne Dip Coating	3-12
4-1.	Schematic of Electrostatic Powder Spray Process	4-4
4-2.	Sophisticated Recovery System	4-8
4-3.	Schematic of Fluidized Bed Apparatus	4-13
4-4.	Typical Electrodeposition System Diagram	4-19
4-5.	Diagram of an Activated-Carbon Adsorber System	4-28
4-6.	Effluent Concentration Curve of Butane Vapor From an Activated Carbon Bed as Function of Time	4-32
4-7.	Forced-Draft System Eliminating Solvent Vapors from Surface Coating Process	4-35
4-8.	Coupled Effects of Temperature and Time on Rate of Pollutant Oxidation	4-38
4-9.	Schematic Diagram of Catalytic Afterburner Using Torch-Type Preheat Burner with Flow of Preheat Waste Stream Through Fan to Promote Mixing	4-40
4-10.	Effect of Temperature on Oxidative Conversion of Organic Vapors in a Catalytic Incinerator	4-41

LIST OF TABLES AND FIGURES (Continued -5)

FIGURES		<u>Page</u>
4-11.	Emission Reduction Potential (Percent) With Use of Higher Solids Coatings in Place of 28 Volume Percent Solvent-Borne Paint (50 Percent Deposition Efficiency)	4-48
6-1.	Flow Diagram - Alternative A-2 Application of Solvent-Borne Coating by Electrostatic Spray Base Case with Incinerator on Oven	6-5
6-2.	Flow Diagram - Alternative A-3 Application of Solvent-Borne Coating by Electrostatic Spray Base Case with Carbon Adsorber on Spray Booth	6-6
6-3.	Flow Diagram - Base Case Alternatives A-4 and A-6 Application of Coating by Electrostatic Spray Conventional (Base Case), or High Solids (A-4) Solvent-Borne Coatings or Water-Borne Coatings (A-6)	6-8
6-4.	Flow Diagram - Alternative A-5 Application of Powder Coating Electrostatic Spray	6-9
6.5.	Flow Diagram - Alternative B-2 Application of Water-Borne Coating by Electrodeposition (EDP)	6-10
6-6.	Flow Diagram - Alternative B-3 Application of Solvent-Borne Dip Coating Base Case with Carbon Adsorber on Dip Tank	6-12
6-7.	Flow Diagram - Alternative B-4 Application of Solvent-Borne Dip Coating Base Case with Incinerator on Oven	6-13
8.1-1.	Real Gross National Product and Metal Furniture Industry Shipments in Constant Dollars, 1967 - 1975	8-9
8.1-2.	Percent Change From Previous Year in Real Gross National Product and Constant Dollar Metal Furniture Industry Shipments	8-10

2. INTRODUCTION

Standards of performance are proposed following a detailed investigation of air pollution control methods available to the affected industry and the impact of their costs on the industry. This document summarizes the information obtained from such a study. Its purpose is to explain in detail the background and basis of the proposed standards and to facilitate analysis of the proposed standards by interested persons, including those who may not be familiar with the many technical aspects of the industry. To obtain additional copies of this document or the Federal Register notice of proposed standards, write to EPA Library (MD-35), Research Triangle Park, North Carolina, 27711. Specify Standards Support and Environmental Impact Statement, Volume 1: Proposed Standards of Performance for Surface Coating of Metal Furniture, document number EPA 450/3-78-006 when ordering.

2.1. AUTHORITY FOR THE STANDARDS

Standards of performance for new stationary sources are established under Section 111 of the Clean Air Act (42 U.S.C. 7411), as amended, hereafter referred to as the Act. Section 111 directs the Administrator to establish standards of performance for any category of new stationary source of air pollution which " . . . causes or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare."

The Act requires that standards of performance for stationary sources reflect, " . . . the degree of emission limitation achievable through the application of the best technological system of continuous emission reduction . . . the Administrator determines has been adequately demonstrated." In addition, for stationary sources whose emissions result from fossil fuel combustion, the standard must also include a percentage reduction in emissions. The Act also provides that the cost of achieving the necessary emission reduction, the non-air quality health and environmental impacts and the energy requirements all be taken into account in establishing standards of performance. The standards apply only to stationary sources, the construction or modification of which commences after regulations are proposed by publication in the Federal Register.

The 1977 amendments to the Act altered or added numerous provisions which apply to the process of establishing standards of performance.

1. EPA is required to list the categories of major stationary sources which have not already been listed and regulated under standards of performance. Regulations must be promulgated for these new categories on the following schedule:

25 percent of the listed categories by August 7, 1980

75 percent of the listed categories by August 7, 1981

100 percent of the listed categories by August 7, 1982

A governor of a state may apply to the Administrator to add a category which is not on the list or to revise a standard of performance.

2. EPA is required to review the standards of performance every four years, and if appropriate, revise them.

3. EPA is authorized to promulgate a design, equipment, work practice, or operational standard when an emission standard is not feasible.

4. The term "standards of performance" is redefined and a new term "technological system of continuous emission reduction" is defined. The new definitions clarify that the control system must be continuous and may include a low-polluting or non-polluting process or operation.

5. The time between the proposal and promulgation of a standard under Section 111 of the Act is extended to six months.

Standards of performance, by themselves, do not guarantee protection of health or welfare because they are not designed to achieve any specific air quality levels. Rather, they are designed to reflect the degree of emission limitation achievable through application of the best adequately demonstrated technological system of continuous emission reduction, taking into consideration the cost of achieving such emission reduction, any non-air quality health and environmental impact and energy requirements.

Congress had several reasons for including these requirements. First, standards with a degree of uniformity are needed to avoid situations where some states may attract industries by relaxing standards relative to other states. Second, stringent standards enhance the potential for long-term growth. Third, stringent standards may help achieve long-term cost savings by avoiding the need for more expensive retrofitting when pollution ceilings may be reduced in the future. Fourth, certain types of standards for coal burning sources can adversely affect the coal market by driving up the price of low-sulfur coal or effectively excluding certain

coals from the reserve base because their untreated pollution potentials are high. Congress does not intend that new source performance standards contribute to these problems. Fifth, the standard-setting process should create incentives for improved technology.

Promulgation of standards of performance does not prevent state or local agencies from adopting more stringent emission limitations for the same sources. States are free under Section 116 of the Act to establish even more stringent emission limits than those established under Section 111 or those necessary to attain or maintain the National Ambient Air Quality Standards (NAAQS) under Section 110. Thus, new sources may in some cases be subject to limitations more stringent than standards of performance under Section 111, and prospective owners and operators of new sources should be aware of this possibility in planning for such facilities.

A similar situation may arise when a major emitting facility is to be constructed in a geographic area which falls under the prevention of significant deterioration of air quality provisions of Part C of the Act. These provisions require, among other things, that major emitting facilities to be constructed in such areas are to be subject to best available control technology. The term "Best Available Control Technology" (BACT), as defined in the Act, means " . . . an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under this Act emitted from or which results from any major emitting facility, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility through application of production processes and available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of each such pollutant. In no event shall application of 'Best Available Control Technology' result in emissions of any pollutants which will exceed the emissions allowed by any applicable standard established pursuant to Section 111 or 112 of this Act."

Although standards of performance are normally structured in terms of numerical emission limits where feasible, alternative approaches are sometimes necessary. In some cases physical measurement of emissions from a new source may be impractical or exorbitantly expensive. Section 111(h) provides that the Administrator may promulgate a design or equipment standard in those cases where it is not feasible to prescribe or enforce a standard of performance. For example,

emissions of hydrocarbons from storage vessels for petroleum liquids are greatest during tank filling. The nature of the emissions, high concentrations for short periods during filling, and low concentrations for longer periods during storage, and the configuration of storage tanks make direct emission measurement impractical. Therefore, a more practical approach to standards of performance for storage vessels has been equipment specification.

In addition, Section 111(h) authorizes the Administrator to grant waivers of compliance to permit a source to use innovative continuous emission control technology. In order to grant the waiver, the Administrator must find: (1) a substantial likelihood that the technology will produce greater emission reductions than the standards require, or an equivalent reduction at lower economic, energy or environmental cost; (2) the proposed system has not been adequately demonstrated; (3) the technology will not cause or contribute to an unreasonable risk to public health, welfare or safety; (4) the governor of the state where the source is located consents; and that, (5) the waiver will not prevent the attainment or maintenance of any ambient standard. A waiver may have conditions attached to assure the source will not prevent attainment of any NAAQS. Any such condition will have the force of a performance standard. Finally, waivers have definite end dates and may be terminated earlier if the conditions are not met or if the system fails to perform as expected. In such a case, the source may be given up to three years to meet the standards, with a mandatory progress schedule.

2.2. SELECTION OF CATEGORIES OF STATIONARY SOURCES

Section 111 of the Act directs the Administrator to list categories of stationary sources which have not been listed before. The Administrator, " . . . shall include a category of sources in such list if in his judgement it causes, or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare." Proposal and promulgation of standards of performance are to follow while adhering to the schedule referred to earlier.

Since passage of the Clean Air Amendments of 1970, considerable attention has been given to the development of a system for assigning priorities to various source categories. The approach specifies areas of interest by considering the broad strategy of the Agency for implementing the Clean Air Act. Often, these "areas" are actually pollutants which are emitted by stationary sources. Source categories which

emit these pollutants were then evaluated and ranked by a process involving such factors as: (1) the level of emission control (if any) already required by state regulations; (2) estimated levels of control that might be required from standards of performance for the source category; (3) projections of growth and replacement of existing facilities for the source category; and (4) the estimated incremental amount of air pollution that could be prevented, in a pre-selected future year, by standards of performance for the source category. Sources for which new source performance standards were promulgated or are under development during 1977 or earlier, were selected on these criteria.

The Act amendments of August 1977, establish specific criteria to be used in determining priorities for all source categories not yet listed by EPA. These are: (1) the quantity of air pollutant emissions which each such category will emit, or will be designed to emit; (2) the extent to which each such pollutant may reasonably be anticipated to endanger public health or welfare; and (3) the mobility and competitive nature of each such category of sources and the consequent need for nationally applicable new source standards of performance.

In some cases, it may not be feasible to immediately develop a standard for a source category with a high priority. This might happen when a program of research is needed to develop control techniques or because techniques for sampling and measuring emissions may require refinement. In the developing of standards, differences in the time required to complete the necessary investigation for different source categories must also be considered. For example, substantially more time may be necessary if numerous pollutants must be investigated from a single source category. Further, even late in the development process the schedule for completion of a standard may change. For example, inability to obtain emission data from well-controlled sources in time to pursue the development process in a systematic fashion may force a change in scheduling. Nevertheless, priority ranking is, and will continue to be, used to establish the order in which projects are initiated and resources assigned.

After the source category has been chosen, determining the types of facilities within the source category to which the standard will apply must be decided. A source category may have several facilities that cause air pollution and emissions from some of these facilities may be insignificant or very expensive to control.

Economic studies of the source category and of applicable control technology may show that air pollution control is better served by applying standards to the more severe pollution sources. For this reason, and because there is no adequately demonstrated system for controlling emissions from certain facilities, standards often do not apply to all facilities at a source. For the same reasons, the standards may not apply to all air pollutants emitted. Thus, although a source category may be selected to be covered by a standard of performance, not all pollutants or facilities within that source category may be covered by the standards.

2.3. PROCEDURE FOR DEVELOPMENT OF STANDARDS PERFORMANCE

Standards of performance must: (1) realistically reflect the best demonstrated control practice; (2) adequately consider the cost, and the non-air quality health and environmental impacts and energy requirements of such control; (3) be applicable to existing sources that are modified or reconstructed as well as new installations; and (4) meet these conditions for all variations of operating conditions being considered anywhere in the country.

The objective of a program for development of standards is to identify the best technological system of continuous emission reduction which has been adequately demonstrated. The legislative history of Section 111 and various court decisions make clear that the Administrator's judgement of what is adequately demonstrated is not limited to systems that are in actual routine use. The search may include a technical assessment of control systems which have been adequately demonstrated but for which there is limited operational experience. In most cases, determination of the " . . . degree of emission reduction achievable . . . " is based on results of tests of emissions from well controlled existing sources. At times, this has required the investigation and measurement of emissions from control systems found in other industrialized countries that have developed more effective systems of control than those available in the United States.

Since the best demonstrated systems of emission reduction may not be in widespread use, the data base upon which standards are developed may be somewhat limited. Test data on existing well-controlled sources are obvious starting points in developing emission limits for new sources. However, since the control of existing sources generally represents retrofit technology or was originally designed to meet an existing state or local regulation, new sources may be able to meet more stringent

emission standards. Accordingly, other information must be considered before a judgment can be made as to the level at which the emission standard should be set.

A process for the development of a standard has evolved which takes into account the following considerations.

1. Emissions from existing well-controlled sources as measured.
2. Data on emissions from such sources are assessed with consideration of such factors as: (a) how representative the tested source is in regard to feedstock, operation, size, age, etc.; (b) age and maintenance of the control equipment tested; (c) design uncertainties of control equipment being considered; and (d) the degree of uncertainty that new sources will be able to achieve similar levels of control.
3. Information from pilot and prototype installations, guarantees by vendors of control equipment, unconstructed but contracted projects, foreign technology, and published literature are also considered during the standard development process. This is especially important for sources where "emerging" technology appears to be a significant alternative.
4. Where possible, standards are developed which permit the use of more than one control technique or licensed process.
5. Where possible, standards are developed to encourage or permit the use of process modifications or new processes as a method of control rather than "add-on" systems of air pollution control.
6. In appropriate cases, standards are developed to permit the use of systems capable of controlling more than one pollutant. As an example, a scrubber can remove both gaseous and particulate emissions, but an electrostatic precipitator is specific to particulate matter.
7. Where appropriate, standards for visible emissions are developed in conjunction with concentration/mass emission standards. The opacity standard is established at a level that will require proper operation and maintenance of the emission control system installed to meet the concentration/mass standard on a day-to-day basis. In some cases, however, it is not possible to develop concentration/mass standards, such as with fugitive sources of emissions. In these cases, only opacity standards may be developed to limit emissions.

2.4. CONSIDERATION OF COSTS

Section 317 of the Act requires, among other things, an economic impact assessment with respect to any standard of performance established under Section 111 of the Act. The assessment is required to contain an analysis of:

1. the costs of compliance with the regulation and standard including the extent to which the cost of compliance varies depending on the effective date of the standard or regulation and the development of less expensive or more efficient methods of compliance;
2. the potential inflationary recessionary effects of the standard or regulation;
3. the effects on competition of the standard or regulation with respect to small business;
4. the effects of the standard or regulation on consumer cost, and,
5. the effects of the standard or regulation on energy use.

Section 317 requires that the economic impact assessment be as extensive as practical, taking into account the time and resources available to EPA.

The economic impact of a proposed standard upon an industry is usually addressed both in absolute terms and by comparison with the control costs that would be incurred as a result of compliance with typical existing state control regulations. An incremental approach is taken since both new and existing plants would be required to comply with state regulations in the absence of a federal standard of performance. This approach requires a detailed analysis of the impact upon the industry resulting from the cost differential that exists between a standard of performance and the typical state standard.

The costs for control of air pollutants are not the only costs considered. Total environmental costs for control of water pollutants as well as air pollutants are analyzed wherever possible.

A thorough study of the profitability and price-setting mechanisms of the industry is essential to the analysis so that an accurate estimate of potential adverse economic impacts can be made. It is also essential to know the capital requirements placed on plants in the absence of federal standards of performance so that the additional capital requirements necessitated by these standards can be placed in the

proper perspective. Finally, it is necessary to recognize any constraints on capital availability within an industry, as this factor also influences the ability of new plants to generate the capital required for installation of additional control equipment needed to meet the standards of performance.

2.5. CONSIDERATION OF ENVIRONMENTAL IMPACTS

Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969 required federal agencies to prepare detailed environmental impact statements on proposals for legislation and other major federal actions significantly affecting the quality of the human environment. The objective of NEPA is to build into the decision-making process of federal agencies a careful consideration of all environmental aspects of proposed actions.

In a number of legal challenges to standards of performance for various industries, the Federal Courts of Appeals have held that environmental impact statements need not be prepared by the Agency for proposed actions under Section 111 of the Clean Air Act. Essentially, the Federal Courts of Appeals have determined that " . . . the best system of emission reduction, . . . require(s) the Administrator to take into account counter-productive environmental effects of a proposed standard, as well as economic costs to the industry . . ." On this basis, therefore, the Courts" . . . established a narrow exemption from NEPA for EPA determination under Section 111."

In addition to these judicial determinations, the Energy Supply and Environmental Coordination Act (ESECA) of 1974 (PL-93-319) specifically exempted proposed actions under the Clean Air Act from NEPA requirements. According to Section 7(c)(1), "No action taken under the Clean Air Act shall be deemed a major federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act of 1969."

The Agency has concluded, however, that the preparation of environmental impact statements could have beneficial effects on certain regulatory actions. Consequently, while not legally required to do so by Section 102(2)(C) of NEPA, environmental impact statements will be prepared for various regulatory actions, including standards of performance developed under Section 111 of the Act. This voluntary preparation of environmental impact statements, however, in no way legally subjects the Agency to NEPA requirements.

To implement this policy, a separate section is included in this document which is devoted solely to an analysis of the potential environmental impacts associated with the proposed standards. Both adverse and beneficial impacts in such areas as air and water pollution, increased solid waste disposal, and increased energy consumption are identified and discussed.

2.6. IMPACT ON EXISTING SOURCES

Section 111 of the Act defines a new source as " . . . any stationary source, the construction or modification of which is commenced . . ." after the proposed standards are published. An existing source becomes a new source if the source is modified or is reconstructed. Both modification and reconstruction are defined in amendments to the general provisions of Subpart A of 40 CFR Part 60 which were promulgated in the Federal Register on December 16, 1975 (40 FR 58416). Any physical or operational change to an existing facility which results in an increase in the emission rate of any pollutant for which a standard applies is considered a modification. Reconstruction, on the other hand, means the replacement of components of an existing facility to the extent that the fixed capital cost exceeds 50 percent of the cost of constructing a comparable entirely new source and that it be technically and economically feasible to meet the applicable standards. In such cases, reconstruction is equivalent to new construction.

Promulgation of a standard of performance requires states to establish standards of performance for existing sources in the same industry under Section 111(d) of the Act if the standard for new sources limits emissions of a designated pollutant (i.e., a pollutant for which air quality criteria have not been issued under Section 108 or which has not been listed as a hazardous pollutant under Section 112). If a state does not act, EPA must establish such standards. General provisions outlining procedures for control of existing sources under Section 111(d) were promulgated on November 17, 1975, as Subpart B of 40 CFR Part 60 (40 FR 53340).

2.7 REVISION OF STANDARDS OF PERFORMANCE

Congress was aware that the level of air pollution control achievable by any industry may improve with technological advances. Accordingly, Section 111 of the Act provides that the Administrator " . . . shall, at least every four years, review and, if appropriate, revise . . ." the standards. Revisions are made to assure that the

standards continue to reflect the best systems that become available in the future. Such revisions will not be retroactive but will apply to stationary sources constructed or modified after the proposal of the revised standards.

3. THE METAL FURNITURE INDUSTRY

3.1. GENERAL DESCRIPTION

In 1972 the metal furniture industry consisted of 1,588 companies which employed 109,600 persons and sold \$2.8 billions worth of metal furniture a year. As compared with the levels in 1967 the number of companies decreased by 5 percent, employment by 6 percent and shipments increased by 35 percent.

The metal furniture industry is highly fragmented, including the following categories of products:

- | | | |
|----|-------------------------------|----------|
| 1. | Household Metal Furniture | SIC 2514 |
| 2. | Office Metal Furniture | SIC 2522 |
| 3. | Public Building Furniture | SIC 2531 |
| 4. | Metal Partitions and Fixtures | SIC 2542 |

The metal furniture industry consists of many small-scale companies employing less than 100 employees per company. During 1972, 85 percent of the metal furniture manufacturing industry was represented by facilities with less than 100 employees and 37 percent of the industry involved manufacturing companies with less than ten employees.

The employment data for the metal furniture industry is tabulated in Table 3-1.

Table 3-1. EMPLOYMENT STATISTICS
(Number of Persons)

	<u>1972</u>
Metal household	34,400
Metal office	27,600
Public building	21,400
Partitions and fixtures	<u>26,200</u>
Total	109,600

The metal household furniture industry is comprised of companies manufacturing metal furniture for kitchen, porch, lawn and outdoor usage and others including metal bed frames, card tables and chairs. Of the 467 establishments manufacturing metal household furniture 369 had less than 100 employees in 1972¹.

The metal office industry is established from companies primarily involved in manufacturing office chairs, desks, cabinets and cases and other metal office furniture (including bookcases, storage cabinets, costumers, etc.). Of the 192 establishments manufacturing metal office furniture, 132 establishments had less than 100 employees in 1972¹.

Public building furniture may be metal or wood for schools, theaters, assembly halls, churches and libraries. Companies manufacturing seats for automobiles and aircraft are also included in this industry. Of the reported 422 companies manufacturing public building furniture, 363 companies employ less than 100 persons in 1972¹.

The industry of metal partitions and fixtures comprises establishments primarily manufacturing metal shelving, storage racks, lockers, office and store fixtures, prefabricated partitions and related fabricated products.

Of the 507 companies manufacturing metal partitions and fixtures 443 companies had less than 100 employees.

The metal furniture industry shipments value has shown an estimated 10 percent growth since 1972. The growth of the industry is mainly affected by the growth in construction of houses, schools, hospitals, air terminals and office buildings. The sales volume of metal furniture was estimated at 3.2 billion dollars, including shipments of household furniture, office and building furniture and metal partitions and fixtures in 1976. Table 3-2 shows sales of metal furniture by category.

The growth rates of each segment of the industry from 1972 to 1985 is based on actual growth excluding inflation of the dollar. The household furniture industry annual average growth rates are: 2.4 percent for 1973 to 1980 and 3.9 percent for 1980 to 1985³. The other segments of the furniture industry, excluding household furniture, are showing the following annual growth rates: 4.4 percent for 1973 to 1980 and 3.0 percent for 1980 to 1985.

A geographical break-down of the metal furniture establishments is shown in Table 3-3. The Middle Atlantic and East/North Central states accounted for almost 50 percent of all establishments.

**Table 3-2. METAL FURNITURE TRENDS AND PROJECTIONS
IN THOUSAND DOLLARS AT CONSTANT PRICE (1972)**

	<u>1972^a</u>	<u>1973^b</u>	<u>1974^b</u>	<u>1975^b</u>	<u>1976^b</u>	<u>1980^b</u>	<u>1985^b</u>
Household	890	911	933	956	979	1076	1303
Office	791	815	851	889	928	1102	1278
Public building	485	506	529	552	576	684	793
Partitions and fixtures	<u>713</u>	<u>744</u>	<u>777</u>	<u>811</u>	<u>847</u>	<u>1006</u>	<u>1167</u>
Total	2869	2976	3090	3208	3330	3868	4541

Sources: ^a 1972 Census of Manufacturers

^b BLS Review, November 1976, p 5

Table 3-3. METAL FURNITURE ESTABLISHMENTS

	<u>Household</u>	<u>Office</u>	<u>Public Buildings^a</u>	<u>Partitions and Fixtures</u>
New England	24	6	19	22
Maine	--	-	1	--
Massachusetts	17	3	--	12
Connecticut	5	-	5	--
Middle Atlantic	134	55	61	177
New York	90	31	24	113
New Jersey	15	7	11	29
Pennsylvania	29	17	26	35
East North Central	76	48	105	118
Ohio	12	11	31	32
Indiana	9	10	11	7
Illinois	43	11	27	42
Michigan	8	10	20	30
Wisconsin	4	6	16	--
West North Central	13	17	32	34
Minnesota	2	--	6	10
Iowa	--	2	8	--
Missouri	8	8	6	13
Kansas	--	2	8	6
Nebraska	--	--	--	2
South Atlantic	75	14	48	35
Maryland	8	--	--	--
Delaware	--	1	--	--
Virginia	6	2	9	1
North Carolina	16	3	16	5
Georgia	6	3	--	7
Florida	36	4	13	11
East South Central	33	9	36	21
Kentucky	7	3	--	3
Tennessee	10	2	17	8
Alabama	10	3	9	9
Mississippi	6	-	5	-
West South Central	25	8	45	28
Arkansas	3	-	17	2
Texas	17	5	22	20
Mountain Division	7	-	17	5
Utah	-	-	3	-
Colorado	5	-	-	-
Pacific Division	80	34	59	67
Washington	--	--	10	--
California	77	32	43	63
United States Total	467	192	422	507

Source: The above data were compiled from information given in the 1972 Census of Manufacturers, U. S. Department of Commerce.

^a Includes wood, metal and plastic furniture

3.2. PROCESSES OR FACILITIES AND THEIR EMISSIONS

3.2.1. The Basic Processes

The metal furniture coating industry includes all establishments which manufacture metal furniture for office, public building and household use. Metal furniture is usually made from low carbon steel sheet, strip or tubing.

Presently the metal furniture industry employs mostly solvent-borne coatings for spray, dip coating and flow coating processes. Coating thickness ranges from 0.5 to 1.5 mils. Powder coating containing less than 5 percent volatiles is becoming more acceptable for use on outdoor and institutional metal furniture. Coatings for metal furniture must be resistant to abrasion scuffing and maintain good appearance. Institutional furniture is subjected to a more abusive environment and in addition must withstand regular cleaning with alkali type cleaners.

3.2.1.1. Spray Coating

Spray coating is generally applied by a combination of manual and automatic spray. Semi-assembled furniture pieces are loaded onto an overhead conveyor moving at a speed of $8\frac{1}{2}$ to 24 feet per minute. The plants usually operate on the basis of one shift per day (8 hours) for 48 weeks per year⁴.

Although finishing lines may vary from plant to plant, they have some common characteristics which allow us to show the following major steps of such lines employing organic solvent-borne paint systems.

Three-stage or five-stage washer

Oven

Manual touch-up spray

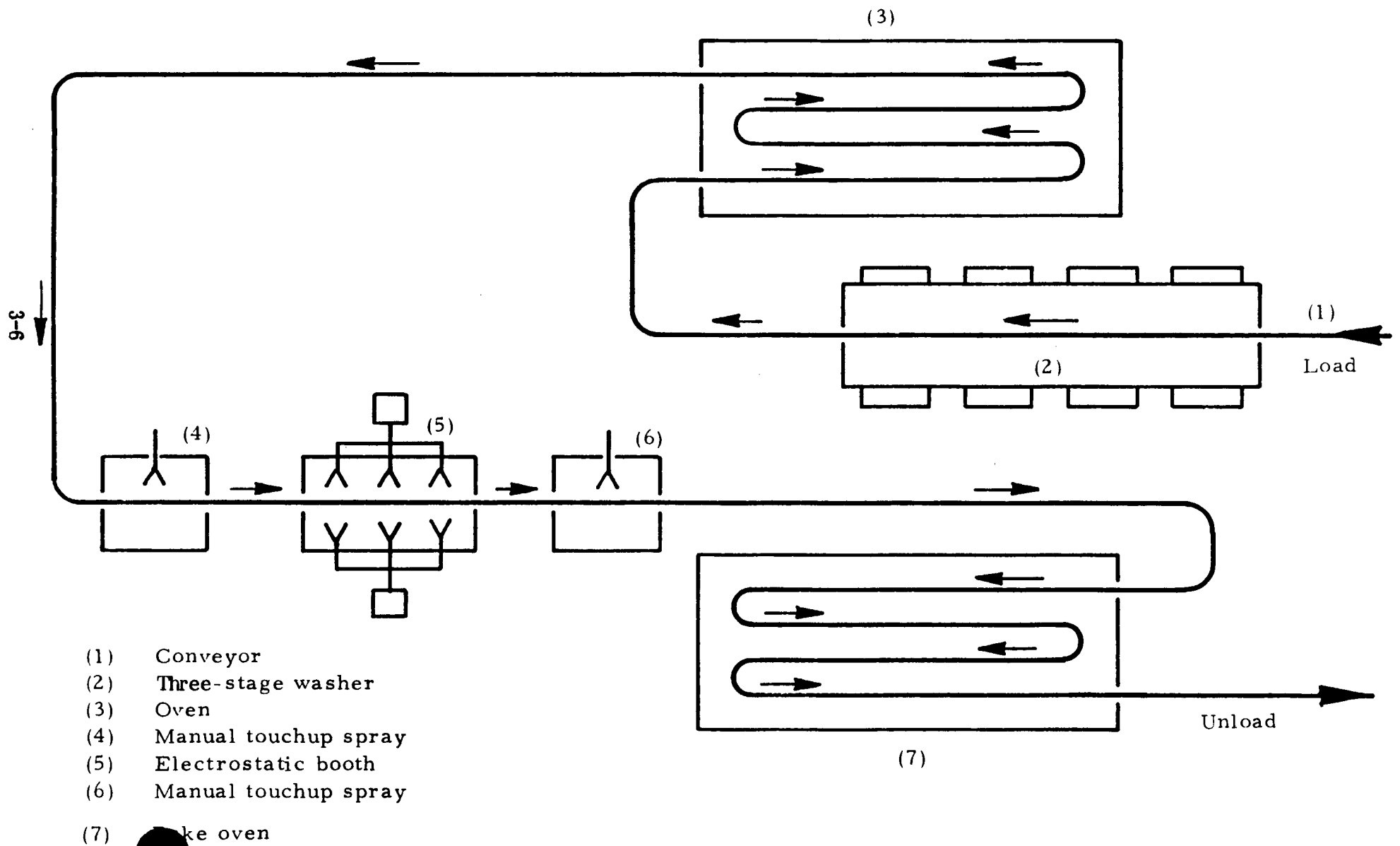
Electrostatic spray

Manual touch-up spray

Oven

The block diagram of these consecutive steps of the metal finishing process is presented in Figure 3-1. Looking at each step of the operation we first examine the washer. The pieces loaded on a conveyor go through a cleaning process which occurs in the following sequence.

Figure 3-1. ELECTROSTATIC SOLVENT SPRAY COATING SYSTEM



1. Alkaline cleaner wash
2. Iron phosphate
3. Hot water rinse
4. Chromic wash
5. Cold water rinse

The alkaline cleaner washes the oil and grease and the phosphate treatment improves the surface of the metal promoting adhesion of the coating.

After being washed and treated, the parts pass through a dry-off oven and then into a touch-up booth, where manual air spray guns apply a reinforcement coating to the intricate parts before the topcoat is applied. This step may be eliminated, its inclusion depending on the configuration of the part being coated.

The topcoat operation is the most important step in the metal furniture finishing process. This is usually applied by automatic or manual electrostatic spraying technique. The paint is fed to the application equipment through a piping system from the paint room. Average percent solids content in the paint is in the range of 25 to 35 percent volume basis.

Because of the length of time that the item of furniture is in the spray booth and flash off area, 70 to 90 percent of the solvent evaporates in the booth and flash-off area⁵.

Color change methods vary depending on the operation. In small manual spray operations the operator purges the line with solvent, wipes the gun and connects the line to the required color coating supply. On larger manual operations alternate spray guns may be used each with different colors as required. Automated operations use multiple spray guns programmed for color sequence as scheduled or in some cases the line is purged with solvent and the guns are cleaned and set for the next scheduled color. Some larger operations perform color mixing compounding with computer programming to eliminate operator error. The color ingredients are selected in accordance with computerized programs designed to meet customer requirements.

A material balance is shown in Table 3-4 which includes the discharge of emissions at steps in the process. This data is based on a model coating line. Discharge of solvents in the metal furniture finishing process occurs in the following manner: 75 percent loss at the application and flash-off step and 25 percent loss in the cure oven step of the operation. Figure 3-2 is a flow diagram showing process steps of the topcoat operation.

Table 3-4. MATERIAL BALANCE
METAL FURNITURE ELECTROSTATIC SPRAY COATING

<u>Process Steps</u>	<u>Liters Per 278,000 Square Meters</u>	<u>Gallons Per 3,000,000 Square Feet^a</u>
1. Coating applied ^d	31,226	8,250
2. Material loss in the application ^b		
Solid	3,825	1,010
Solvent and trimmer ^c	15,223	4,023
3. Total coating on furniture item	20,297	5,363
4. Oven evaporation loss - solvent discharge	5,074	1,341
5. Net dry solids on furniture item	7,104	1,876

^a 3,000,000 square feet is the annual production figure based on the following:

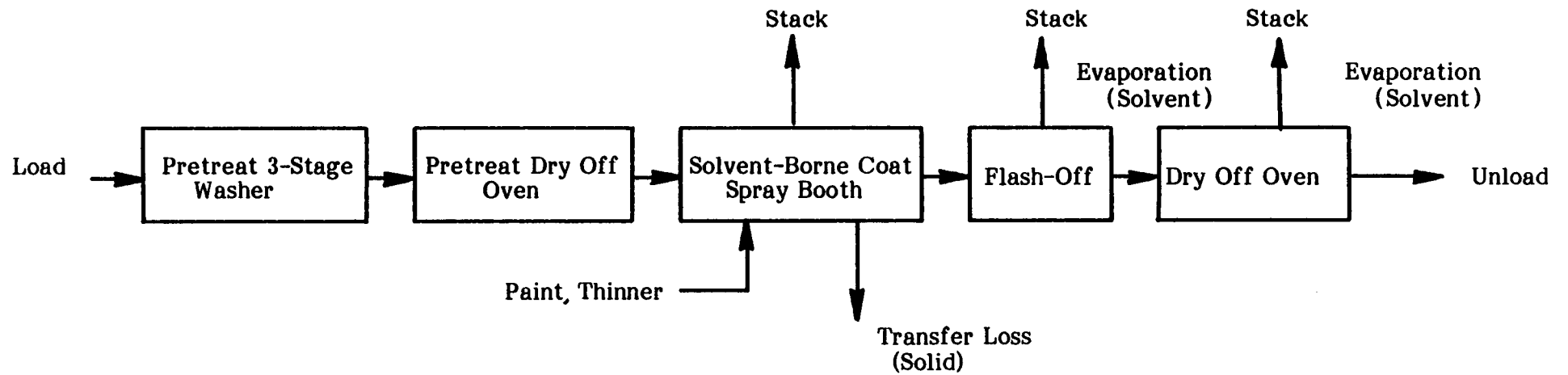
- (1) production rate - 1,562.5 square feet per hour
- (2) time - 1 shift (8 hours per shift) per day; 240 days per year; 1,920 hours per year (1,562.5 square feet per hour times 1,920 hours per year equals 3,000,000 square feet)

^b Application includes spray booth and flash-off area. Transfer efficiency of electrostatic sprayed coating is 65 percent.

^c Water-wash spray booths capture solvents in the water curtain temporarily. About 15 percent of the solvent is carried in the recirculated water and eventually is discharged by evaporation into the venting system.

^d Coating at 35 percent solids - volume basis thickness 1 mil, dry.

Figure 3-2. FLOW DIAGRAM - MATERIAL FOR ELECTROSTATIC
SPRAY SOLVENT-BORNE COATING



Energy requirements of the metal furniture coating operation are tabulated in Table 3-5. This data is based on a model coating line.

Table 3-5. ENERGY BALANCE
METAL FURNITURE COATING PROCESS

<u>Operation Steps</u>	<u>10⁶ BTU Per Year^a</u>
Application	590
Cure	3,905
Total	4,495

^a Annual energy consumption calculations were based on 3,000,000 feet produced per year, working from the following:

- (1) production rate - 1,562.5 square feet per hour
- (2) time - a shift (8 hours per shift) per day, 240 days per year; 1,920 hours per year (1,562.5 square feet per hour times 1,920 hours per year equals 3,000,000 square feet)

3.2.1.2. Dip Coating

A metal furniture coating application was observed to utilize the dip coating technique. The percent solids range for dip coating is estimated at 20 to 35 percent volume basis. Dip coating may be done manually or automatically, depending on the size of the parts to be coated. For large pieces of furniture dipping is done manually⁶.

For dip coating the washing step may be eliminated. It is not unusual in some dip operations for the paint to be contaminated by foreign material on the parts. The conveyor is loaded with a number of parts (50 to 100)⁶ and lowered into a dipping tank. After the parts are coated they pass over a drain board. Following a flash-off period the coated parts are moved into an oven.

A material balance is shown in Table 3-6 which includes the discharge of emissions at steps in the process. Discharge of solvents in the coating application occurs in the following manner: 40 to 70 percent loss at the application and flash-off step and 30 to 60 percent loss in the cure oven step of the operation⁵.

Figure 3-3 is a flow diagram showing process steps of the dip coating operation based on a model coating line.

Table 3-6. MATERIAL BALANCE
METAL FURNITURE DIP COATING

<u>Process Steps</u>	<u>Liters Per 2,086,957 Square Meters</u>	<u>Gallons Per 222.5×10^6 Square Feet^a</u>
1. Coating applied	168,356	44,480
2. Material loss in the application ^b		
Solid	5,893	1,557
Solvent discharge	65,658	17,347
3. Total coating on wet body	96,805	25,576
4. Oven evaporation loss-solvent discharge	43,774	11,565
5. Net dry solids on body	53,032	14,011

^a 2,086,957 square meters is the annual production figure based on the following:

- (1) production rate - 108.67 square meter per hour
- (2) time - 1 shift (8 hours per shift) per day; 240 days per year; 1,920 hours per year (109.67 square meters per hour times 1,920 hours per year equals 2,086,957 square meters per year)
- (3) based on 1 mil dry weight coating - 35 percent volume solids applied

^b Application includes spray booth and flash-off area. Transfer efficiency of dip coating is 90 percent.

Energy requirements of the primer coat are tabulated in Table 3-7.

Figure 3-3. FLOW DIAGRAM - MATERIAL FOR SOLVENT-BORNE DIP COATING

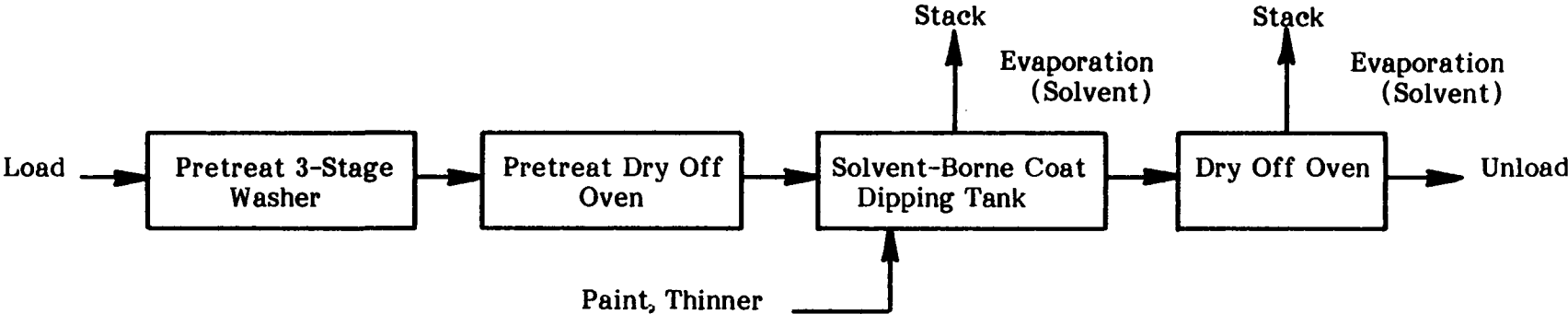


Table 3-7. ENERGY BALANCE
DIP COATING METAL FURNITURE

<u>Operation Steps</u>	<u>10⁶ BTU PER YEAR^a</u>
Application	472
Cure	6,725
Total	7,197

^a Annual energy consumption calculations were based on 2,086,957 square meters produced per year, working from the following model line:

- (1) production rate - 108.67 square meters per hour
- (2) time - 1 shift (8 hours per shift) per day; 240 days per year
- (3) conversion factors 3412 BTU/KWH and 1000 BTU per 1 cubic foot of gas

3.2.1.3. Flow Coating

Some manufacturers may use flow coating for finishing metal furniture. The flow coating method, in some of its aspects, resembles dipping, particularly since the process requires liquid coating that will flow out easily. Viscosity of coating must be closely controlled to provide satisfactory coverage without excessive runs or sags.

In flow coating parts are carried by a horizontal conveyor through a flow coating chamber. The paint is directed against the parts from all angles through a large number of nozzles. The excess coating drips off the lower edges of the parts and leaves no strings and few, if any, congealed drops.

The simplest flow-coating equipment has paint nozzles over the work and on all sides of the tunnel. Sometimes as many as 100 or more nozzles are used. The flow coating method has less amount of solvent emitted than dip coating. Flow coating is done in an enclosed booth, while evaporation takes place over the whole surface of the dip tank.

3.2.2. Equipment Characteristics

Equipment of the metal furniture finishing line associated with organic emissions consists of the spraying booths, dip tanks, and ovens. Other equipment involved in the metal furniture finishing operation includes the washer and the conveyor for moving the parts to be painted through the process system.

The metal furniture coating is applied by either spraying, dipping or flow coating methods.

Electrostatic spraying is probably one of the most widely used methods because of its sharp reduction in the overspray.

Spray booth lengths vary for each facility because of the length of time that the metal furniture item is in the spray booth. The majority of solvents are emitted in the spraying area. An exhaust fan or blower is used to draw the contaminated air out of the spray booths. To comply with OSHA regulations, a minimum air velocity for exhaust devices is required to prevent personal breathing of excessive vapors and paint particulates. The make-up air for the spray booth is usually kept at about 60°F⁷ and some relative humidity.

Water-washed spray booths are coming into use because of the increased effort required to keep the spray booths clear of overspray particulate.

In a typical water-wash spray booth, the overspray paint particles are removed by means of a curtain of water flowing down the side surfaces of the booth enclosure.

A dry-style spray booth uses a filter to remove the overspray paint particles from the exhaust.

Bake oven temperatures range from 300 to 325°F. Solvent concentration in the oven, usually measured as a percentage of the lower explosive limit (LEL) of solvent in the air, is about 10 to 25 percent.

For some large parts and parts that do not need a perfect painting finish, dipping and flow coating are the coating methods that will apply satisfactory coating within a reasonable cost range. The dipping system consists of a tank to hold the paint and a drain board to collect the dripped paint. Required air volume in the dip tank area is less than that needed for spraying paint since there is less solvent lost in transfer of the coating. Flow coating consists of a cabinet having nozzles on the top, sides and bottom which directs the paint at the work from all angles. An improved flow coating system eliminates all nozzles on top and sides of the cabinet and streams of paint only from the bottom are directed against the work.

3.2.3. Emission Characteristics

The two types of organic solvent-borne coatings used in the metal furniture industry are enamels and lacquers.

"Enamel is a type of paint consisting of an intimate dispersion of pigments in a varnish or resin vehicle. The vehicle may be an oil-resin mixture, or an entirely synthetic resin. Those containing drying oils are converted to film by oxidation; those comprised wholly of synthetic resins may be converted by either heat or oxygen or both."⁸

Lacquers in contrast to enamels, do not undergo a chemical reaction when exposed to heat. Applied lacquers are dried by evaporation of the solvent to form the coating film.

The traditional coating materials used in the metal furniture coating industry are organic solvent-borne compositions. Alkyd resins account for the largest portion of all resins used in finishing metal furniture. Others include acrylics, amines, vinyls and cellulose. Some metallic coatings are used in finishing metal office furniture.

The solvents used in coatings for metal furniture are mixtures of aliphatics, xylene, toluene and other aromatics, MEK and other solvents.

According to a recent survey by the National Paint and Coatings Association in 1975, the metal furniture and fixtures consumed 116 million pounds of solvents or 6 percent of the total industrial coating solvent usage⁹.

Based on our survey the average solvent emission for an electrostatic spray operation was calculated to be 2.10 gallons per 1000 square feet. Assuming that a metal furniture finishing line operates at a production rate of 1562.5 square feet an hour for one shift (8 hours per day), this will mean that 12,500 square feet are produced per day and that approximately 26.25 gallons of solvent are discharged daily from the metal furniture spray coating operation. Loss from overspray was calculated to be 15 kilograms per 1000 meters² based on data collected from the industry.

Average solvent emission for a dip coat operation was calculated to be 1.37 gallons per 1000 square feet. Assuming that a metal furniture dip line operates at a production rate of 11,700 square feet per hour for eight hours per day, it will mean that 93,000 square feet are produced per day and approximately 128 gallons of solvent are discharged daily from the line.

Calculations of solvent emissions from plants visited result in the following emission factors for the spray and dip coat operations (Table 3-8).

**Table 3-8. AVERAGE EMISSIONS FOR THE
METAL FURNITURE FINISHING PROCESS
Liters of Solvent Per 1000 Square Meters
(Gallons of Solvent Per Square Foot)**

<u>Coatings</u>	<u>Application</u> ^a	<u>Cure</u>	<u>Total</u> ^b
Spray			
Solvent-borne coat	64.50 (1.57)	21.50 (0.53)	86 (2.10)
Dip			
Solvent-borne coat	31.35 (9.75)	25.65 (9.62)	57 (1.37)

^a Application includes spray booth and flash-off area

^b Data presented as unconfirmed data reported from field surveys

Effluents from water wash in spray booths contain contaminants from overspray of coatings. The water used in the spray booth curtain may be discharged into a sludge tank where solids are removed and the water is recirculated. Immiscible solvents captured by water curtains in spray booths evaporates from the water as it recirculates and leaves at the booth vent. Solid waste discharge by the landfill method may be the most appropriate for the metal furniture finishing operations.

3.2.4. Parameters Affecting Emissions

Metal furniture industry solvent emissions are directly related to the types of coating materials used. Naturally the greater the quantity of solvents in the coating composition the greater will be the air emissions. Lacquer having 15 to 17 volume percent solids are higher in organic solvents than enamels which have 30 to 35 volume percent solids. The usage of add-on equipment such as incinerators and carbon adsorbers will also affect the solvent emissions. Springborn Laboratories' survey of the metal furniture industry however, did not discover any add-on pollution control equipment for treating solvent emissions.

The advance of powder coating materials in the metal furniture operations will affect the emission discharge of the industry. Powder coating was found to be a popular method in outdoor furniture¹⁰ and institutional furniture¹¹.

The advance of powder coating materials in the metal furniture industry has been attributed to achieving better performance coating a slightly higher cost over solvent-borne systems. Environmental improvement was an additional benefit.

Water-borne coatings have not penetrated the furniture industry in significant volume because they are relatively new in this industry¹². This technique will no doubt develop when more pressure to reduce emissions from solvent-borne coating is applied to the industry.

Higher solids coatings are making inroads. In one case an institutional furniture manufacturer used higher solids coating to minimize air pollution and provide a coating with minimum solvent content on its product⁴¹.

Emissions are also influenced by the thickness of the coating and transfer efficiency of the coating technique used. There are minor transfer problems involved with the use of dip coating; essentially, all of the paint solids are transferred to the part. The dipped paint is normally returned to the dip tank. Coating loss with non-electrostatic spraying ranges from 40 to 70 percent; with electrostatic spraying the range is from 13 to 32 percent¹³. In this industry a loss of 35 percent is probably more realistic as an average because of the variety of parts coated. Flow coating transfer efficiency is about 90 percent.

Emissions are also influenced by state or intrastate regulations. Only thirteen states had statewide regulations in effect; but eight other states with a total of twelve districts within these states, had promulgated individual district, non-statewide regulations. Some states do not have limits on the amounts of exempt or

non-photochemically reactive solvents that can be emitted. Connecticut on the other hand is more stringent in this regard, allowing only 800 pounds per day versus the 3000 pounds per day specified by Rule 66.

3.3. REFERENCES

1. 1972 Census of Manufacturers, Volume II, Industry Statistics, U. S. Department of Commerce
2. U. S. Outlook 1977 - p 305
3. BLS Review - November 1976 - p 5
4. Springborn Laboratories' (formerly DeBell & Richardson, Inc.) survey of the metal furniture companies.
5. Air Pollution Engineering Manual. U. S. Department of Health, Education and Welfare; Cincinnati, Ohio 1967 p 711.
6. Oge, M.T. Trip Report - Lyon Metals, Aurora, Illinois. Springborn Laboratories, Inc., (formerly DeBell & Richardson, Inc.) Enfield, Connecticut. Trip Report 91, March 12, 1976.
7. Industrial Finishing Journal - July 1976 - p 22
8. The Condensed Chemical Dictionary by VanNostrand Reinhold Company 1971, p 346
9. Bruce Ocko, Modern Paint and Coating Magazine, March 1977 - p 61.
10. Oge, M.T. Trip Report - Bunting Company, Philadelphia, Pennsylvania, Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.) Enfield, Connecticut. Trip Report 86, March 8, 1976.
11. Oge M. T. Trip Report - Goodman Brothers Manufacturing Company, Philadelphia, Pennsylvania, Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.) Enfield, Connecticut. Trip Report 85, March 8, 1976.
12. Telephone Conversation, William Holley of Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.) with John Dunhan, Hanna Chemical Coatings Company, August 25, 1977.
13. Waste Disposal from paint systems. Discussed at Detroit, Michigan. American Paint and Coating Journal. February 23, 1976 - pp 35-36.

4. EMISSION CONTROL TECHNIQUES

This chapter and Chapter 6 are both analyses of available emission control technology for the metal furniture finishing industry. The purpose of this chapter is to define the emission reduction performance of specific control techniques, while Chapter 6 evaluates complete systems which include finishing processes in combination with one or more emission reduction techniques.

The purpose of the control techniques as referred to in this chapter is to minimize emissions of volatile organic compounds to the air. These compounds - ketones, alcohols, esters, saturated and unsaturated hydrocarbons, and ethers - make up the major portion of solvents used for paints, thinners, and cleaning materials associated with industrial finishing processes.

There are several types of control techniques either presently in use within the metal furniture industry or which would have utility based on technology transfer from related industries. These methods can be broadly categorized as either "add-ons" or "new coating" systems. Add-ons are used to reduce emissions by either recovering or destroying the solvents before they are emitted into the air. Such techniques include thermal and catalytic incinerators and carbon adsorbers. New coatings refers to application methods which use coating materials containing relatively low levels of organic solvents. Such methods include electrodeposition, spray, dip or flow coating of water-borne paints and electrostatic spray of high solids and powder coatings. Because of the lower solvent content of the "new" coating materials, these application methods are inherently less polluting than processes which use "conventional" organic solvent-borne coatings.

The following discussion characterizes the control techniques and defines the emission reduction performance associated with each technique as applied to the metal furniture industry.

4.1. THE ALTERNATIVE EMISSION CONTROL TECHNIQUES

4.1.1. Powder Coating

On the control techniques presently in use in the metal furniture finishing industry, powder coating is the most common. Most of the powder is being used for outdoor furniture with lesser amounts being applied to shelves, bed and chair frames and miscellaneous parts.

While powder is generally suitable for painting metal furniture, there can be problems of color matching. For example, there can be difficulties where merchandise is made for resale from one manufacturer to another, particularly if one is using a solvent-borne paint. This problem may not exist, however, where both finishers are using the same coating.

Powder coating, although considered here as a new coating method, has been in use for decades¹, fluidized-bed coating beginning in the early 1950's and electrostatic spray in the early 1960's. Powder coating, regardless of process, involves the application of nearly 100 percent solid materials in dry powder form: no solvents are used, although small percentages of organics can be driven off from the resins during curing.

Powder coating is being used throughout the industrial finishing industry for such diverse painting applications as wire goods (baskets, racks, and shelves), piping and tubing, fencing and posts², garden tractors, lawn equipment³, and bicycles⁴; in the automotive industry powder coating is being used for topcoats^{5,6,7}, under-the-hood parts such as oil filters and air cleaners^{8,9} as well as bumpers, trailer hitches, and emergency brake cable guides^{10,11,12}.

Powder coating has made significant penetration into the metal furniture finishing industry primarily in outdoor and patio furniture. One industry expert estimates that approximately 60 companies in the metal furniture, display shelving and office equipment industries are presently using electrostatically sprayed powder for finishing¹³, representing approximately 15 percent of the total number of powder spray installations¹⁴. It has been estimated that by 1980, the metal furniture and architectural metal industries will consume approximately 12 percent of the 113 million kilograms (250 million pounds) of powdered resin that will be used annually for both fluidized bed and electrostatic spray coating¹³.

The use of powder in the metal furniture finishing industry can in general be divided into two categories: thin-film thermosetting polymers applied from electrostatic spray and to a lesser extent, thick-film thermoplastic materials deposited by the fluidized bed technique.

The leading thermoset powder coating materials, are the epoxies and polyesters^{14,15}. these materials provide hard, smooth surfaces that have excellent adhesion to most metallic substrates. The coatings are tough, with good resistance to abrasion and chemicals. Thermosetting acrylic is of lesser importance but is growing in usage.

These powdered thermosets are used in the metal furniture industry for such general decorative applications as chair and bed frames, tubular metal furniture, patio and casual furniture, office furniture, and shelving. Examples of the use of powder in the furniture industry appear in Table 4-1.

Thermoplastic powders comprise polymers such as polyvinyl chloride ("vinyl"), various nylons, and cellulose acetate butyrate. These materials are normally applied in thick films typically 5 to 15 mils to heavy wear areas such as chair legs, bases and arms; and miscellaneous parts such as springs and handles.

The three significant application techniques in use commercially for powder coatings are: electrostatic spray, fluidized bed, electrostatic fluidized bed; the first two are in evidence in the metal furniture industry.

4.1.1.1. Electrostatic Spray

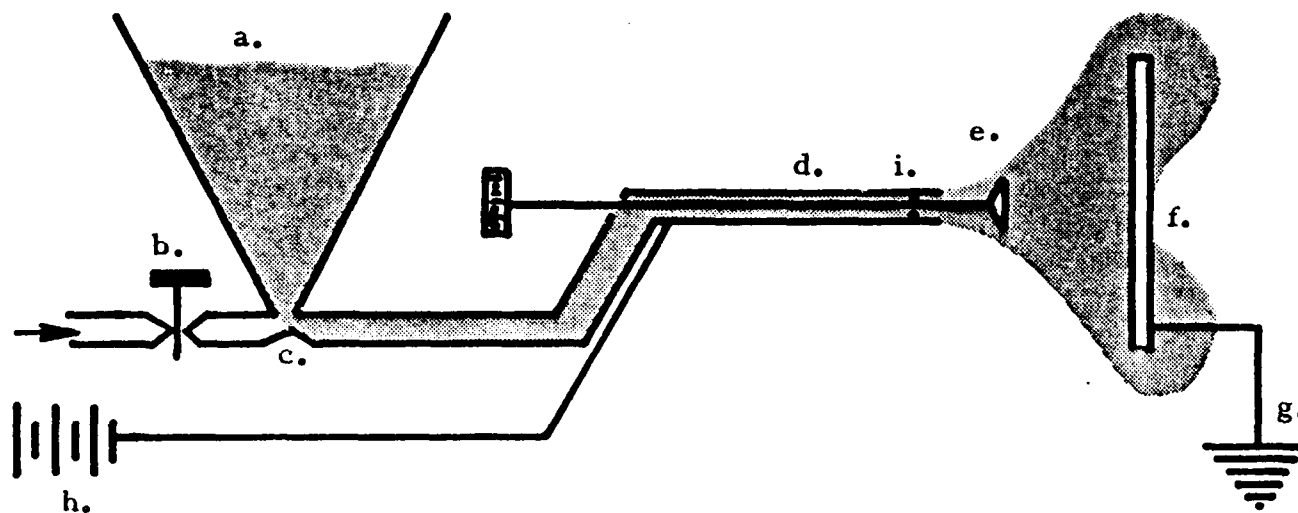
The electrostatic powder spray process is shown schematically in Figure 4-1 and can be described as follows³⁵:

Powder is drawn from the hopper and carried to the gun by compressed air. As the powder passes through the gun, it picks up an electrostatic charge from the electrodes in the tip of the gun. The part to be coated is grounded and at a lower potential than the powder particles. When an electrostatic field is generated between the tip of the gun and the part, the powder particles are attracted to the part and adhere. As the coating forms, the part becomes insulated and the deposited powder begins to repel additional particles. The result is a uniform film relatively free of voids.

The powder adheres to the part until it is fused to the surface and heat-cured in the oven. Film thickness normally varies from 1.5 to 6 mils (0.038 to 0.127 mm), depending on the preheated temperature of the part, the particle size of the powder, the electrical potential, and the duration of the spray³⁶.

Electrostatic spray units range from relatively small manually operated job-shop, touchup models up to large production units with several automatic reciprocating guns and complex powder recovery systems. The basic components of all units are as follows³⁷:

Figure 4-1 SCHEMATIC OF ELECTROSTATIC POWDER SPRAY PROCESS³⁸



- | | | | |
|----|--|----|-------------------|
| a. | Powder hopper | e. | Deflector plate |
| b. | Compressed air control | f. | Part to be coated |
| c. | Powder injector and tube | g. | Ground |
| d. | Spray gun with integral high-voltage generator | h. | Power supply |
| | | i. | Electrode |

**Table 4-1. EXAMPLES OF METAL FURNITURE FINISHING
WITH POWDER COATINGS**

<u>Product Process</u>	<u>Process</u>	<u>Type of Powder</u>	<u>Reference</u>	<u>Thickness</u>
Stadium seating	Manual ES ^a	Thermoplastic polyester	163	3 mils
Hospital beds	ES	Nylon 11	17	—
Indoor and outdoor furniture	Automatic ES	Epoxy and Polyester	18, 19	1-3 mils
Hospital bed frames and parts	Automatic ES	Epoxy	20	2-4 mils
Chair frames	Automatic	Epoxy	21	2-3 mils
Tubular metal furniture	Manual ES	Epoxy and thermoplastic polyester	22	1.5 mils
Steel tubing for furniture	Automatic ES	Polyvinyl chloride thermosetting polyester	23	2.5 mils 1.0 mils
Library shelves	Automatic ES	Epoxy	24	2.2 mils
Metal chairs	Automatic ES	Polyester	25, 26	1.5 mils
Dinette tables	ES	Cellulose acetate butyrate	19	—
Metal furnishing parts	Manual ES	Epoxy	27, 28	2.5-4.0 mils
Patio and casual furniture	Automatic ES	Polyester	29	1-5 mils
Hospital beds	ES	Epoxy	30	—
Office furniture	Automatic ES	Epoxy	31	3-8 mils
Shop furniture	ES	Cellulose acetate butyrate	51	3.5-4.0 mils
Chair base and arms	FB ^b	Nylon 66	21	6-7 mils
Chairs	FB	Polyvinyl chloride/polyester	32	15 mils total
Hospital furnishing parts	FB	Nylon	28	—
Hospital bed handles	FB	Polyvinyl chloride	33	—

a ES - electrostatic spray

b FB- fluidized bed

(a) Basic Console

The console or cabinet contains the power supply which converts line current to high-voltage direct current; the air supply with drier; the powder reservoir with vibrator and air fluidizer to keep the powder fluidized so that it will flow through the hose to the gun; and the control module for regulating air volume and pressure, voltage, amperage, vibrator frequency in the powder reservoir, and powder flow rate.

(b) Powder Spray Gun

A trigger switch on the gun activates both powder flow and transfer of voltage. A deflector mounted in the nozzle of the gun controls the spray pattern. Connected to the gun are the material hose and high-voltage cable.

Automatic guns are similar in design construction and operation, but are turned on and off by a master switch on the control panel. Automatic guns are often mounted on variable-speed/variable-stroke vertical reciprocators³⁹.

The number of guns in a unit generally varies from one to twelve, and is dependent on the size and complexity of the parts to be coated, the extent and rate of travel of the reciprocating guns, and the conveyor speed. It is better to use several guns at a moderate output since excessive output from a gun will lower deposition efficiency, increase overspray, and clog the guns⁴⁰.

(c) Spray Booth

Powder spray booths are much simpler in design than normal paint booths with floors sloped in order to recover oversprayed powder. Guns are normally mounted in the side walls of the booth; openings are kept small to minimize powder loss. The interior walls are vertical and free of projections in order to minimize hang-up of powder⁴⁰.

The dimensions of the booth are governed by the part size, conveyor size, conveyor speed, and the number of guns.

Figure 4-2. shows a typical booth with recovery system and reciprocating gun. Air flow from top to bottom in the booth helps scavenge oversprayed powder and carry it through the bottom of the booth.

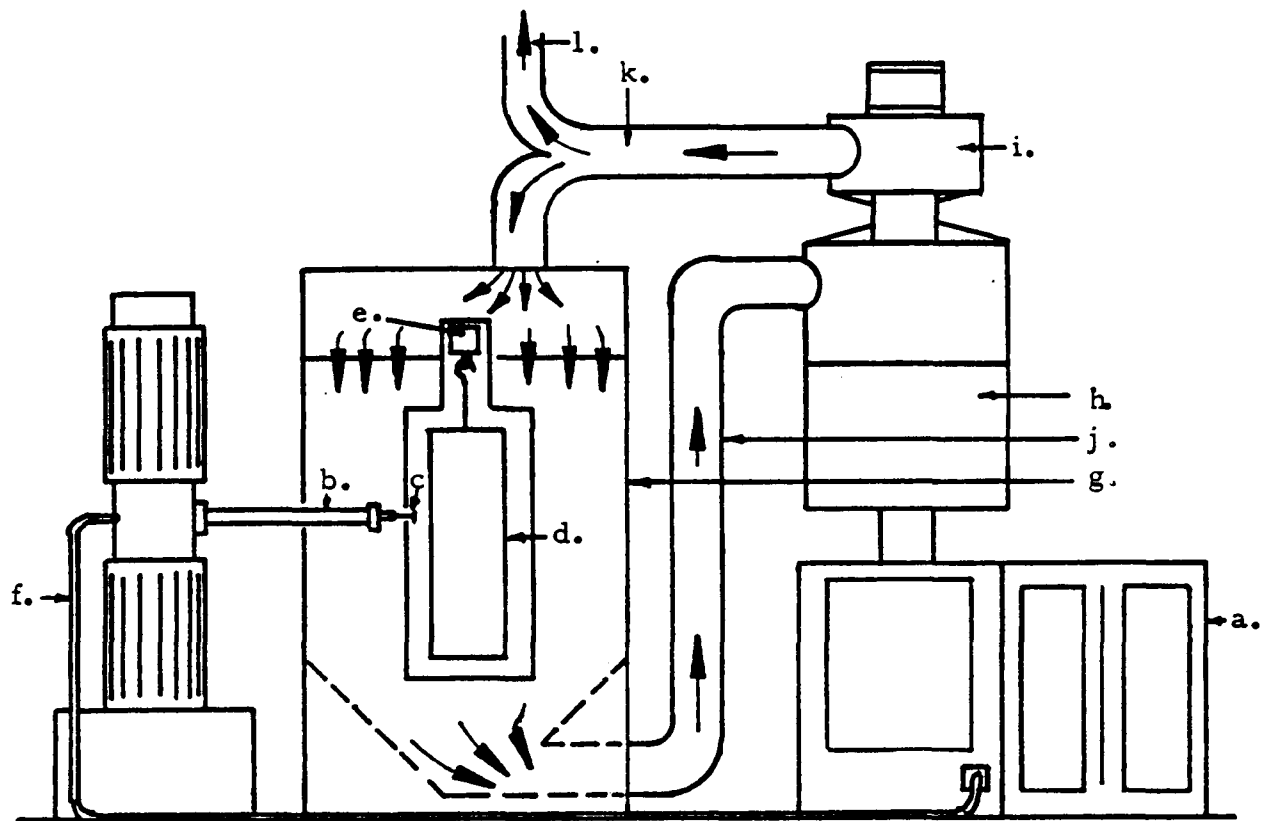
(d) Recovery System

A recovery system is also shown in Figure 4-2. Recovery of oversprayed powder is the key to economical powder coating. Most systems comprise a bag or tube filter, with or without one or more cyclones. The powder goes through the cyclones first, where the centrifugal action spins the heavier particles to the outside and recovers them. Recovery in the cyclone is often in the range of 75 to 85 weight percent,¹⁸⁵ but can be as high as 90 to 95 weight percent if high efficiency units are used¹⁸⁶.

Powder which passes through the cyclone contains primarily smaller particles which are collected on the filter. The filter plus cyclone remove a total of greater than 99 weight percent of the oversprayed powder. If an additional "absolute" filter is used, a total of approximately 99.97 percent of the powder can be removed from the air stream¹⁸⁶.

In paint operations where a single color is used, powder from both the cyclone and bag filter can be reused and overall powder utilization for such operations is 98 percent or better⁴². Where color changes are occasionally made, however, powder from the filters must be discarded in order to prevent color contamination. For such operations overall powder utilization is dependent on a combination of the efficiency of the powder recovery unit and the initial transfer efficiency of powder from the gun to the part. The effect of these two variables on powder utilization has been shown in Table 4-2.

Figure 4-2. SOPHISTICATED RECOVERY SYSTEM⁴¹



- a. Reservoir and controls
- b. Elevator-mounted industrial spray gun
- c. High-voltage electrode and deflector plate
- d. Part being coated
- e. Grounded conveyor
- f. Powder tube and high-voltage cable
- g. Spray booth
- h. Powder recovery unit
- i. Exhaust fan
- j. Exhaust line for powder recovery
- k. Clean air returned to booth
- l. Clean air exhausted to atmosphere

Table 4-2. OVERALL WEIGHT PERCENT OF POWDER UTILIZED ^a

<u>Weight Fraction</u>	<u>Weight Fraction Transfer</u> ^b		
<u>Powder Recovery</u>	<u>50</u>	<u>65</u>	<u>80</u>
80	82.5	90.1	95.2
85	85.7	91.8	96.4
90	89.2	94.6	97.5

^a Assuming color changes, with powder in bag filters discarded

^b Weight fraction deposited on the part to be painted

Normal operating parameters for powder spray units used for metal furniture finishing are as follows^{42,43,44,45,46}:

Preheat	None
Conveyor speed	1.52-13.7 meters/minute (5-45 feet/minute) ^{26,34,22,20,18}
Electrical output	70-90 KV DC (maxiumum)
Polarity	Positive or negative
Compressed air output	1416-7080 cu cm/sec at 146-488 kg/sq meters (30-100 psig)
Powder output	0-36 KG (0-80 lb)/hour/gun
Powder cure	171-232 ^o C (340-450 ^o F) for 4-30 minutes ^{18,20,22,24,26}

The voltage on most units is variable up to 90 KV, which permits control of film thickness⁴². A low voltage will allow penetration into holes and recesses. Although polarity is often variable, most powders are sprayed successfully with a negative charge. An adjustable deflector on the gun also controls the spray pattern. A narrow pattern aids penetration while broad clouds are useful for large flat areas⁴⁷.

Powder deposition on the parts can reach 85 percent on large flat surfaces, but irregularly shaped objects result in reduced transfer efficiency⁴⁰. Deposition can be as low as 30 percent on wire products such as racks and baskets, but of course this overspray is almost always recovered⁴⁰.

The following is a generalized process description based on an investigation of several lines presently in operation in the metal furniture finishing industry^{18,20,24,26,28,29,31}. Such systems are used for finishing metal shelves, bed frames, chairs, springs, etc.

Most systems are nearly fully automated with the exception of loading and unloading of conveyors, and occasional manual-spray touchup.

(1) Conveyor

All electrostatic powder spray systems investigated use conveyors, generally overhead types, which carry the parts to be painted through the pretreatment and dry-off sections, paint booth, and bake oven to the unload area. Although conveyors are used at speeds of from 1.52 to 13.7 meters per minute (5 to 45 feet per minute) they generally travel in the range of from 3.05 to 4.57 meters per minute (10 to 15 feet per minute). Parts are hung on hooks at uniform intervals as governed by the size of the parts; 0.305 or 0.610 meter (one or two foot) spacing is common. Conveyors are normally loaded by hand, but automatic loaders are in use²⁴.

(2) Pretreatment

The metal parts are generally cleaned and phosphated in a three stage washer. The treatment is normally done by spraying the parts, as they are conveyed, but batch type pretreatment can be used prior to placing the parts on the conveyor²⁹. For heavy-duty cleaning a wheel-o-brator can be used prior to conventional treatment.

The first stage is a phosphate wash, followed by a water rinse, and then an acid rinse, generally chromic. The wet parts are run through a "dry-off" oven for 5 to 15 minutes at temperatures of from 93 to 260°C (200 to 500°F), followed by a cool-off period. The parts are cooled by allowing them to travel along the conveyor in the open room for 5 to 15 minutes.

(3) Powder Spray

After the cool-off period, the parts are conveyed through the spray booth where the powder is applied from spray guns. The spray booths, sometimes called tunnels or chambers depending on their size and shape, are often designed especially to accommodate the type of part to be coated. Long booths with large wide openings are used to coat large items with complicated shapes or are used where the mix of part sizes and shapes varies. Where the parts are narrow, such as in the case of metal shelves, the booth can be correspondingly narrow (e.g. 3.65 meters long by 3.05 meters high by one meter wide or 12 feet by 10 feet by 3 feet, 4 inches wide³¹).

Powder coating is best suited to the finishing of flat exterior surfaces or open frames. Due to a Faraday caging phenomenon, it is often difficult to coat parts with recesses which are surrounded by metal, such as interior corners of desks or cabinets. This problem can be overcome in part by preheating the substrate, coating at a reduced voltage, or focusing the spray directly at the problem recess.

The powder is normally applied with from two to six guns; but booths with as many as 16 guns are in use²⁴. Automatic guns are the most common, often mounted on verticle reciprocators.

Some operations use a smaller touchup booth after the main booth where unpainted areas are covered by manual spray^{18,29}.

Most operations recover oversprayed powder for reuse, using cyclones and bag filters. One rather unique booth draws the exhaust air from the top of the booth rather than from the bottom as is commonly done. This exhaust system plus electrically charged precipitator plates which repel powder away from the booth walls permit an overall 85 per cent transfer efficiency²⁴. No powder is recovered on this powder spray line.

(4) Baking

Baking time and temperature are governed by the mass of the coated part and the nature of the powdered polymer. Baking schedules vary from 4 to 30 minutes at temperatures of from 171 to 232°C (340 to 450°F).

4.1.1.2. Fluidized Bed

Fluidized bed coating involves the dipping of a preheated metal part into a tank of powder which has been intimately mixed with air to a relatively low bulk density. The process is analogous to the conventional organic solvent-borne paint dipping technique.

The powder is kept fluidized by passing a stream of air up through the bottom of the tank. The bed when fluidized has the appearance of boiling water, and if the tank is tipped, the powder bed flows like a liquid¹.

The powdered resin fuses and adheres to the heated part; coating thickness is governed by the temperature and mass of the part and the dwell time in the bed.

Fluidized bed coating is generally used where a heavy durable coating is desired with thicknesses between 6 and 60 mils. Typical applications include chain link fence; wire baskets and shelves for use in appliances such as freezers, refrigerators and dish washers; handles for tools and small appliances; and furniture⁴⁸.

With the exception of the bed itself, fluidized bed powder coating is done with conventional finishing equipment. The bed is a relatively simple apparatus as illustrated in Figure 4-3, consisting of a tank of suitable size separated into an upper and lower chamber by a porous divider. Air generally from a compressor or blower, is introduced into the lower chamber where it passes uniformly through the porous divider and into the powder bed. The powder in the upper chamber is aerated and suspended into a "fluidized bed".

Air flow through the bed is approximately 15.2 to 61.0 cubic meters per hour per square meter of plate (50 to 200 cubic feet per hour per square foot of plate).⁴⁹ A vibrator is generally used to keep the expansion of the bed uniform and to prevent air from channeling through the powder.

The tank should be of sufficient size so that the parts to be coated can be dipped below the level of the expanded powder.

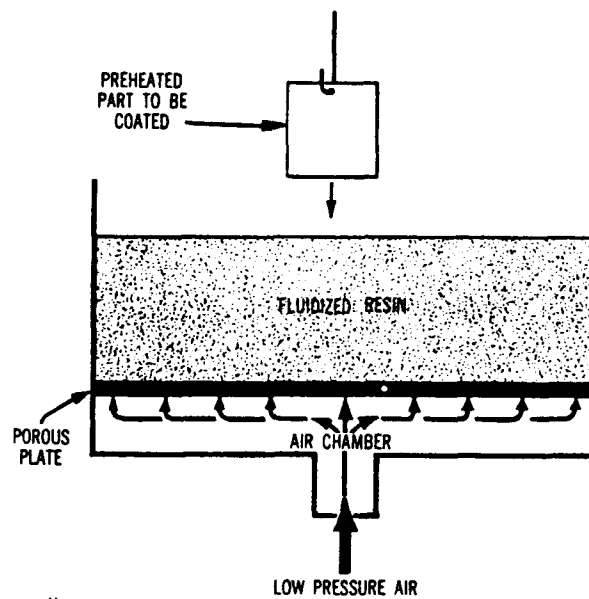


Figure 4-3. SCHEMATIC OF FLUIDIZED BED APPARATUS⁴⁹

As with most metal finishing, the process begins with a thorough cleaning and phosphating as described on page 4-10 after which parts are normally hung on an overhead conveyor. For some applications requiring high adhesion with the use of thermoplastic powders, primers are employed. These are generally organic solvent-borne materials applied either by dip, spray or flow coating⁵². After leaving the pretreatment section parts enter a dry-off/preheat oven, where the metal is heated approximately 40°C above the melting point of the polymer, or higher if the part has a small mass and is apt to cool rapidly between preheat and dipping⁴⁹. The time and temperature of the preheat are dependent on the polymer being used and the mass of the part. A heavy cast iron valve to be coated with epoxy might require 45 minutes at 200°C⁵⁰, while a chair arm might require only 4.5 minutes at 330°C to fuse a nylon coating²¹.

To apply the powder, the preheated part is dipped into the fluidized bed; this is done as soon as the part exits the oven in order to minimize heat losses.

Adequate dwell time and motion of the part in the bed are required in order to obtain a satisfactory coating, free from pin holes and an "orange peel-like" surface. Coating thickness is governed by the dwell time in the bed; the longer the dwell time, the thicker the coating. Typical immersion times range from 3 to 20 seconds⁵³.

Depending on the size of the operation, parts are dipped either automatically or are removed from the conveyor on exiting the oven and dipped manually. Excess powder is often removed from the coated parts by a blast of air, prior to post-heating, or cooling of the part⁴⁹.

If the powder is a thermoset, or if a more uniform coating is desired with a thermoplastic powder, the part is given a final bake.

4.1.2. Water-Borne Coatings

Of the control techniques presently in use in the metal furniture industry, water-borne coatings next to powder are the most common. Most of the water-bornes for furniture are being applied by electrodeposition (ED or EDP) for use as one-coat finishes. Water-borne spray is being used to a lesser extent.

The terminology for water-borne coatings tends to be confusing; the names of the various coating types are often misused or used synonymously. The term water-bornes as discussed here refers to any coating material which uses water primarily as the carrier, and is meant to distinguish such coatings from organic solvent-borne paints.

There are three types of water-borne coating materials: latex or emulsion paints, partially solubilized dispersions, and water-soluble coatings. Table 4-3 lists the significant characteristics of these three types of coating materials.

The majority of water-borne industrial finishes are based on partially solubilized resins in the 3.5 to 8.0×10^4 molecular weight range⁵⁴ and are applied by electrodeposition (EDP). Emulsions are growing in interest for some applications, however, because of their ability to build relatively thick films without causing blister⁵⁵. They also require no noxious amine solubilizers and no solvents⁵⁶.

Most of the solubilized water-borne coatings used are based on alkyd, polyester, acrylic, modified silicone, and epoxy resins - often made crosslinkable with amine resins such as hexamethoxymethyl melamine⁵⁷. A common method of solubilizing is to incorporate carboxyl-containing materials such as maleic anhydride and acrylic acid into the polymer backbone. The acids are then "solubilized" with low molecular weight amines such as triethylamine, or to a lesser extent with potassium hydroxide⁵⁷.

After application, solubilized coatings are baked and the amine, solvent, and water evaporate to leave a cured film that closely resembles an organic solvent-borne finish⁵⁸.

Although the use of water-borne coatings in the metal furniture industry is limited at this time it will probably increase. One industry consultant feels that the market for water-borne finishes for office, home, and institutional furniture "should grow well - both as ED coatings and as sprayed or dipped coatings"⁵⁹.

Current usage in the metal furniture and related fields includes office and shop furniture^{60,61,63}, shelving⁶², computer cabinets^{65,66}, metal doors⁶⁷, card table legs and chairs⁵⁵, and other tubular folding table frameworks⁶⁸.

4.1.2.1. Electrodeposition

Many of the finishes used for institutional and office furniture are applied in very thin coats, generally 2.5×10^{-3} cm (1 mil) or less^{65,69}. The fact that electrodeposition is limited to one coat application of thin films in one color makes it an attractive finishing method for certain products in the metal furniture industry. Examples where EDP is in use on metal furniture finishing lines can be found in Table 4-4.

Table 4-3. WATER-BORNE COATINGS

<u>Properties</u>	<u>Latex or Emulsion Paints</u>	<u>Partially Solubilized Dispersions</u>	<u>Water-Soluble Coatings</u>
Resin particle size	0.1 micron	Ultrafine	-
Molecular weight	up to 1 million	50,000 - 200,000	20,000-50,000
Viscosity	Low-not dependent on molecular weight	Somewhat dependent on molecular weight	Very dependent on molecular weight
Viscosity control	Require thickeners	Thickened by addition of cosolvent	Governed by molecu- lar weight and solvent percent
Solids at application	High	Intermediate	Low
Gloss	Low	Low to medium-high	Low to highest
Chemical resistance	Excellent	Good to excellent	Fair to good
Exterior durability	Excellent	Excellent	Very good
Impact resistance	Excellent	Excellent	Good to excellent
Stain resistance	Excellent	Good	Fair to good
Color retention on oven bake	Excellent	Excellent to good	Good to Fair
Reducer	Water	Water	Water or water/ solvent mix
Washup	Difficult	Moderately difficult	Easy

Source: Industrial Finishing (July 1973) p 13

Table 4-4. ELECTRODEPOSITION IN THE METAL FURNITURE INDUSTRY

<u>Application/Product</u>	<u>Tank Capacity Liters (Gallons)</u>	<u>Paint Concentration Percent Solids</u>	<u>Dwell Time Min.</u>	<u>Film Thickness cm x 10⁻³(mils)</u>	<u>Reference</u>
Topcoat/shop furniture	37,900 (10,000)	10	2	2.54-3.05 (1.0-1.2)	60, 61
Topcoat/shelves	53,000 (14,000)	7.5-8.0	2	2.54-3.05 (1.0-1.2)	62
Topcoat/shop furniture	106,000 (28,000)	—	3.5	2.54 (1)	63
Topcoat/institutional furniture	68,100 (18,000)	7.9-8.1	—	1.78-2.03 (0.7-0.8)	64
Primer/outdoor furniture	79,500 (21,000)	—	—	—	60
Topcoat/office furniture	9,500 (2,500)	—	—	—	60

Autophoretic coating, similar in nature to EDP, is not being used for metal furniture, since the color for this paint technique is limited to black at the present time¹⁹³.

Electrodeposition is limited to waterborne coatings. During application, the parts are immersed in a bath of low-solids water-borne coating solution; the tank or grids on the periphery of the tank are subjected to a negative charge while the parts are grounded. The process is analogous to electroplating; negatively charged polymer is attracted to the metal item and is deposited as a highly uniform coating⁷⁰. Systems of the opposite polarity can also be used.

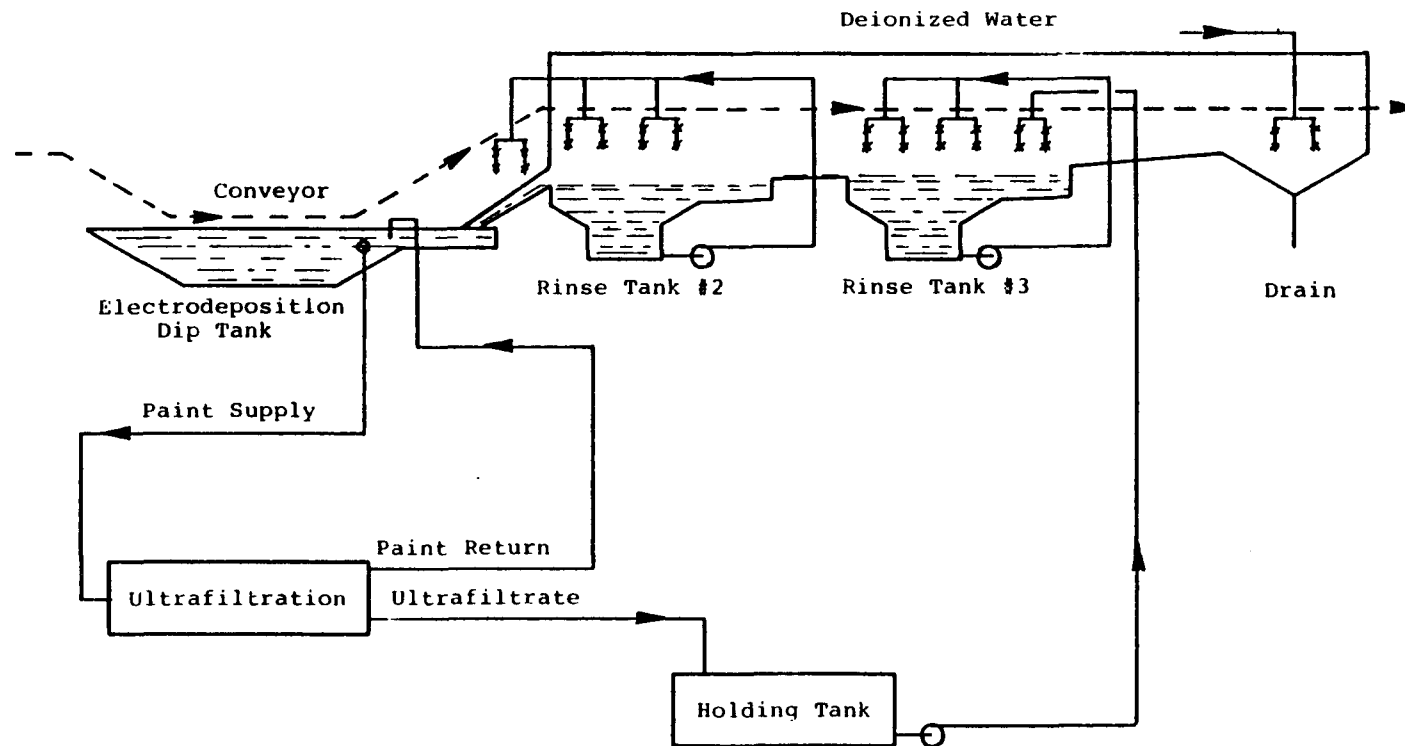
Figure 4-4 shows a typical closed-loop electrocoating line.

In a typical EDP operation, parts are loaded on a conveyor which carries them first through a conventional cleaning and pretreating section. An additional rinse with deionized water is often used, but since EDP is an aqueous system dry-off between pretreatment and finishing is not required. The washed and treated parts are lowered automatically into the EDP tank containing the water-borne paint, normally a 7 to 10 percent dispersion of a colloidal polymer^{71,62,64}. The body or part becomes the anode of the electrical system while the tank or grids mounted in the tank become the cathode. To avoid stripping the coating the DC current is not applied until the part is totally submerged. Current flow through the bath causes the paint "particles" to be attracted to the metal surface, where they deposit as a uniform film. The polymer film that builds up tends to insulate the part and prevent further deposition. Dwell time in the tank is typically 1½ to 2 minutes^{61,62,71,72}.

The current is then shut off and the parts are raised out of the bath, allowed to drain, rinsed in deionized water to remove "dragout", and then baked. Solids from the dragout are collected in the rinse water and usually are returned to the EDP tank. This recovery can result in a paint savings of from 17 to 30 percent^{67,73}, with paint solids utilization approaching 100 percent⁷⁴. Excess water removed from the paint bath with an ultrafilter⁷⁴, is generally used for rinsing and eventually dumped to the sewer to control the buildup of impurities.

The conveyors, pretreatment section, and bake oven used for EDP are conventional items; the critical components of the system are^{70,75}:

Figure 4-4. TYPICAL ELECTRODEPOSITION SYSTEM DIAGRAM 159



(1) Dip Tank

The dip tank is a large rectangular container generally with a capacity of 37,850 to 113,550 liters (10,000 to 30,000 gallons), depending on part size^{61,62,63,64}. The tanks are coated internally with a dielectric material such as epoxy and are electrically grounded for safety^{63,71,76}. Shielded cathodes are submerged and usually run along both sides of the tank.

(2) Power Supply

Direct current electrical power is supplied by a rectifier with a capacity of approximately 30 to 300 volts and 300 to 750 amperes, depending on the number of square feet per minute to be finished^{62,63,64}.

(3) Heat Exchangers

Paint drawn from the dip tank is passed through a heat exchanger to dissipate heat which is developed during the "painting" operation. The temperature is normally maintained at within $\pm 1^{\circ}\text{C}$ of 20 to 24°C ($\pm 2^{\circ}\text{F}$ of 68 to 75°F)^{62,71,76}.

(4) Filters

An "in-line" filter is also placed in the recirculating system to remove dirt and polymer agglomerates from the paint.

(5) Pumps

Circulating pumps are used to keep the paint solution moving.

(6) Paint Mixing Tanks

Paint mixing tanks are used to premix and store paint solids for addition to the dip tank as needed.

(7) Control Panel

The electrodeposition process is generally controlled from a central control console. This panel contains all start-stop switches plus instruments for monitoring voltage, amperage, paint temperature, and pH.

Proper pretreatment can be critical to paint performance - particularly if the substrate has grease or oil on the surface. Solvent-borne paints will generally "dislodge" an occasional oil spot, but water-bornes will not^{77,78}. Cleaners developed for conventional systems are generally adequate for EDP, however.

Painting in the dip tank is affected by voltage, current density, temperature, dwell time, pH, and solids content⁷⁹.

By increasing the voltage or the temperature in the bath, the film thickness can be increased. Excessively high voltage will cause holes in the films due to gassing, however. Too high a temperature is also undesirable; some paints will flocculate at temperatures approaching 90°C.

At high pH, there is a reduction in the deposition; if the pH drops below the isoelectric point, the entire tank of paint can coagulate.

If the solids content in the tank is too high, the voltage cannot "wring" the moisture from the deposited film; if the bath is too dilute, then the film will be thin, below 2.54×10^{-2} mm (one mil).

For successful operation of an EDP system it is necessary to monitor on a regular basis: voltage, amperage, pH, temperature, and solids and organic solvents. For satisfactory appearance of the final finish, it is important to rinse the parts thoroughly after painting; the final rinse should be with deionized water.

Ultrafiltration Rinsing

A portion of the bath is pumped through an ultrafiltration membrane to provide permeate for rinsing of parts emerging from the tank. The permeate collects into a tank of suitable capacity. Permeate is delivered from the holding tank #3 for a final rinse.

Waste Treatment

The liquid in the waste treatment tank is monitored for pH. Such a system treats accumulated wastes from the ultrafilter rinses and drains and raises their pH to precipitate the resin prior to discharging to drain. The precipitate forms a rubber-like material in a chamber that is readily cleaned. The remaining solution passes into the plant's waste system.

Furniture parts painted with EDP are normally baked from 15 to 30 minutes at 135 to 205°C (275 to 400°F).

Solvent emissions are related to both paint composition and production rate. The greater the quantity of solvent in the water-borne coating, the greater the air emissions. Solvents used are high molecular weight alcohols, added to aid in fusing the paint particles into a continuous film.

Production in terms of square meters per hour has an influence on emissions: the higher the rate, the greater the emissions. This rate depends on the area of the parts, their spacing on the conveyor, and the conveyor speed.

Emissions are also influenced by coating thickness; thicker coatings will carry a greater amount of solvent. The thickness depends on the "throwing power" used during the deposition - i.e., the voltage and amperage applied across the electrodes. Normally there are no transfer efficiency problems with electrodeposition; with the use of ultrafilters nearly all of the paint solids are transferred to the part⁷⁴. There can be dripping associated with dragout, but this material is recovered in the rinse water and returned to the dip tank.

The emission reduction capacity of EDP is related to the solvent content of the paint, and the percent solids of the paint as the part emerges from the bath, both of which influence the weight of solvent associated with applying a given weight of dry paint solids. Of course the percent emission reduction is also related to the emission level for the solvent-borne paint being replaced, which can also vary, depending on the percent solvent in the paint and the transfer efficiency.

4.1.2.2. Water-Borne Spray

While spray painting with water-bornes has found relatively little use in the metal furniture industry to date, there is fairly widespread use of this technology throughout much of the industrial finishing industry. Typical applications include industrial equipment⁸⁰; automobile topcoats^{81,82,83}, engines⁸⁴, and parts^{85,86}; farm machinery⁸⁷; cans⁸⁸; computer cabinets^{89,90}; business machines⁹¹; and air conditioners⁹²; as well as metal furniture⁶⁸.

A recent survey of 100 major appliance; air conditioner; and business, vending, and commercial machinery firms indicates that, 15 were using water-borne spray painting⁹³, compared to 11 using electrodeposition and 8 using either flow or dip coating.

Most of the solvent-borne paint presently being used for indoor home, office, and institutional furniture is alkyd and to a lesser extent acrylic and polyester^{94,95}. It is likely that in converting to water-borne finishes, these same binders will continue to be used.

Since water-borne paints are readily atomized, they can be applied by air, airless, or electrostatic spray or electrostatic disc, using either manually operated or automatic guns^{93,96}. With both water-borne and solvent-borne paints, being relatively low viscosity fluid systems with approximately the same solids content, few if any modifications are generally required in order to convert from the use of one paint to the other. Some water-bornes are corrosive due to high pH, requiring the use of stainless steel or plastic pipes and pumps^{54,96}, and stainless steel or aluminum spray nozzles.

Electrostatic spray presents no problems, but for safety reasons because a highly conductive fluid is being used, pumps, lines, guns and paint supply tanks must generally be insulated or isolated⁵⁴. One unique gun design allows for changing of the paint particles at the gun, obviating the need for isolation of the rest of the system¹⁹².

Water-borne paints are generally water-reducible coatings with some emulsions being used. The water reducible materials are thermosetting paints with 25 to 40 volume percent solids^{54,57} and a ratio of 82/8 to 88/12 water to organic solvent in the volatile portion of the paint.

With water-borne paints, as with any solvent containing paint, the emission of volatile organics into the air is dependent on the percent solvent in the paint and the thickness of the coating that is applied.

In addition, the emissions are influenced by the number of units produced per hour and the surface area of each unit.

One critical factor in any spray operation, a factor that can have a serious effect not only on emissions but on cost and secondary pollutants, is transfer efficiency - that percentage of the spray paint that actually deposits on the part. With conventional spray being used, transfer efficiencies are normally in the range of 30 to 60 percent. If electrostatic spray is used, transfer can increase to 70 to 90 percent²⁹. The variation in percent transfer for a given spray technique is influenced by part geometry and in the case of manual spray, by the spray gun operator.

4.1.2.3 Water-Borne Dip

Water-borne dip coating has also found relatively little use in the metal furniture industry to date, but as with water-borne spray coating there is increasing use of this technology throughout the industrial finishing industry. Reports from a recent symposium on water-borne coating systems indicate that water-borne dipping enamels are finding use as primers and one coat finishes in industrial finishing applications where a nominal 2.5×10^{-3} cm (1 mil) thick finish is desired⁹⁸. Present use of dip coating includes applications such as primers for bicycles and autos^{99,100,101}, topcoats for major appliances, etc.⁹³.

Most of the solvent-borne finishes for metal furniture are applied by either spray or dip coating⁶⁵. Therefore for a finisher already applying dip coatings, conversion to water-borne paint should be relatively simple, requiring the replacement of the dip tank with a tank of stainless steel or other inert material.

One industry expert feels that water-borne dip coats should make good penetration into the metal furniture and fixture market⁵⁹, but the occasional problem of poor appearance due to runs and drips may slow this penetration¹⁹³.

The water-borne dip process is nearly identical to that for solvent-borne materials, the major difference coming in the dry and bake schedule. As with water-bornes applied by other methods a longer slower drying schedule is required in order to prevent blistering of the coatings.

The factors governing emission of solvents are the same as for spray coatings discussed above. In the case of dip coating, the transfer efficiency is nearly 100 percent with only some small losses due to dripping in some operations.

4.1.2.4. Water-Borne Flow Coating

Flow coating is a finishing technique that is used for painting a wide variety of products including, farm equipment, appliances, machinery, electrical equipment, and air conditioners^{93,189,190}, as well as furniture.

In flow coating, paint is made to flow or cascade over the part to be painted, by squirting the paint onto the part through small nozzles. These nozzles are often mounted in the bottom of the coating cabinet, where they create a column of paint through which the parts must pass. Excess paint flows to the bottom of the cabinet where it is collected and reused.

Since flow coating involves the use of a fluid paint, conversion from organic solvent-borne to water-borne materials is logical; such conversions have been made in the major appliance, air conditioner^{92,93}, and trailer industries¹⁸⁷, as well as in the metal furniture industry¹⁸⁸.

Once again, the factors governing emission of solvent vapors to the air are the same as for spray coating discussed above. In the case of flow coating, the transfer efficiency is in the range of 75 to 90 percent. Hollow articles may receive a coating inside where it is unnecessary - and therefore result in low effective transfer efficiency.

4.1.3. Higher Solids Coatings

Higher solids coatings hold the potential of being able to apply the same weight of paint solids with reduced emissions of volatile organic solvent. Such coatings fall in the general categories of radiation curable systems, "high-solids coatings", and powder coatings. Powder coatings have already been discussed (Section 4.1.1. - page 4-1). Radiation-cured coating involves the photocuring of mixtures of low molecular weight polymers or oligomers dissolved in low molecular weight acrylic monomers. These formulations contain no solvent carriers and can cure using either electron beam or ultraviolet light sources to essentially 100 percent solids coatings^{102,103,104}. These coatings have generated little interest in the metal furniture industry, presumably because of the health hazard associated with the spray application of these relatively toxic monomer mixtures and the difficulties involved in obtaining adequate cure of the paint when applied to irregularly shaped substrates.

High-solids coatings are a relatively new family of materials that is currently being developed and investigated in the automotive, can, coil, appliance, and metal furniture industries. The attraction of such coatings seems based on a low solvent content, the promise of application with modified conventional finishing equipment, and the promise of energy savings through the use of more reactive systems. Although the traditional definition of high solids as specified in "Rule 66" indicates no less than 80 volume percent solids¹⁰⁵, most of the people in industry are considering everything from 50 percent to 100 percent.

There will very likely be no radically new resin binders associated with high-solids coatings; most are modifications of their low-solids counterparts. The coatings can be categorized as either two-component/ambient-curing or single-component/heat-converted materials.

The coatings that are of the most immediate interest are the two-component/ambient-cure materials; they offer not only a reduced solvent content but also a tremendous energy savings since they require little or no baking. Resin systems being investigated include epoxy-amine, acrylic-urethane, and urethane^{106,107,108,109}.

The heat-converted, high-solids coatings being developed include epoxy, acrylic, polyester, and alkyd¹¹⁰. Most contain reactive hydroxyls or carboxyls which allow crosslinking with amino compounds such as hexamethoxy methylmelamine. These coatings are baked at temperatures similar to low-solids counterparts - nominally 150 to 175°C (300 to 350°F).

The most significant problem with high-solids coatings is the high working viscosity of the high-solids solution (i.e., 60 to 80 volume percent)¹⁰⁸. The viscosity can be controlled to some degree by reducing the molecular weight of the base polymer or by using reactive diluents, but these techniques can result in a greatly altered product with inferior properties. A more effective means of reducing viscosity is to heat the coating during the application¹⁰⁸.

Heated high solids can be applied as airless, air, or electrostatically sprayed finishes from heated equipment¹⁶⁴, and can be roll-coated. One new type of coating apparatus, the high-speed turbine disc or bell, seems particularly well suited to the application of high-solids coatings since the coatings can be applied without heating of the paint^{160,161}.

While it is generally agreed that high-solids coatings hold a great deal of promise, they are still an emerging technology and must be considered to be still in their infancy¹⁶². Of the approximately 1514 million liters (400 million gallons) of industrial finishes consumed in 1975, less than 1 percent were high solids¹⁶³.

Principal uses for high-solids coatings are presently in coil and can coating¹⁶³. While there has been a great deal of interest in high-solids coatings in the industrial finishing industry⁹⁵, there are only a few production lines in the metal furniture industry at the present time^{95,160,165,166}.

The current usage of high solids paints in the industrial finishing industry, including the metal furniture industry, generally involves the application of "higher solids" or intermediate solids materials, that is 40 to 55 volume percent solids¹⁶⁵. While the use of high solids coatings (i.e. 70 to 80 volume percent solids) is feasible and has been demonstrated on at least one institutional metal furniture finishing

line¹⁶⁶, "higher solids" coatings of 65 volume percent solids are generally considered to be the practical upper limit at the present time for industrial finishes. For materials above 65 volume percent solids there are often adhesion and application problems resulting from the high viscosity and low solvent content of these paints.

4.1.4. Carbon Adsorption

Carbon adsorption as a technique for solvent recovery has been in use commercially for several decades. Applications include recovery of solvent from dry cleaning, metal degreasing, printing operations, and rayon manufacture¹¹¹. While adsorbers have not been used in the metal furniture finishing industry they have been used in other industrial finishing industries^{112,113,114}, and although the recovery of coating solvents from industrial finishing operations using adsorption is not without some technical problems, the process is essentially no different from any other being used for solvent recovery.

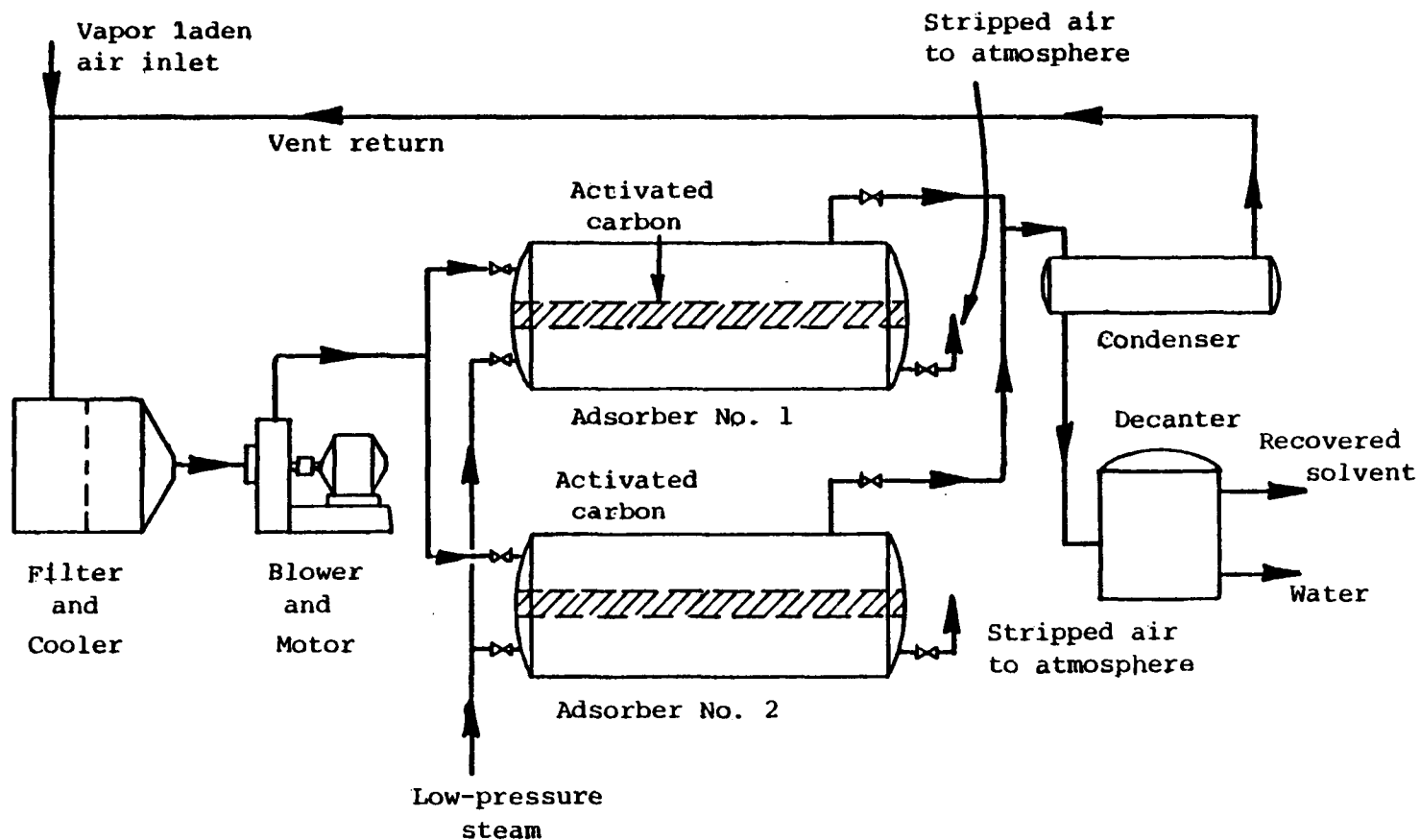
The adsorption process is made possible through the use of specially "activated" carbon, which has a fine pore structure and therefore a tremendous surface area per unit weight - as great as 1,000,000 square meters per kilogram¹¹⁵. Through secondary bonding and capillary action, this carbon can adsorb onto its surface large quantities of volatile organics.

A typical adsorption unit is shown in Figure 4-5. Air containing the organic vapors is passed through a filter to remove particulates and then through a cooler to reduce the temperature of the gas to no greater than 38°C. A blower forces the vapors through one of two adsorbers, packed with activated carbon. Two units are normally adequate for continuous operation; one unit can be operated while the other is being regenerated.

During the course of operation, the carbon becomes saturated with organics, and it is necessary to regenerate. The organics are desorbed from the carbon by passing either steam or hot gases through the bed¹¹⁶. The revolatilized organics are then recovered downstream in a condenser. The regenerated gas can also be directly incinerated, which is always the case for hot gas regeneration.

For most industrial applications, adsorption is used to recover solvents for reuse. Coating solvents used in industrial finishing, however, are normally complex mixtures of aliphatics, aromatics, esters, ketones, alcohols, ect.^{118,119}. To recover such solvents with sufficient purity for reuse would require costly fractional

Figure 4-5. DIAGRAM OF AN ACTIVATED-CARBON ADSORBER SYSTEM



From Adsorption, by Mantell. Copyright 1945, 1951 by the McGraw-Hill Book Company, Inc. Used with permission of the McGraw-Hill Book Company.

distillation, which is probably not economically feasible. The most practical use for these solvents, since they are all flammable, is incineration. The heat generated can be used to produce some of the steam necessary for regeneration of the adsorber¹²⁰.

There are several variables which effect the performance of carbon adsorbers and most are related to the adsorptive capacity of the carbon. This adsorptive capacity, the weight of solvent that can be retained on a given weight of carbon, can be expressed as follows^{121,122}:

$$\text{Adsorptive capacity} = \frac{V_m}{T \log (C_o/C_i)}$$

in $\frac{\text{g solvent}}{\text{g carbon}}$

Where V_m = liquid molar volume of pollutant at normal boiling point
 T = absolute temperature
 C_o = concentration of saturated vapor
 C_i = initial pollutant vapor concentration into adsorber

The liquid molar volume of a given solvent is related to both its molecular weight and density at the boiling point. In general, the greater the V_m of the solvent the higher the molecular weight and therefore the boiling point. In other words, carbon will generally have a greater adsorptive capacity for higher boiling solvents.

For these compounds with relatively high V_m , adsorption will occur, but because of their low vapor pressures desorption becomes difficult. Generally, solvents with a molar volume of between 80 and 190 cm³/mole present no problems with adsorption and regeneration¹²³. Fortunately most of the solvents used in industrial finishing fall within this range. Table 4-5 lists some of the problem solvents for carbon adsorption. Of the solvents listed, nonane (a component of most grades of mineral spirits) is commonly used in metal furniture finishing. Mineral spirits are used in substantial proportions in many alkyd and acrylic enamels but should be effectively desorbed with either super heated steam or hot gas¹²⁴.

Table 4-5. PROBLEM SOLVENTS FOR CARBON ADSORPTION

<u>Solvent</u>	<u>V_m cm³/mol</u>	<u>Boiling Point</u>	
		<u>°F</u>	<u>(°C)</u>
Dodecane	274	421	(216)
Undecane	251	383	(195)
2-ethylhexyl acetate	238	390	(199)
Decane	229	345	(174)
Butyl carbitol	213	448	(231)
Nonane	207	302	(150)
2,6-dimethyl 4-heptanone	207	345	(174)
Diethyl cyclohexane	207	-	-
Butyl cyclohexane	207	345	(174)
1-methyl pentyl acetate	194	-	-
Diethyl cyclopentane	192	307	(152)
Nitroethane	75	239	(116)
Propanone	74	133	(56)
Dichloromethane	65	104	(40)
Ethanol	61	173	(78)
Nitromethane	53	214	(101)
Methanol	42	149	(66)

Source: Stern, A.C. Air Pollution. Academic Press, New York. Vol. II, Second Edition, Chapter 16 (1968)

Temperature of the inlet gas stream also affects adsorptive capacity; the higher the temperature the lower the adsorptive capacity. At temperatures in excess of approximately 38°C, solvents which are normally adsorbed and desorbed with no difficulty will be poorly retained by the carbon^{125,126}. Low inlet vapor concentration also has an adverse effect on adsorptive capacity¹²⁷, and of course capacity is also affected by the surface area of the carbon as influenced by particle size and degree of porosity.

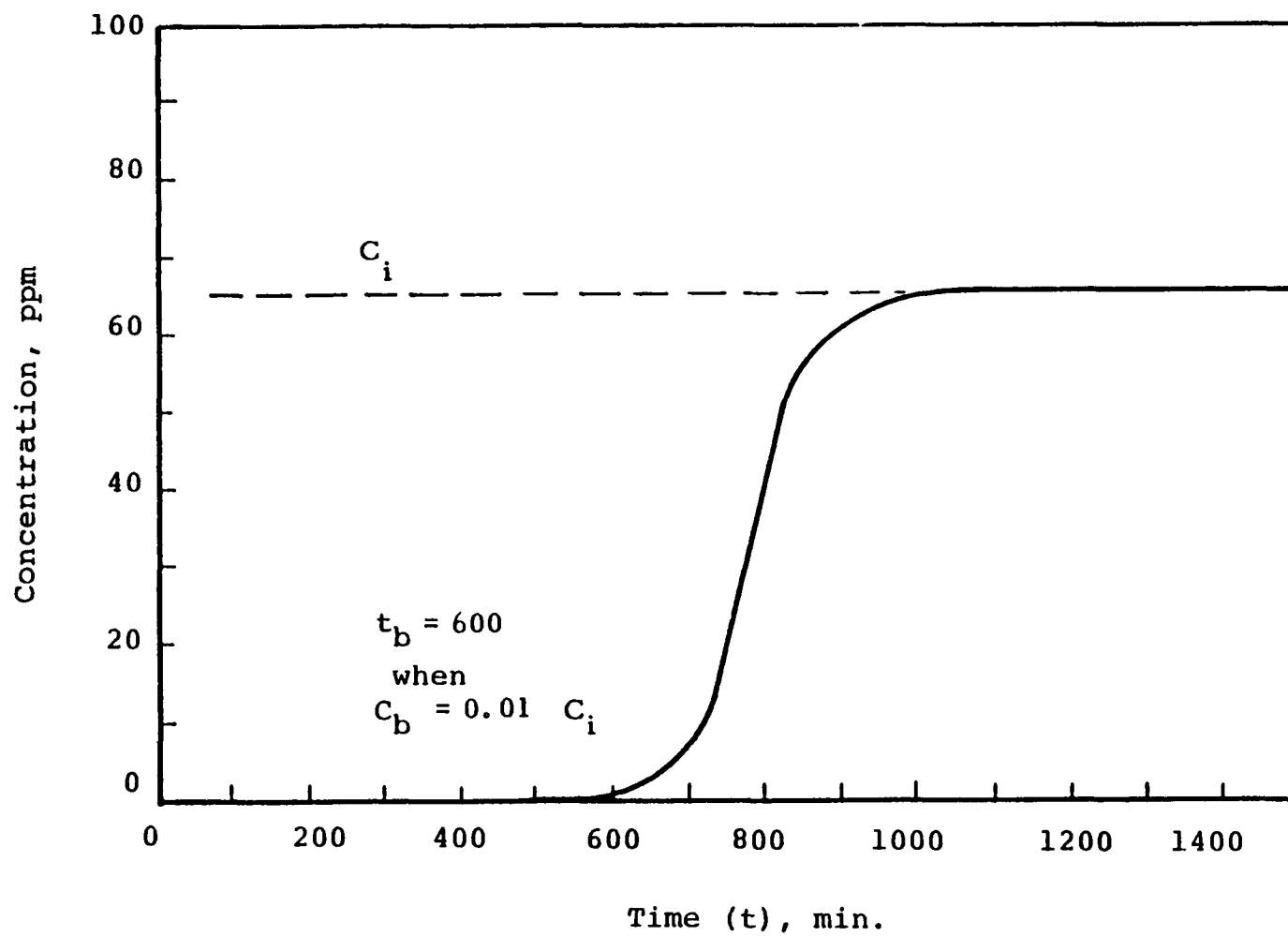
Although adsorption will generally remove 90 percent or more of the volatile organics from a gas stream, this performance tends to deteriorate with time as the active sites on the carbon surface are depleted. This is shown graphically in Figure 4-6. Although the performance begins to deteriorate after 500 minutes (i.e., effluent concentration starts to increase), the carbon is not completely exhausted until 1000 minutes have elapsed. The overall performance of an adsorber, then, is largely dependent on when and how completely the unit is regenerated. If the unit in the example given is regenerated after every 500 minutes, the overall performance will be quite high, but the cost of treatment will also be higher than with longer cycle times as a result of more frequent regeneration. Normally there will be some trade-off between cost and performance.

The size of a given adsorber is determined by the adsorptive capacity of the carbon and the quantity of volatile organic to be removed. Of course the adsorptive capacity will depend on the V_m of the solvent or solvent blend. In the case of mixed solvents, the bed depth necessary to adsorb each of the vapors can be estimated from the sum of the bed depths necessary to remove each vapor if it were alone in the air stream¹²⁸.

The cross-sectional area of each bed is determined from the volume of air that must flow through the unit. A face velocity (defined as flow rate in CFM or cubic meters per minute divided by the cross-sectional area) of 9.1 to 30 meters per minute (30 to 100 feet per minute) is normally used to avoid excessive pressure drop through the bed¹²⁹ and to get an effective utilization of the equilibrium capacity of the bed¹³⁰.

In the metal furniture industry the solvent emissions of greatest concern come from two general areas, the application and flash-off area, and the bake oven.

Figure 4-6. EFFLUENT CONCENTRATION CURVE OF BUTANE VAPOR
FROM AN ACTIVATED CARBON BED AS FUNCTION OF TIME ¹³⁵



In the case of spray booths, adsorbers must be designed to handle air with a high water vapor content. This high humidity results from the use of water curtains on both sides of the spray booths to capture overspray. Although carbon preferentially adsorbs organics, water will compete for available sites on the carbon surface. Generally the relative humidity should be kept below 80 percent to minimize the problem¹³¹.

The exhaust from the spray booths, particularly during periods of cool ambient temperatures, can reach saturation with moisture¹³². One solution to this problem would be to preheat the moisture-laden air to lower the relative humidity to below 80 percent; a 4 to 5°C heating would be sufficient¹³³.

Prior to adsorption, particulates from oversprayed paint have to be removed from the air streams, since this material will coat the carbon or plug the interstices between carbon particles. Such plugging will destroy efficiency and increase pressure drop through the bed. Such particulates can be removed by using either a fabric filter¹³¹ or the combination of a centrifugal wet separator plus prefilter and bag filter¹³⁴.

Another variable which should be considered in designing an adsorber for metal furniture finishing application is the potential variability of the solvent systems between different grades or types of paint. Although all conventional low solids paints contain the same families of solvents (i.e., glycol ethers, esters, C₈ and C₉ aliphatics, etc.), the various paints employed can differ widely with regard to specific compounds and relative proportions. Solvent systems therefore could differ in their adsorptive capacity and, as a result, their ability to be removed by the adsorber. On lines where different grades of paint are used from time to time, adsorbers will probably have to be over designed in adsorptive capacity.

Ovens are the second important source of solvent emissions; it has been estimated that approximately 10 percent of the volatiles from a solvent-based paint are emitted in the oven¹³²; the remaining 90 percent goes off in the application area.

The individual solvents in an application area tend to evaporate at different rates. The 90 percent of the solvent that is emitted in the application area will comprise a large percentage of "low boilers" such as acetone, butanol, toluene, etc. The 10 percent which remains in the film as it enters the oven contains primarily less volatile solvents. Therefore, adsorbers for ovens will have to be designed to handle a different solvent mix than is found with the application areas. High-boiling solvents

may not be consistently and completely stripped during regeneration, in which case more frequent replacement of the carbon would be likely. In any case, hot gas or super heated steam regeneration would probably be required¹²⁴.

In the oven, high temperatures and flame contact with the volatiles can cause polymerization of degradation products into high molecular weight resinous materials which can deposit on and foul the carbon bed. Various high molecular weight volatiles in the coatings such as oligomers, curing agents, or plasticizers could cause a similar problem. Filtration and/or condensation of the oven exhaust air would be necessary prior to adsorption in order to remove these materials.

In order to get satisfactory performance, it will also be necessary to cool the oven exhaust to a temperature no greater than 38°C. Without cooling, many of the more volatile organics will not adsorb but will pass through the adsorber^{125,126}.

4.1.5. Incineration

Incineration is the most universally suitable technique for reducing the emission of volatile organics from industrial processes; in the industrial finishing industry these volatile organic emissions consist mostly of solvents made up of carbon, hydrogen, and oxygen, which can be burned or oxidized in specially constructed incinerators into carbon dioxide and water vapor.

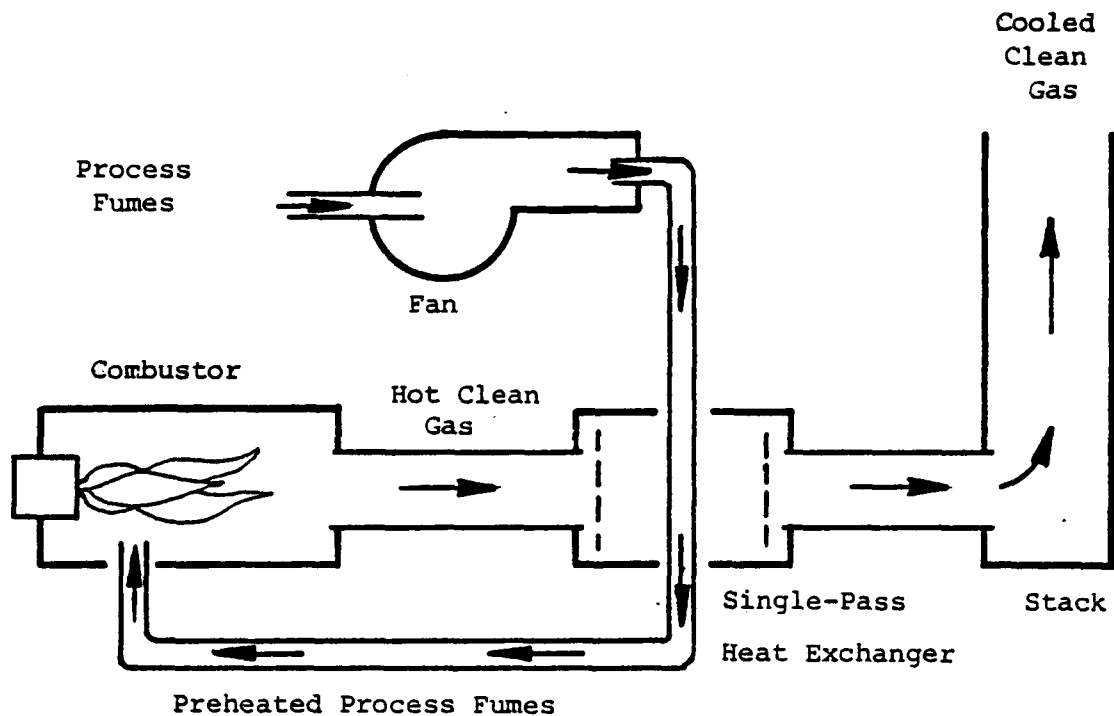
Industrial incinerators or afterburners are either noncatalytic (commonly called thermal or direct fired) or catalytic¹³⁶, with sufficient differences between the two to warrant a separate discussion for each.

4.1.5.1. Thermal Incinerators

Direct-fired units operate by heating the solvent-laden air to near its combustion temperature and then bringing it in direct contact with a flame. A typical unit is shown schematically in Figure 4-7. In general, high temperature and organic concentration favor combustion; a temperature of 760°C (1400°F) is generally sufficient for near complete combustion.

To prevent a fire hazard, industrial finishing ovens are seldom operated with a concentration of solvent vapor in the air greater than 25 percent LEL, and some operations - particularly ovens - in the automobile and light duty truck industry can achieve concentrations of only 5 to 10 percent LEL. These low concentrations are the result of high air flows necessary in order to prevent escape of oven gas at oven openings and to prevent condensation of high-boiling organics on the inner surfaces of the oven¹³⁷.

Figure 4-7. FORCED-DRAFT SYSTEM ELIMINATING SOLVENT VAPORS
FROM SURFACE COATING PROCESS¹⁴⁰



Since the solvent emissions are below the combustible limit, auxiliary heating of the air is necessary for incineration. The quantity of heat to be supplied is dependent on the concentration of the organic in the air stream; the higher the concentration the lower the auxiliary heat requirement because of the fuel value of the organic.

For most solvents, the fuel value is equivalent to 4.45 gram-kilocalories per cubic meter (0.5 BTU/scf), which translates into a temperature rise of approximately 15.3°C (27.5°F) for every percentage point of LEL that is incinerated. For an air stream with an organic solvent content of 25 percent of LEL, the contribution from the heat of combustion of the solvent would be approximately 115 gram-kilocalories per cubic meter (13 BTU/scf)¹³⁸, equivalent to a temperature rise of 345°C (620°F).

If the desired exhaust temperature is 816°C (1500°F), then the inlet air stream would have to be heated to only 471°C (880°F). On the other hand, if the process air contains only 10 percent LEL, as is the case with the exhaust from automobile bake ovens, then the solvent would contribute only 135°C (275°F) and the air entering the incinerator would have to be preheated to 681°C (1225°F) in order to attain the same final temperature, 816°C (1500°F).

To make thermal incineration less costly, heat transfer devices are often used to recover some of this heat of combustion. Primary heat recovery is often in the form of a recuperative heat exchanger, either tube or plate type, which is used to preheat the incoming process fumes as illustrated in Figure 4-7¹⁴⁰. Units of this type are capable of recovering 50 to 70 percent of the heat from the original fuel input^{140,141}.

A more satisfactory type of heat recovery device and one that finds wide use in fume incineration equipment is the regenerative heat exchanger, both refractory and rotary plate types¹⁴⁰. Units of this type are capable of heat recoveries of 75 to 90 percent^{142,143,144}. In some cases secondary recovery is also used to convert additional exhaust heat into process steam or to warm "make-up" air for the plant¹⁴⁰.

There are several operating parameters which affect the emission reduction potential of thermal incinerators; following are the most significant ones:

For efficient combustion of the hydrocarbons in the air stream it is necessary to have sufficient temperature and residence time in the incinerator. Figure 4-8. shows the combined effect of these two parameters. Insufficient residence time results in incomplete combustion and the generation of carbon monoxide. A residence time of 0.3 to 1.0 seconds is typical.

If the air stream to the incinerator contains sulfur-, nitrogen-or halogen-containing organics there will be a secondary pollution problem. Incineration of these materials will produce sulfur and nitrous oxides and acids such as hydrochloric and hydrobromic. Fortunately none of the solvents used for metal furniture finishing contain these elements.

Solvent type can also influence incinerator performance. While 593 to 677°C (110-1250°F) is adequate to combust most solvent vapors, certain organics require temperatures of 760 to 816°C (1400 to 1500°F) for nearly complete oxidation¹³⁶.

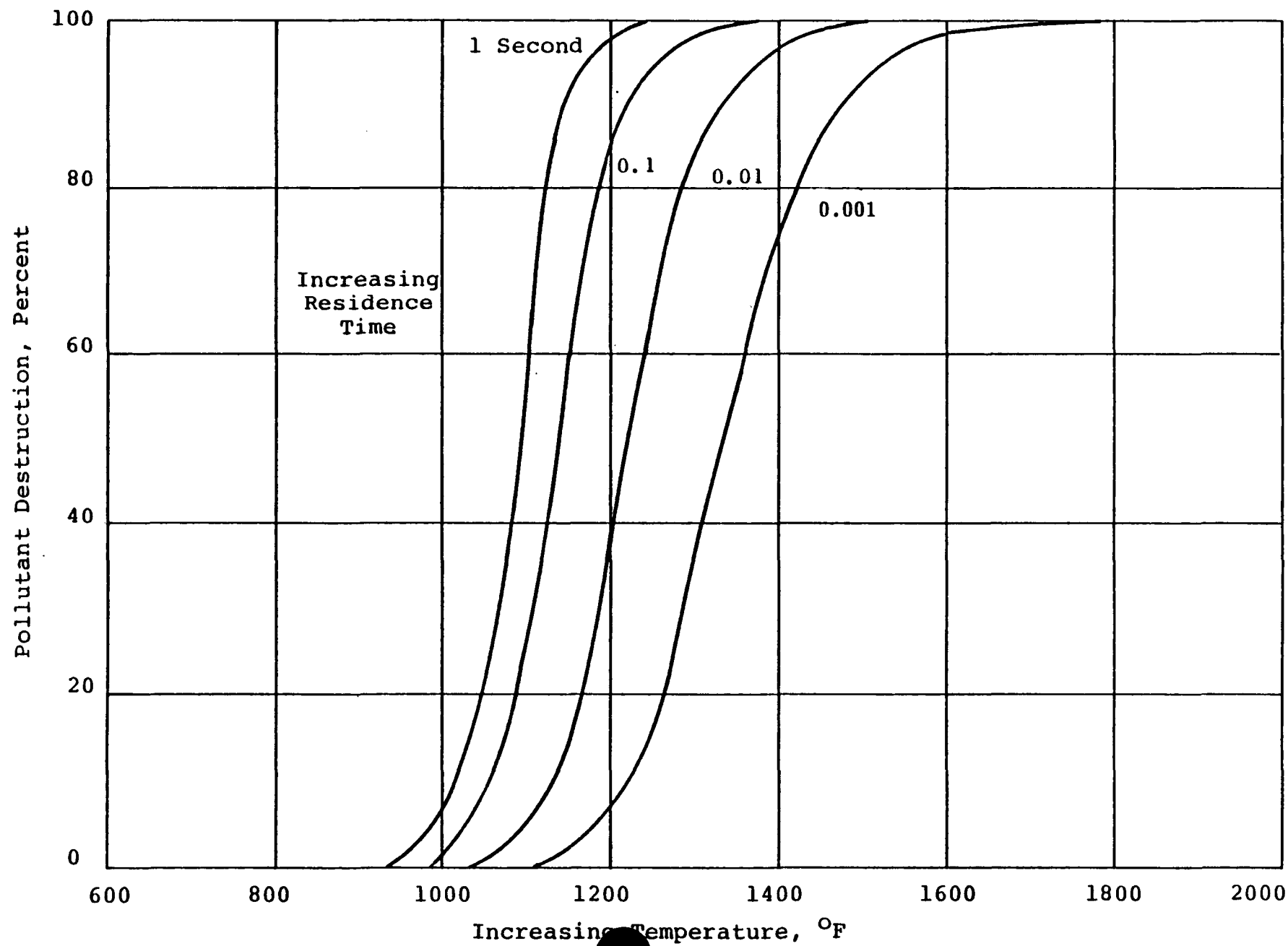
On a finishing line in the metal furniture industry, the two potential areas for the use of incinerators are again on the application section and on the ovens used for baking.

Although a survey of the metal furniture finishing industry found no incinerators in use on bake ovens, such an application presents no significant problem. Thermal incinerators are in place on ovens in several automotive assembly plants, particularly in California^{145,146,147}, as well as in plants in the paper¹⁴⁸, can¹⁴⁹, and coil coating industries^{150,151}. Typical emission reductions with such units is over 90 percent. Since the air exiting the ovens is generally at a temperature of 120 to 150°C (250 to 300°F), the air preheating requirements are less than they would be for incoming air at ambient temperature.

Incinerators on the bake ovens are controlling approximately 10 percent of the solvent emissions; the remaining 90 percent of the volatiles are emitted in the application and flash-off areas.

Although incineration of the air from application areas is possible, our survey revealed no applications in the metal furniture finishing industry. Because of the relatively large air flow in spray booths, and the resulting low solvent concentration

Figure 4-8. COUPLED EFFECTS OF TEMPERATURE AND TIME ON RATE OF POLLUTANT OXIDATION 135



of the air stream, large quantities of natural gas or equivalent fuel would be required to heat the vapor-laden air from near ambient to the 700 to 760°C (1300 to 1400°F) necessary to effect near complete combustion.

4.1.5.2. Catalytic Incineration

This add-on control method makes use of a metal catalyst to promote or speed combustion of volatile organics. Oxidation takes place at the surface of the catalyst to convert organics into carbon dioxide and water; no flame is required¹³⁶.

A schematic of a typical catalytic afterburner is shown in Figure 4-9. The catalysts, usually noble metals such as platinum and palladium, are supported in the hot gas stream in such a way that a high surface area is presented to the waste organics. A variety of designs are available for the catalyst, but most units use a noble metal electrodeposited on a high area support such as ceramic rods or honeycomb or alumina pellet^{136,152}.

As with thermal incinerators, the performance of the catalytic unit is dependent on the temperature of the gas passing across the catalyst and the residence time. In addition, the efficiency of the afterburners varies with the type of organic being oxidized¹⁵². These effects of temperature and organic type are illustrated graphically in Figure 4-10. While high temperatures are desirable for good emission reduction, temperatures in excess of 593 to 649°C (1100 to 1200°F) can cause serious erosion of the catalyst through vaporization^{136,152}.

The use of a catalyst permits lower operating temperatures than are used in direct-fired units; temperatures are normally in the range of 260 to 316°C (500 to 600°F) for the incoming air stream and 399 to 538°C (750-1000°F) for the exhaust. The exit temperature from the catalyst depends on the inlet temperature, the concentration of organic, and the percent combustion. The increase in temperature results from the heat of combustion of the organics being oxidized.

As with thermal incinerators, primary and secondary heat recovery can be used to minimize auxiliary heating requirements for the inlet air stream and to reduce the overall energy needs for the plant (see page 4-36. Although catalysts are not consumed during chemical reaction, they do tend to deteriorate with time, causing a gradual loss of effectiveness in burning the organics. This deterioration is caused by poisoning with chemicals such as phosphorous and arsenic, which react with the catalyst; by coating the catalyst with particulates or condensates; and by high

Figure 4-9.

SCHEMATIC DIAGRAM OF CATALYTIC AFTERBURNER USING
TORCH-TYPE PREHEAT BURNER WITH FLOW OF PREHEAT
WASTE STREAM THROUGH FAN TO PROMOTE MIXING 135

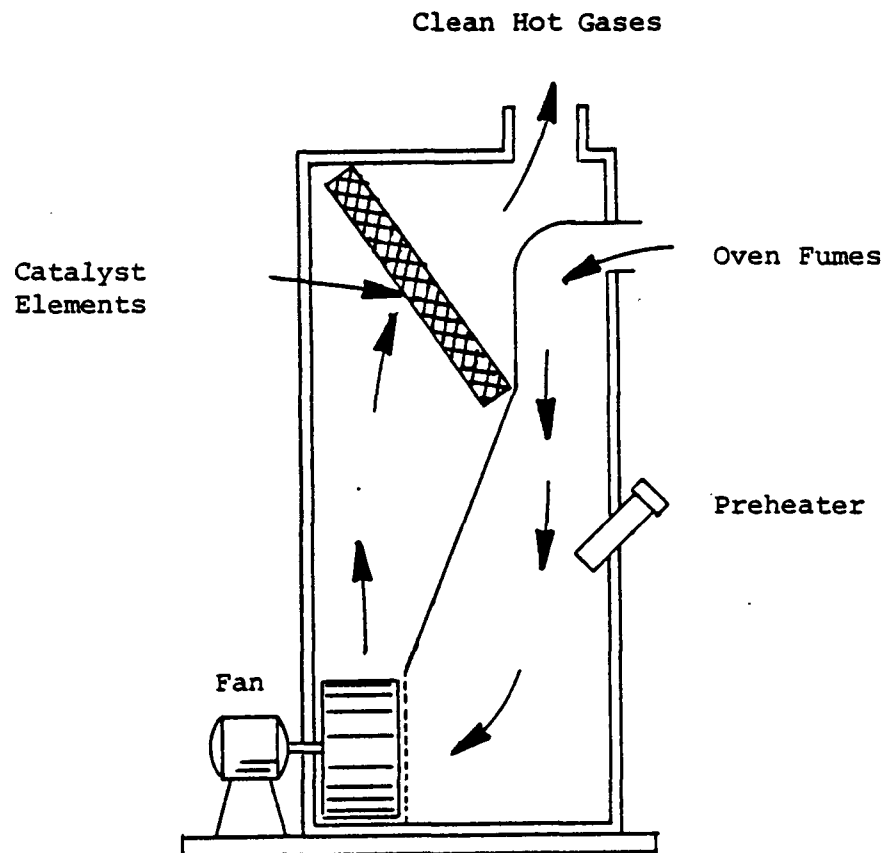
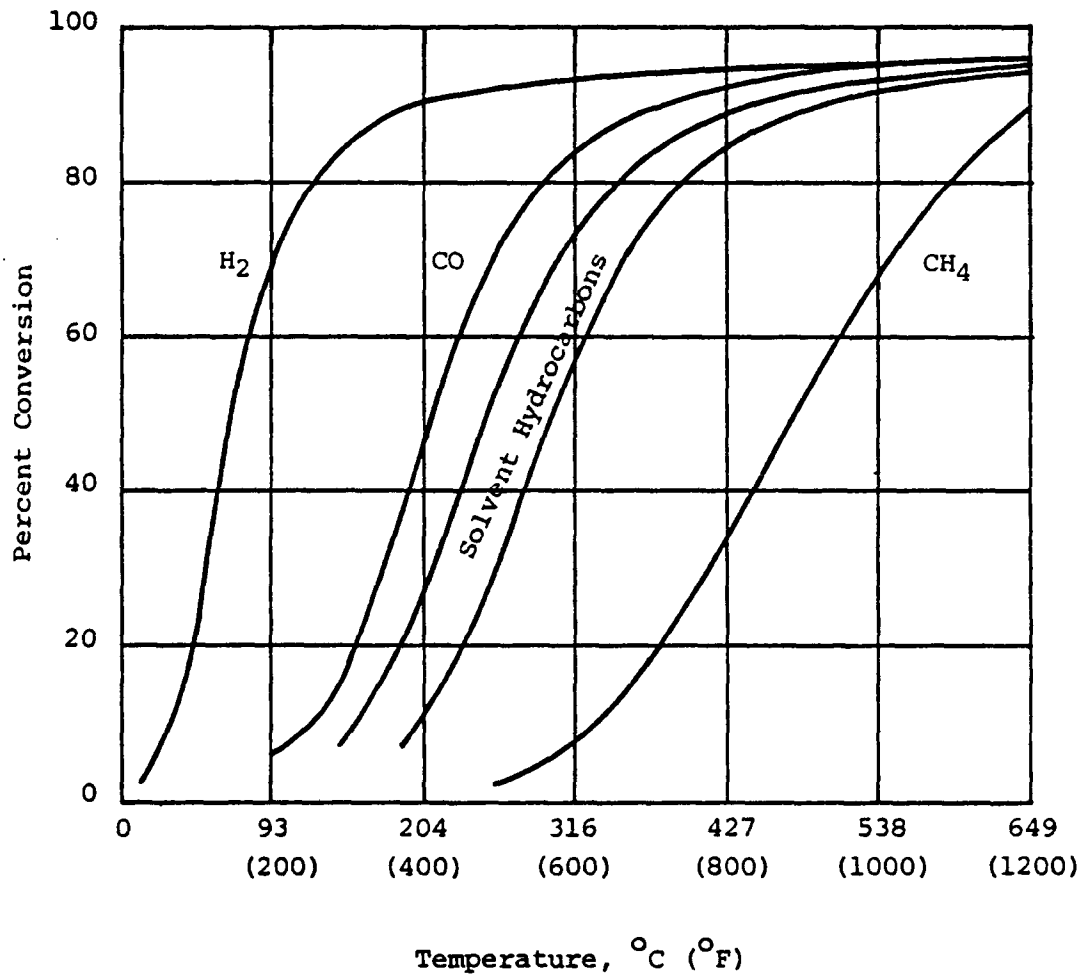


Figure 4-10. EFFECT OF TEMPERATURE ON
OXIDATIVE CONVERSION OF ORGANIC VAPORS
IN A CATALYTIC INCINERATOR 135



operating temperatures, which tend to vaporize the noble metal. In most cases catalysts are guaranteed for one year by the equipment supplier¹⁵³, but with proper filtration, cleaning, and attention to moderate operating temperatures the catalyst should have a useful life of two to three years^{136,153,154}.

Although catalytic incineration has the potential for reducing volatile organic emissions, our survey found no units in regular use in the metal furniture finishing industry.

While catalytic incinerators can probably be adapted to baking ovens with relatively little difficulty, the use of these add-ons for controlling spray booth emissions will present the same design considerations that were discussed for thermal incinerators. These factors include high air flow, low vapor concentration, and the need to incorporate a highly efficient heat recovery system in order to minimize the need for auxiliary heating of inlet air.

4.2. EMISSION REDUCTION PERFORMANCE OF CONTROL TECHNIQUES

Emissions can be controlled either through the use of "new coatings" or "add-on" control devices. The emission reduction associated with add-ons is related to the ability of the technique to either capture or destroy the organic solvent emissions.

The emission reduction potential for new coatings, however, is related to the quantity of volatile organic material in the "paint" before application and cure. The emissions of any paint can be expressed quantitatively in terms of the amount of solvent or other volatile organic emitted per unit of dry coating resin applied to the substrate. These relative solvent emissions (RSE) can be derived from the weight percent solids of the coating materials as follows¹⁰⁸:

$$\text{RSE} = \% \text{ Organic Solvent} / \% \text{ Solids}$$

It can be shown that the relative organic solvent emissions are not only dependent on the solids content of the paint but rise exponentially as the solids content is lowered¹⁰⁸.

The RSE of any paint/application method is also related to the deposition or transfer efficiency; that is, the percentage of the paint used that actually deposits on the substrate. For spray application, 30 to 60 percent is normal when using air or airless spray, while the electrostatic spray techniques will permit depositions of 60 to 90 percent. The RSE then can be expressed as:

$$\text{RSE} = \% \text{ Organic Solvent} / (\% \text{ Solids}) (\% \text{ Deposition})$$

4.2.1. Powder Coating - Electrostatic Spray

There is a tremendous emission reduction potential associated with the use of powder coating materials which are nearly 100 percent solids.

Some powders emit small percentages of volatile organics during fusion or cure, and the type and amount tends to vary with the generic type of binder used. For thermosetting powders, the emission of organic volatiles for various resins in weight percent is as follows: Epoxy - 0.5% to 3.0%; polyester (urethane type) 2.0% to 4.0%; polyesters (other types) - generally less than 1%; and acrylics - 0.5% to 1.0%^{155,184}. For thermoplastic powders such as polyvinyl chloride and cellulose acetate butyrate, organic volatile emissions can run as high as 5 to 10% due to evaporation of plasticizers from the powders during cure¹⁸⁴.

With electrostatic spray of powder coatings, the powder which does not deposit on the part to be painted is mostly contained in the spray booth. With properly designed equipment, the oversprayed powder can be recovered, providing overall transfer efficiencies in the range of 83 to 98 percent. See Table 4-2, page 9. The RSE when adjusted for transfer efficiency becomes 0.021 to 0.134; and when compared against conventional solvent-borne lacquers and enamels, there is a potential emission reduction in the range of 94 to 99%.

4.2.2. Powder Coating - Fluidized Bed

The same basic emission reduction considerations that were presented for electrostatic spray of powder coatings apply to fluidized bed coating.

In general, the powder, other than that deposited on the parts, is contained in the bed. A small amount of unfused powder is generally carried with the coated part, however. This powder is usually blown-off and recovered.

Overall emission reduction then is again high, in the range of 94 to 99 percent.

4.2.3. Electrodeposition of Water-Bornes

The electrodeposition process, as described on page 4-15 has three possible sources of organic solvent emission: the painted substrate as it is baked, evaporation from the surface of the EDP tank, and evaporation of organic solvent from the cascading rinse water and the drain.

The paint films on the substrates are approximately 95 percent solids as they emerge from the bath. The remaining 5 percent is primarily water with only 3 to 5 percent of the volatiles as organic solvent¹⁵⁶.

Another more likely source of fugitive emissions is escape of the organic solvent into the rinse water. During operation, a portion of the paint from the EDP tank is pumped through an ultrafilter; the permeate is generally is used for rinsing purposes, while the paint concentrate is returned to the tank. Since ultrafiltration will remove nothing smaller than 500 molecular weight^{157,158}, a portion of the water-miscible organic solvents such as alcohols and glycol ethers¹⁵⁶, which have molecular weights under 150, will likely end up in the permeate.

The permeate is then used for spray rinsing where the high surface area of the spray is conducive to evaporation. Depending on the water requirements for the closed loop system, some of the permeate is sent to the drain. It is possible that much of the organic solvent may be lost in this manner.

Since the quantities of organic solvent involved with EDP are quite small by comparison with organic solvent-borne finishes, there has been no effort to our knowledge to quantify these fugitive emissions.

The RSE, regardless of the source of the emissions, can be related to the organic solvent content of the paint. Most EDP paints are supplied with an organic solvent to solids ratio of 0.06 to 0.12 by weight. Since transfer efficiency is essentially 100 percent, the RSE is also 0.06 to 0.12. These RSE translate into percent emission reductions of 97.7 to 98.8 percent when compared against conventional enamels.

4.2.4. Water-Borne Spray

In considering emission reduction for water-borne spray coatings, it is necessary to assess the effect of organic solvent content and solids content of the paint as well as transfer efficiency for not only the water-borne but also the organic solvent-borne paint which it is replacing.

For spray painting the transfer efficiencies cover a broad spectrum, going from 30 to 95 percent¹⁹¹. These efficiencies are influenced by the type of spray method; i.e. conventional air or airless spray, electrostatic air or airless spray or centrifugally atomized electrostatic spray using either a disc or bell, with electrostatic techniques giving much greater transfer efficiencies than the conventional techniques. Transfer is also influenced by the geometry of the parts to be coated,

with higher efficiencies for large flat surfaces and lower efficiencies for open structures such as chairs or bed frames. Finally, the efficiency can be influenced by the individual operator in those cases where manual spray is employed.

Table 4-6 shows the combined effects of solids content, transfer efficiency and solvent content of the paint on the emission reduction potential of water-borne spray coatings when compared against their organic solvent-borne counterparts. Emission reductions are shown for two types of water-bornes, containing a volume ratio of either 88/12 or 82/18 water to solvent in the volatile portion of the paint. These paints are compared against a 35 volume percent solids content organic solvent-borne paint applied at both 65 and 80 percent transfer efficiency. In the case of both the water-borne and solvent-borne paints, a solids content of 35 volume percent as applied from the gun was assumed.

Table 4-6. PERCENT EMISSION REDUCTION FOR
WATER-BORNE COATINGS APPLIED BY SPRAY TECHNIQUES

Water-Borne Transfer Efficiency %	<u>Percent Emission Reduction by Type of Water-Borne Coating</u>			
	Versus Organic Solvent-Borne Paint at 65% Transfer Efficiency		Versus Organic Solvent-Borne Paint at 80% Transfer Efficiency	
	88/12 (1)	82/18 (1)	88/12 (1)	82/18 (1)
	<u>Water/Solvent</u>	<u>Water/Solvent</u>	<u>Water/Solvent</u>	<u>Water/Solvent</u>
50	84.4	76.6	80.8	71.3
65	88.0	82.0	85.2	77.9
80	90.2	85.4	88.0	82.0
90	91.3	87.0	89.3	84.0

(1) Volume ratio of water to solvent in the volatile portion of the paint with 35 volume percent solids as applied in both water-borne paints.

One paint supplier estimates that an emission reduction in the range of 72 to 84 percent will result from substituting water-bornes for organic solvent-borne enamels in spray applications. See Table 4-7.

Table 4-7. REDUCTION OF ORGANIC SOLVENT EMISSIONS
 92,400 Square Meters (1,000,000 Square Feet)
 Sprayed at 65 Percent Efficiency
 Approximately 30 Percent Volume Solids

<u>Coating Type</u>	<u>Liters (Gallons) of Organic Solvent Emitted</u>	<u>Percent Reduction</u>
Convention enamel	10,931 (2,888)	-
Water base, 33 percent organic solvent	2,861 (756)	72
Water base, 18 percent organic solvent	1,560 (412)	84

Source: SME Technical Paper FC74-639, 1974. Page 3

4.2.5. Water-Borne Dip and Flow Coatings

As with water-borne spray coatings, the emission reduction potential is influenced by the solids content and solvent content of both the water-borne paint and the solvent-borne material which it is replacing as well as the transfer efficiencies for both.

The transfer efficiencies for dip coating are in the range of 70 to 80 percent compared to 90 to 95 percent for flow coating^{191,192}. The effect of these transfer efficiencies on emission reduction for two types of water-borne coatings compared against an organic-solvent-borne paint, is shown in Table 4-8. For both water-borne and solvent-borne paints, we have assumed 25 volume percent solids as applied. We have also assumed 80 percent transfer efficiency for solvent-borne dip coating and 95 percent efficiency for solvent-borne flow coating.

Table 4-8. PERCENT EMISSION REDUCTION FOR
WATER-BORNE COATINGS APPLIED BY DIP AND FLOW COATING

<u>Coating Process</u>	<u>Transfer Efficiency %</u>	<u>Percent Emission Reduction by Coating Type (1)</u>	
		<u>88/12 (2) Water/Solvent</u>	<u>82/18 (2) Water/Solvent</u>
Dip	70	86.3	79.4
	80	88.0	82.0
Flow	90	87.3	81.0
	95	88.0	82.0

- (1) Compared against a 25 volume percent solids organic solvent-borne enamel at 80 percent transfer efficiency for dip and 95 percent for flow coating.
- (2) Volume ratio of water to solvent in the volatile portion of the paint with 25 volume percent solids in both water-borne paints.

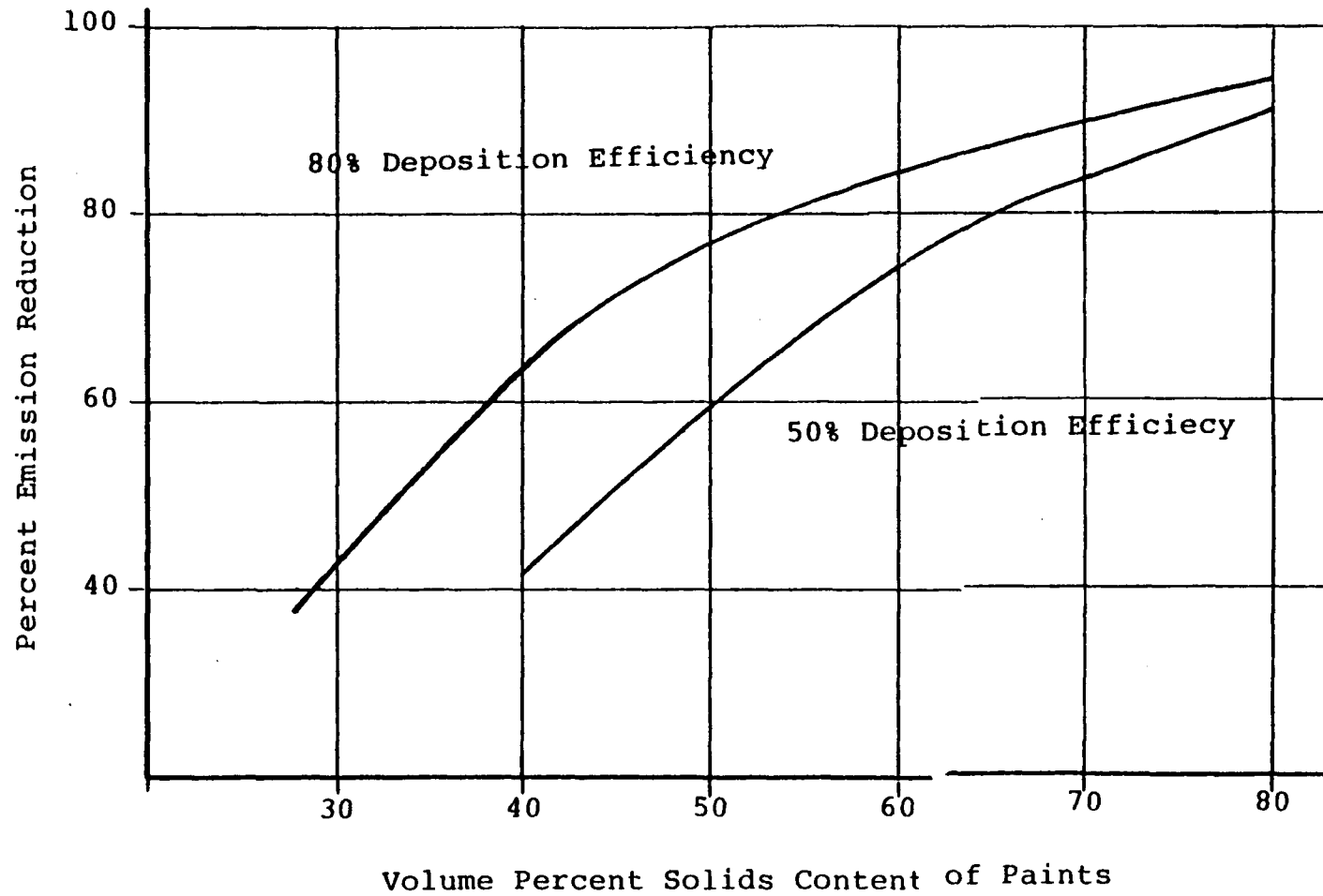
4.2.6. Higher Solids Coatings

To determine the emission reduction potential associated with higher solids coatings, the RSE of various solids content paints in the range of 30 to 80 volume percent were compared against the RSE organic solvent-borne paint with 28 volume percent solids. In preparing these estimates, the deposition or transfer efficiency was also taken into consideration. Application by air spray (50 percent deposition) and electrostatic spray (80 percent deposition) was compared against application of conventional solvent-borne paints with air spray.

Figure 4-11 shows that if 28 volume percent solvent-borne coatings were replaced by higher solids coatings of 60 volume percent solids, then an emission reduction of 74 to 84 percent would be possible.

If the same 28 volume percent paint were replaced by an 80 volume percent solids high solids coating then there would be an emission reduction of greater than 90 percent.

Figure 4-11. EMISSION REDUCTION POTENTIAL (PERCENT) WITH USE OF
HIGHER SOLIDS COATINGS IN PLACE OF 28 VOLUME PERCENT SOLVENT-BORNE PAINT
(50 PERCENT DEPOSITION EFFICIENCY)



4.2.7. Incineration

Incineration is currently being used to control solvent emissions in such finishing industries as paper¹⁴⁸, fabric¹⁷⁴, wire^{175, 176}, can^{149,177}, coil^{150,151} coating, and auto finishing^{145,146}. Field investigations indicate that incineration, both thermal and catalytic, is capable of removing at least 90 percent of the solvents from exhaust air streams^{142,146,175,176,178,179,180}.

4.2.8. Carbon Adsorption

Carbon adsorption is being used successfully in the paper^{169,170,171} and fabric¹⁷² industries for controlling solvent emissions, and has been evaluated on a pilot scale in the automobile industry where it is acknowledged to be capable of 85 percent or greater emission reduction when used for solvent emissions from spray booths^{181,182,183}.

4.3. REFERENCES

1. Pegg, F.E. Applying Plastic Coatings With The Fluidized Bed Process. *Plastics Design and Processing*. 10(9):38, September 1970
2. Levinson, S.B. Powder Coat. *Journal of Paint Technology*. 44(570):52, July 1972.
3. Poll, G.H., Jr. High-Production Acrylic Powder Coating. *Products Finishing* 38(12):46-52, September 1974.
4. Iverson Powder Coats Bicycles in 20 Colors. *Industrial Finishing*. 50(9):58-63, September 1974.
5. Cole, E.N. Coatings and Automobile Industries Have Common Interest. *American Paint and Coatings Journal*. 58(51):60, June 3, 1974.
6. Gabris, T. Trip Report-Ford Motor Company, Metuchen Plant. Springborn Laboratories (formerly DeBell & Richardson) Enfield, Connecticut. Trip Report 38, January 23, 1976.
7. Mazia, J. Technical Developments in 1976. *Metal Finishing*. 75(2):75, February 1977.
8. Schrantz, J. Powder Coatings Brings Advantages to Baldwin. *Industrial Finishing*. 52(9):58-61, September 1976.
9. Automotive Powder Under the Hood. *Products Finishing*. 41(2):56-57, November 1976.
10. Cehanowicz, L. The Switch is on for Powder Coatings. *Plastics Engineering*. 31(9):29, September 1975.
11. Robinson, G.T. Powder Coating Trailer Hitches. *Products Finishing*. 38(9):76, June 1974.
12. How Nylon Powder Coatings Help. *Products Finishing*. 38(7):81, April 1974.
13. Cole, G.E. The Powder Coatings Market. Preprints, NPCA Chemical Coatings Conference, Powder Coating Session. April 22, 1976.
14. Cole, C.E. Thermoset Powders: The Materials, Markets and Applications. *Products Finishing*. 42(3):81, December 1975.
15. Maybe Its Not Goodbye Paint, But It's Certainly Hello Powder Coating. *Modern Plastics*, 49(5):49, May 1972.
16. Powder Coating Seating Scores At Iowa State's New Stadium. *Powder Finishing World*. 2(3):50-52, 3rd Quarter 1975.
17. Hospital Beds Protected By Nylon II Powder Coating. *Powder Finishing World*. 2(2):28, 2nd Quarter 1975.

18. Oge, M.T. Trip Report-Bunting Company, Philadelphia, Pennsylvania. Springborn Laboratories (formerly DeBell & Richardson), Enfield, Connecticut. Trip Report 86, March 8, 1976.
19. Obrzut, J.J. Powder Coating: 'A Finisher's Finish'. Iron Age. November 16, 1972.
20. Oge, M.T. Trip Report-Goodman Brothers Manufacturing Company, Philadelphia, Pennsylvania. Springborn Laboratories (formerly DeBell & Richardson), Enfield, Connecticut. Trip Report 85, March 8, 1976.
21. Oge, M.T. Trip Report-Steelcase Company, Grand Rapids, Michigan. Springborn Laboratories (formerly DeBell & Richardson), Enfield, Connecticut. Trip Report 72, February 24, 1976.
22. Fisher, J.R. Trip Report-Virco Manufacturing Corporation, Gardena, California. Springborn Laboratories (formerly DeBell & Richardson), Enfield, Connecticut. Trip Report 57, February 11, 1976.
23. Schrantz, J. High-Production System Powder Coats Structural Steel Tubing. Industrial Finishing 53(4):52-60, April 1977.
24. Poll, G.H. Powder Coating Over One Million Square Feet Per Month. Products Finishing. 40(3):58-65, December 1975.
25. Cehanowicz, L. The Switch Is On For Powder Coating. Plastics Engineering. 31(9):29, September 1975.
26. Schrantz, J. Automatic Powder Systems Coat Lawn Furniture. Industrial Finishing. 51(4):32-38, April 1975.
27. Powder Coating Systems-Why One Manufacturer Switched. Furniture Design and Manufacturing. 45(9):100 and 126.
28. Oge, M.T. Trip Report-Herman Miller Incorporated, Zeeland, Michigan. Springborn Laboratories (formerly DeBell & Richardson), Enfield, Connecticut, Trip Report 100, April 2, 1976.
29. Realizing Objectives With a Powder System. Powder Finishing World. 3(4):24-25, 4th Quarter 1976.
30. Powder Finishing World. 1(1):42, September 1974.
31. Powder System Cuts Finishing Costs At Westinghouse. Powder Finishing World. 2(3):20-21, 3rd Quarter 1975.
32. Poll, G.H. Super-Durable Exterior Powder Coatings. Products Finishing. 39(6):62-63.
33. Overbed Table Incorporates Powder Coated Handle. Powder Finishing World. 2(4):25, 4th Quarter 1975.

34. Conte, A.A., Jr. Painting with Polymers. Chemtech. 4(2):99-103, February 1974.
35. Miller, E.P. and D.D. Taft. Fundamentals of Powder Coating. Dearborn, Society of Manufacturing Engineers, 1974. 17-21.
36. Miller, E.P. and D.D. Taft. Fundamentals of Powder Coating. Dearborn, Society of Manufacturing Engineers, 1974. 22-23 and 31-32.
37. Levinson, S.B. Powder Coat. Journal of Paint Technology. 44(570):42, July 1972.
38. Why Powder Coat? Technical Bulletin Number 1. Interrad Corporation; Stamford, Connecticut.
39. Miller, E.P. and D.D. Taft. Fundamentals of Powder Coating. Dearborn, Society of Manufacturing Engineers, 1974. 26.
40. Automatic Powder Coating System Design. Technical Bulletin 2. Interrad Corporation; Stamford, Connecticut.
41. Levinson, S.B., Powder Coat. Journal of Paint Technology. 44(570):44, July 1972.
42. Conte, A.A., Jr. Painting with Polymer Powders. Chemtech. 4(2):101, February 1974.
43. Electrostatic Powder Spraying Equipment. Bulletin E 106. Electro-ion Inc., Farmington, Michigan.
44. Finish for the Future with Nordson Electrostatic Powder Spray Systems. Product Bulletin 306-18-70. Nordson Corporation: Amherst, Ohio.
45. Gema Model 721-V. Data Sheet 125. Interrad Corporation; Stamford, Connecticut.
46. Interrad/Gema 730 Automatic. Data Sheet 128. Interrad Corporation; Stamford, Connecticut.
47. Miller, E.P. and D.D. Taft. Fundamentals of Powder Coating. Dearborn, Society of Manufacturing Engineers, 1974. 24.
48. Pegg, F.E. Applying Plastic Coatings with the Fluidized Bed Process. Plastics Design and Processing. 10(9):41, September 1970.
49. Levinson, S.B. Powder Coat. Journal of Paint Technology. 44(570):38, July 1972.
50. Miller, E.P. and D.D. Taft. Fundamentals of Powder Coating. Dearborn, Society of Manufacturing Engineers, 1974. 11.
51. Thompson, M.S. Trip Report - U.S. Furnitures Industries, Blacksmith Shop Division, Highpoint, North Carolina, Springborn Laboratories (formerly DeBell & Richardson, Inc.) Enfield, Connecticut. Trip Report-108, April 6, 1976.

52. Pegg, F.E. Applying Plastic Coatings with the Fluidized Bed Process. *Plastics Design and Processing*. 10(10):23, October 1970.
53. Pegg, F.E. Applying Plastic Coatings with the Fluidized Bed Process. *Plastics Design and Processing*. 10(10):24, October 1970.
54. Henning, C.C. and M.J. Krupp. Compelling Reasons for the Use of Water Reducible Industrial Coatings. SME Technical Paper. FC74-639:306,1974.
55. Holley, William H. Springborn Laboratories, Enfield, Connecticut. Memo to Robert Diehl, Springborn Laboratories, covering phone call to Walter Kurnik, Ashland Chemical, Columbus, Ohio, August 24, 1977.
56. Holley, William H. Springborn Laboratories, Enfield, Connecticut. Memo to Robert Diehl, Springborn Laboratories, covering phone conversation with John Dunham, Hanna Chemical Coatings, Columbus, Ohio, August 25, 1977.
57. Jones, F.N. What Properties Can You Expect from Aqueous Solution Coatings. SME Technical Paper, FC74-641:3-4, 1974.
58. Paolini, A. and M.A. Glazer. Water Borne Coatings, A Pollution Solution. Preprints for ACS Division of Environmental Chemistry, 98, Fall 1976.
59. Prane, J.W. Water-Borne Coating Usage—Current and Future. Preprints, NPCA Chemical Coatings Conference, Water-Borne Session. 3, April 23, 1976.
60. Binks Electrocoating Installations. Supplier Bulletin from Binks Manufacturing Company; Livonia, Michigan.
61. Oge,M.T. Trip Report-Angel Steel Company, Plainwell, Michigan, Springborn Laboratories (formerly DeBell & Richardson), Enfield, Connecticut. Trip Report 103, April 5, 1976.
62. One-Coat Finish for Supermarket Shelving by Electrocoat, Product Bulletin F-46, George Koch Sons, Inc. Evansville, Indiana.
63. Electrocoating Twins Offer Two Colors,Product Bulletin F-38, George Koch Sons, Inc. Evansville, Indiana.
64. Soft Water Rinse Cuts EDP Costs at Equipto, Product Bulletin F-43, George Koch Sons, Inc. Evansville, Indiana.
65. Holley, William H. Springborn Laboratories,, Enfield, Connecticut. Memo to Robert Diehl, Springborn Laboratories covering phone conversation with Bob Kirkpatrick, Lilly Industrial Coatings, Indianapolis, Indiana, August 26, 1977.
66. Holley, William H. Springborn Laboratories, Inc. Enfield, Connecticut. Memo to Robert Diehl, Springborn Laboratories, covering phone conversation with Howard Smith, Lilly Industrial Coatings, Templeton, Massachusetts, August 24, 1977.

67. Schrantz, J. UF Benefits Conveyorized, Batch-Type EDP Systems. Industrial Finishing. 48(11):26, November 1972.
68. Schrantz, J. Water-Borne Coating Applied Electrostatically. Industrial Finishing, 52(8):24, August 1976.
69. Holley, William H. Springborn Laboratories, Inc. Enfield, Connecticut. Memo to Robert Diehl, Springborn Laboratories covering phone conversation with L. LeBras, PPG Industries, Inc. Pittsburgh, Pennsylvania, August 25, 1977.
70. Levinson, S.B. Electrocoat. Journal of Paint Technology. 44(569):40-49, June 1972.
71. Electrocoat System Speeds Truck and Tractor Seat Painting. Products Finishing. May 1969.
72. Anderson, J.E. Electrocoating Aluminum Extrusions. Products Finishing. September 1967.
73. Schrantz, J. How Ultrafiltration Benefits Equipto. Industrial Finishing. 48(9):28-32, September 1972.
74. Ultrafiltration Systems for Electrocoating. Product Bulletin F-46163. Union Carbide, Membrane Systems Division, Tarrytown, New York.
75. Binks Electrocoating, The Process and Uses. Catalog BE-1. Binks Manufacturing Company; Livonia, Michigan.
76. Primer Electrodeposition at GM South Gate Plant. Products Finishing. March 1968.
77. Brumbaugh, G.E. Preparation of Metal Surfaces for Water-Borne Industrial Finishes. SME Technical Paper. FC75-556:1, 1975.
78. Kuehner, M.A. Pretreatment for Water-Borne Coatings. Metal Finishing 75(4):36, April 1977.
79. Loop, F.M. Automotive Electrocoat. Preprints, NPCA Chemical Coatings Conference, Electrocoating Session. 67-68, April 22, 1976.
80. Water-Borne Coating Applied by Automatic, Electrostatic, Heated, Airless Spray System. Industrial Finishing. 53(8)22, August 1977.
81. Gabris, T. Trip Report - General Motors, South Gate Plant. Springborn Laboratories (formerly DeBell & Richardson), Enfield Connecticut. Trip Report 102, April 5, 1976.
82. Gabris, T. Trip Report - General Motors, Van Nuys Plant. Springborn Laboratories (formerly DeBell & Richardson), Enfield, Connecticut. Trip Report 110, April 6, 1976.

83. Gabris, T. Trip Report - Ford Motor Company Plant, Oakville, Ontario. Springborn Laboratories (formerly DeBell & Richardson), Enfield, Connecticut. Trip Report 56, February 10, 1976.
84. Schrantz, J. Water-Reducible Electrostatic Spray Brings Cost Reduction. Industrial Finishing. 50(7):26, July 1974.
85. Electric Wheel Converts to Water-Borne Alkyd Enamel. Industrial Finishing. 52(12):50, December 1976.
86. Schrantz, J. Truck Wheels Get Water-Base Aluminum-Colored Coating. Industrial Finishing. 50(10):44, October 1974.
87. Thompson, M.S. Trip Report - J.I. Case Division, Tenneco, Racine, Wisconsin. Springborn Laboratories (formerly DeBell & Richardson) Enfield, Connecticut. Trip Report 98, April 2, 1976.
88. Strand, R.C. Water-Borne Coatings In Metal Packaging. Preprints, NPCA Chemical Coatings Conference, Water-Borne Session, 17-42, April 23, 1976.
89. Kloppenburg, W.B. Trip Report-Control Data Corp., Arden Hill, Minnesota. Springborn Laboratories (formerly DeBell & Richardson) Enfield, Connecticut. Trip Report 136, May 26, 1976.
90. Vierling, E.J. Conversion to Water-Reducible Paint. Preprints, NPCA Chemical Coatings Conference, Water-Borne Session, 51-61, April 23, 1976.
91. Heffron, W.H. Conversion To Water-Borne Coatings At Pitney-Bowes. Preprint NPCA Chemical Coatings Conference, Water-Borne Session, 63-69, April 23, 1976.
92. Kloppenburg, W.B. Trip Report - Singer Company, Auburn, New York. Springborn Laboratories (formerly DeBell & Richardson) Enfield, Connecticut. Trip Report 144, July 21, 1976.
93. Consdorf, A.P. Which Way Will You Go On Finishing? Appliance Manufacturer. 25(6):43-49, April 1977.
94. Holley, William, H. Springborn Laboratories, Inc., Enfield, Connecticut. Memo to Robert Diehl covering phone conversation with J.J. Bracco, Mobay Chemical Company, August 23, 1977.
95. Holley, William H. Springborn Laboratories, Inc., Enfield, Connecticut. Memo to Robert Diehl Springborn Laboratories covering phone conversation with L. LeBras, PPG Industries, Inc. August 24, 1977.
96. The Latest in Water-Borne Coatings Technology. Industrial Finishing. 51(9):48, September 1975.

97. Waste Disposal from Paint Systems Discussed at Detroit Meeting. American Paint and Coatings Journal. 60(37):35-36, February 23, 1976.
98. Water-Borne Coating Systems Are Maturing. Industrial Finishing. 53(5):41.
99. Oge, M.T. Trip Report-Schwinn Bicycle Company, Chicago, Illinois. Springborn Laboratories, (formerly DeBell & Richardson), Enfield, Connecticut. Trip Report 97. April 2, 1976.
100. Gabris, T. Trip Report-Chrysler Corporation, Belvidere Plant. Springborn Laboratories (formerly DeBell & Richardson), Enfield Connecticut. Trip Report 14. January 5, 1976.
101. Gabris, T. Trip Report - Chrysler Corporation, Lynch Road Assembly Plant. Springborn Laboratories (formerly DeBell & Richardson), Enfield, Connecticut. Trip Report 8. December 30, 1975.
102. Levinson, S.B. Radiate. Journal of Paint Technology. 44(571):32-36, August 1972.
103. North, A.G. Progress in Radiation Cured Coatings. Pigment and Resin Technology. 3(2):3-11, February 1974.
104. Nickerson, R.S. The State of the Art in UV Coating. Industrial Finishing, 50(2):10-14, February 1974.
105. Rule 66, Organic Solvents. Los Angeles, California. Air Pollution Control District, County of Los Angeles. July 28, 1966. Amendments of November 2, 1972, and August 31, 1974.
106. Young, R.G. and W.R. Howell. Epoxies Offer Fulfillment of High Performance Needs. Modern Paint and Coatings. 65(3):43-47, March 1975.
107. Lunde, D.I. Acrylic Resins Defy Conventional Relationships in New Technology Coatings. Modern Paint and Coatings. 66(3):51-53, March 1976.
108. Mercurio, A. and S.N. Lewis. High Solids Coatings for Low Emission Industrial Finishing. Journal of Paint Technology. 47(607):37-44, August 1975.
109. Baker, R.D. and J.J. Bracco. Two-Component Urethanes: Higher Solids Systems at Lower Cure Temperatures. Modern Paint and Coatings. 66(3):43-48, March 1976.
110. Larson, J.M. and D.E. Tweet. Alkyds and Polyesters Readied for Marky Entry. Modern Paint and Coatings. 65(3):31-34, March 1975.
111. Mantell, C.L. Adsorption. New York. McGraw-Hill, 1951. 237-248.
112. Kanter, C.V., et al. Control of Organic Emissions from Surface Coating Operations. Proceedings of the 52nd APCA Annual Meeting, June 1959.

113. Elliott, J.H., N. Kayne, and M.F. Leduc. Experimental Program for the Control of Organic Emissions from Protective Coating Operations. Report No. 7. Los Angeles APCD, 1961.
114. Lud, H.F. Industrial Pollution Control Handbook. New York. McGraw-Hill, 1971. 13-13 and 19-10.
115. Mantel, C.L. Adsorption. New York. McGraw-Hill, 1951. 9-10.
116. Danielson, J.A. Air Pollution Engineering Manual. Cincinnati, Ohio. Public Health Service Publication 999-AP-40, 1967. 196.
117. Mantell, C.L. Adsorption. New York. McGraw-Hill. 1951. 232.
118. Larson, E.C. and H.E. Sipple. Los Angeles Rule 66 and Exempt Solvents. Journal of Paint Technology. 39(508):258-264, May 1967.
119. Ellis, W.H., et al. Formulation of Exempt Replacements for Aromatic Solvents. Journal of Paint Technology. 41(531):249-258, April 1969.
120. Mattia, M.M. Process for Solvent Pollution Control. Chemical Engineering Progress. 66(12):74-79, 1970.
121. Grant, R.M., M.Manes, and S.B. Smith. Adsorption of Normal Paraffins and Sulfur Compounds on Activated Carbon. AIChE Journal. 8(3):403,1962.
122. Robell, A.J., E.V. Ballow, and F.G. Borgardt. Basic Studies of Gas-Solid Interactions. Lockheed Missiles and Space Company. Report 6-75-65-22, 1965.
123. Cavanaugh, E.C., G.M. Clancy, and R.G. Wetherold. Evaluation of a Carbon Adsorption/Incineration Control System for Auto Assembly Plants. Radian Corporation; Austin, Texas. EPA Contract 68-02-1319, Task 46. May, 1976, 26.
124. Cavanaugh, E.C., G.M. Clancy, and R.G. Wetherold. Evaluation of a Carbon Adsorption/Incineration Control System for Auto Assembly Plants. Radian Corporation; Austin, Texas. EPA Contract 68-02-1319, Task 46. May 1976. 27.
125. Grandjacques, B. Air Pollution Control and Energy Savings with Carbon Adsorption Systems. Calgon Corporation Report APC 12-A, July 19, 1975.
126. Lee, D.R. Activated Charcoal in Air Pollution Control. Heating, Piping and Air Conditioning. 76-79, April 1970.
127. Lund, H.F. Industrial Pollution Control Handbook. New York. McGraw-Hill, 1971, 5-20.
128. Cavanaugh, E.C., G.M. Clancy, and R.G. Wetherold. Evaluation of a Carbon Adsorption/Incineration Control System for Auto Assembly Plants. Radian Corporation; Austin, Texas. EPA Contract 68-02-1319, Task 46. May 1976. 28-29.

129. Package Sorption Device Systems Study. MSA Research Corporation; Evans City, Pennsylvania. EPA-R2-73-202. April 1973.
130. Lund, H.F. Industrial Pollution Control Handbook. New York. McGraw-Hill, 1971, 5-21.
131. Cavanaugh, E.C., G.M. Clancy, and R.G. Wetherold. Evaluation of a Carbon Adsorption/Incineration Control System for Auto Assembly Plants. Radian Corporation; Austin, Texas. EPA Contract 68-02-1319, Task 46. May 1976. 32.
132. Sussman, Victor H. Ford Motor Company, Dearborn, Michigan. Letter to R.G. Wetherold, Radian Corporation, dated March 15, 1976.
133. Handbook of Chemistry and Physics. Weast, R.C. (ed.) Cleveland, The Chemical Rubber Company. 1964. E-26.
134. Roberts, R.E. and J.B. Roberts. An Engineering Approach to Emission Reduction in Automotive Spray Painting. Proceedings of the 57th APCA Annual Meeting. 26(4):353, June 1974.
135. Stern, A.C. Air Pollution. New York. Academic Press. Volume II, Second Edition, Chapter 16, 1968.
136. Lund, H.F. Industrial Pollution Control Handbook. New York. McGraw-Hill, 1971, 5-27 to 5-32.
137. Conversation between Fred Porter, Ford Motor Company, Dearborn, Michigan, and EPA-CTO, Research Triangle Park, North Carolina.
138. Stern, A.C. Air Pollution; Vol. III, Sources of Air Pollution and Their Control. New York. Academic Press, 1968.
139. Benforado, D.M. Air Pollution Control by Direct Flame Incineration in The Paint Industry. Jurnal of Paint Technology. 39(508):265, May 1967.
140. Lund, H.F. Industrial Pollution Control Handbook. New York. McGraw-Hill, 1971, 7-8, to 7-11.
141. Heat Recovery Combined with Oven Exhaust Incineration. Industrial Finishing. 52(6):26-27.
142. Re-Therm Thermal Oxidation Equipment. Product Bulletin REE-1051-975-15M. Reeco Regenerative Environmental Equipment Company, Inc., Morris Plains, New Jersey.
143. Young, R.A. Heat Recovery: Pays for Air Incineration and Process Drying. Pollution Engineering. 7(9):60-61, September 1975.
144. Can Ceramic Heat Wheels Do Industry a Turn? Process Engineering. 42-43, August 1975.

145. Gabris, T. Trip Report - Ford Motor Company, Truck Plant, Milpitas, California. Springborn Laboratories (formerly DeBell & Richardson) Enfield, Connecticut. Trip Report 120. April 8, 1976.
146. Gabris, T. Trip Report - Ford Motor Company, Auto Plant, Milpitas, California. Springborn Laboratories (formerly DeBell & Richardson), Enfield, Connecticut. Trip Report 112. April 7, 1976.
147. Atherton, R.B. Trip Report - Automobile Manufacturers in Detroit, Michigan: Dearborn and Wayne, Michigan. EPA, Industry Survey Section, Research Triangle Park, North Carolina. April 16, 1973.
148. Oge, M.T. Trip Report - Hazen Paper Company; Holyoke, Massachusetts. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.) Enfield, Connecticut. Trip Report 134. May 19, 1976.
149. Gabris, T. Trip Report National Can Corporation; Danbury, Connecticut. Springborn Laboratories, Inc. (formerly DeBell & Richardson) Enfield, Connecticut. Trip Report 128. April 27, 1976.
150. Gabris, T. Trip Report Roll Coater, Inc., Kingsbury, Indiana. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Trip Report 76. February 26, 1976.
151. Gabris, T. Trip Report - Litho-Strip Company, South Kilburn, Illinois. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Trip Report 35. January 22, 1976.
152. Danielson, J.A. Air Pollution Engineering Manual. Cincinnati, Ohio. Public Health Service Publication 999-AP-40, 1967. 178-184.
153. Kent, R.W. Thermal Versus Catalytic Incineration. Products Finishing. 40(2):83-85, November 1975.
154. Fuel Requirements, Capital Cost and Operating Expense for Catalytic and Thermal Afterburners. Combustion Engineering, Air Preheater Division, Wellsville, New York. EPA Contract 68-02-1473, Task 13.
155. Prane, J.W. Nonpolluting Coatings and Energy Conservation. ACS Coatings and Plastics Preprints. 34(1):14, April 1974.
156. Koch, R.R. Electrocoating Materials Today and Tomorrow. SME Technical Paper. FC75-563:4, 1975.
157. Blatt, W.F. Hollow Fibers: A Transition Point in Membrane Technology. American Laboratory. 78, October 1972.
158. Mahon, H.I. and B.J. Lipps. Hollow Fiber Membranes In: Encyclopedia of Polymer Science and Technology. New York. John Wiley and Sons, 1971, 269.

159. Loop, F.M. Automotive Electrocoat. Preprints, NPCA Chemical Coatings Conference, Electrocoat Session. 81, April 22, 1976.
160. Holley, William H., Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Memo to Robert Diehl, Springborn Laboratories, covering phone conversation with J.A. Scharfenberger, Ransburg Corporation, Indianapolis, Indiana, August 29, 1977.
161. Sames Discatron PPH 405, Technical Leaflet PPH 405, Interrad Corporation, Stamford, Connecticut, February 1977.
162. Price, M.B. High Solids Coatings - Where Can They Be Used. Preprints, NPCA Chemical Coatings Conference, High Solids Session. 37, April 22, 1976.
163. Mazia, J. Technical Developments in 1976. Metal Finishing. 75(2):74-75, February 1977.
164. Scharfenberger, J.A. New High Solids Coating Equipment Offers Ecology/Energy Advantages. Modern Plastics. 53(2):52-53, February 1976.
165. LeBras, L.R. - PPG Industries Inc., Pittsburgh, Pennsylvania. Letter to W.H. Holley, Springborn Laboratories, Inc. (formerly DeBell & Richardson), dated September 16, 1977.
166. Oge, M.T. - Trip Report - Simmons Company, Munster, Indiana. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Trip Report 41. January 28, 1976.
167. Holley, William H. - Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Memo to Robert Diehl, Springborn Laboratories, Inc., covering phone conversation with George Wilhelm, Ashland Chemical Company, Columbus Ohio, August 24, 1977.
168. Holley, W.H. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Memo to Robert Diehl, Springborn Laboratories, covering phone conversation with Russell Craig, Rohm and Haas, Philadelphia, Pennsylvania, August 1977.
169. Oge, M.T. Trip Report - Fasson Company, Painesville, Ohio. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Trip Report 141. July 21, 1976.
170. Oge, M.T. Trip Report - Brown-Bridge Mills, Troy, Ohio. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Trip Report 140. July 20, 1976.
171. Solvent Recovery Installations. Supplier Bulletin. Vulcan-Cincinnati, Inc., Cincinnati, Ohio.

172. McCarthy, R.A. Trip Report - Raybestos-Manhattan, Inc., Mannheim, Pennsylvania. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Trip Report 77. February 26, 1976.
173. Gabris, T. Trip Report - American Can Company, Lemoyne, Pennsylvania. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Trip Report 89. March 11, 1976.
174. McCarthy, R.A. Trip Report - DuPont Corporation, Fabric and Finishes Department; Fairfield, Connecticut. Trip Report 130. April 30, 1976.
175. Kloppenburg, W.B. Trip Report - Phelps Dodge Magnet Wire; Fort Wayne, Indiana. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Trip Report 113. April 7, 1976.
176. Kloppenburg, W.B. Trip Report - General Electric Company; Schenectady, New York. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Trip Report 106. April 6, 1976.
177. Gabris, T. Trip Report - Continental Can Company, Inc.; Portage, Indiana. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Trip Report 80. March 3, 1976.
178. Fisher, J.R. Trip Report - Supracote, Inc., Cucamonga, California. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Trip Report 31. January 16, 1976.
179. Gabris, T. Trip Report - American Can Company, Plant 025, Edison, New Jersey. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Trip Report 6. December 29, 1975.
180. Kloppenburg, W.B. Trip Report - Chicago Magnet Wire, Elks Grove Village, Illinois. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Trip Report 124. April 9, 1976.
181. Sussman, Victor H. Ford Motor Company; Dearborn, Michigan. Letter to James McCarthy, EPA-CTO, August 6, 1976.
182. Cavanaugh, E.C., G.M. Clancy, and R.G. Wetherold. Evaluation of a Carbon Adsorption/Incineration Control System for Auto Assembly Plants. Radian Corporation; Austin, Texas. EPA Contract 68-02-1319, Task 46, May 1976.
183. Johnson, W.R. General Motors Corporation; Warren, Michigan. Letter to Radian Corporation commenting on Reference 182; letter dated March 12, 1976.

184. Holley, William H. - Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.). Enfield Connecticut. Memo to Robert Diehl, Springborn Laboratories, Inc., covering telephone conversations with Jim Pfeifer, Pratt and Lambert, Buffalo, New York and Tim Birdsall, Warsaw Indiana. October 18, 1977.
185. Miller, E.P. and Taft, D. D. Fundamentals of Powder Coating. Dearborn, Society of Manufacturing Engineers, 1974. p 95.
186. Holley, William H. - Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.). Enfield, Connecticut. Memo to Robert Diehl, Springborn Laboratories, Covering conversation with Richard Hammel. Interrad Corporation. Stamford Connecticut. November 1, 1977.
187. Switching to a Water-Borne Flow Coat System. Finishing Highlights. p 16-19, March/April 1976.
188. Flow Coating Water Base Paint. Data Sheet F-52. George Koch Sons, Inc. Evansville, Indiana.
189. Oscicator Flow Coating System. Data Sheet F-27. George Koch Sons, Inc. Evansville, Indiana.
190. Flow-Coating Process of Paint Application. Data Sheet F-24. George Koch Sons, Inc. Evansville, Indiana.
191. Brewer, G.E.F. Painting Waste Loads Associated with Metal Finishing. Journal of Coatings Technology. 49(625) : 50, February 1977.
192. Automatic Air Electrostatic Gun For Applying Water-Borne Coatings—Without System Isolation. Products Finishing. 39(11): 98, August 1975.
193. Gabris, T. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Enfield, Connecticut. Memo to Robert Diehl, Springborn Laboratories covering phone conversation with Fred Henning, Amchem Products, Inc. November 15, 1977.

5. MODIFICATION AND RECONSTRUCTION

Proposed standards apply to all affected facilities constructed or modified after the date of proposal of the proposed standards. Provisions applying to modification and reconstruction were originally published in the Federal Register on December 23, 1971. Clarifying amendments were proposed in the Federal Register on October 15, 1974 (39 FR 36946), and final regulations were promulgated in the Federal Register on December 16, 1975 (40 FR 58416).

Modification is defined as "any physical change in, or change in the method of operation of, an existing facility which increases the amount of any air pollutant (to which a standard applies) emitted into the atmosphere by that facility or which results in the emission of any air pollutant (to which a standard applies) into the atmosphere not previously emitted". Reconstruction occurs when components of an existing facility are replaced to such an extent that:

- (1) The fixed capital cost of the new components exceeds 50 percent of the fixed capital cost that would be required to construct a comparable entirely new facility, and
- (2) It is technologically and economically feasible to meet the applicable standards.

There are certain circumstances under which an increase in emissions does not result in a modification. If a capital expenditure that is less than the most recent annual asset guideline repair allowance published by the Internal Revenue Service (Publication 534) is made to increase capacity at an existing facility and also results in an increase in emissions to the atmosphere of a regulated pollutant, a modification is not considered to have occurred.

An increase in working hours - i.e., from one to two-shift operation - or an extension from 8 hours to 10 hours per shift would also increase solvent emissions per day. This situation, however, is also not considered a modification under the definitions set forth in 40 FR 58416, December 16, 1975.

The purpose of this chapter is to identify potential modifications and reconstructions of affected facilities, and any exemptions or special allowances covering changes in existing facilities that should be considered. Exemptions from the regulations may be based on availability of technology and economic considerations.

As will be seen, many of the possible changes do not qualify as modifications by strict definition. They are, however, potential causes of increased solvent emission and as such should be discussed.

5.1. POTENTIAL MODIFICATIONS

The following changes in materials or formulations could cause increased solvent emissions but would qualify primarily as alternate raw materials, not as modifications, under the above definition unless capital expenditures are required to effect the change so as to qualify as a reconstruction.

(1) Lower Solids Coatings

If a change is made from a higher solids to a lower solids coating—e.g., from an enamel to a lacquer—more material, hence more solvent, will be used to maintain the same dry coating thickness. While a change in the direction of lower solids is unlikely, it could occur in any one plant as a result of changing paint systems or colors. It is unlikely, however, that any major capital expenditures to equipment would be required.

(2) Use of Higher Density Solvent

Regulations normally restrict the number of pounds of solvent which can be emitted. A change in the density of the solvents used, even if the volumetric amounts used were the same, would result in more pounds or kilograms being emitted. Again, this could be construed as a raw-material substitution and hence not a modification, as no major capital expenditures would be involved. Such substitutions might come about as a result of solvent shortages, attempts to cut paint costs, or efforts to incorporate less photoreactive solvents.

(3) Increased Thinning of Coatings

A change to a higher viscosity coating could result in an increased use of solvents for thinning the coating to proper application consistency.

While these three cases can be considered as raw material substitutions, they are not of themselves considered to be modifications. The phrase "bubble concept" has been used in Title 40 FR 58416, to refer to a trade-off of emission increases from one facility undergoing a physical or operational change with emission reductions from another facility in order to achieve no net increase in the amount of any air pollutant (to which a standard applies) emitted into the atmosphere by the stationary source as a whole.

Title 40 FR 58416 states: "In those cases where utilization of the exemptions under Paragraph 60.14 (e) (2), (3), or (4) as promulgated herein would effectively negate the compliance measures originally adopted, use of those exemptions will not be permitted."

Other changes that could be made that could result in increased solvent emission include:

(4) Change to Larger Parts

If part sizes were increased and the same production rates were maintained, more coating materials would be used. With the diversity of products produced by the metal furniture industry, it is somewhat difficult to see why this could occur unless a manufacturer began production of large parts such as desks or panels that he had not produced before.

Coating lines in this industry, however, are generally equipped to handle many size parts hence such a change would not qualify as a modification per se. If extensive capital expenditures were involved, such a change could be classified as a reconstruction.

(5) Change to Thicker Coatings

A change to a thicker coating, other factors remaining constant, could result in increased solvent emission. Such a change could result from a desire to increase durability or resistance to outdoor exposure. Most metal furniture manufacturers, especially of office furniture, apply as thin a coating as possible, however.¹

(6) Reduced Deposition Efficiency

Increased overspray because of a process modification such as a switch from electrostatic spray to conventional spray would result in increased emission. For economic reasons if for nothing else, however, a switch in such a direction is unlikely except possibly as a temporary measure.

(7) Additional Coating Stations

If for any reason additional coating stations were added, emissions would be increased. It is possible that new paint systems could result in such a change. This could involve a reconstruction or a new facility and, as such, would be subject to regulation.

(8) Substitution of Equipment

There can be cases where in existing sources, coating line configurations are of a temporary nature to perform a custom coating job. Certain custom coaters in the metal furniture industry perform metal coating services only. These services are offered to metal furniture manufacturers on a contract basis. In the course of this type of business, the coating line configuration may be changed to meet requirements of a specific job. For example, existing line components such as spray booths and dip tanks may be interchanged to accomodate different jobs. As another example, existing ovens may be lengthened or shortened for each job. The aforementioned changes will not be considered to constitute a modification. It is the intent to allow the custom coater to make changes of this nature for short-term contract business without invoking compliance with new source performance standards.

Installation of a line or affected facility previously used at another plant site, however, will require compliance with new source performance standards.

5.2. RECONSTRUCTION

Spray booths and bake ovens used in coating metal furniture last ten to twenty years² and are not replaced before that time unless process changes dictate it. In some cases a line may be moved to another location within the plant and booths or ovens may fall apart necessitating some rebuilding.

Reconstructions would include replacement of spray booths either because of deterioration or because of more advanced design such as the addition of more automatic spraying or electrostatic spraying, if not already being used.

A line could be made longer or faster to permit increased production. This would be considered a reconstruction as long as the requirements outlined in the beginning of this chapter are met.

Ovens could be replaced with more efficient models or to accomodate new energy sources such as electricity.

Changing coating application methods such as from dip coating to electrostatic spray would qualify as a reconstruction, again if requirements were met.

It should be noted that according to 40 FR 58416 that an existing facility, upon reconstruction becomes an affected facility and hence subject to regulation irrespective of any change in emission rate.

It should also be noted that according to 40 FR 58416, Part 60, the decision as to whether a reconstructed facility can meet applicable standards both technologically and economically rests with the EPA Administrator. For example, if the equipment being replaced does not emit air pollutants, it may be determined that controlling the components that do emit air pollutants is not reasonable considering cost, and standards of performance for new sources should not be applied. As another example, if there is insufficient space after the replacements at an existing facility to install the necessary air pollution control system to comply with standards of performance, then reconstruction would not be determined to have occurred.

5.3. CONSTRAINTS

Probably the greatest physical constraint to switching to new coating systems with lower solvent emissions in existing facilities is the added space requirements of some of the systems. The seriousness of this constraint will, of course, vary from line to line or plant to plant. Plants with very tight space requirements might find it difficult to fit in the longer oven and flash-off area required by water-borne spray systems. Electrodeposition tanks are long to allow the necessary immersion time and rinse area.

Add-on controls for controlling bake oven emissions such as incinerators or carbon adsorbers are relatively small and usually can be mounted on top of the oven. It could be difficult if space were tight to find room for a large carbon adsorber to handle spray booth emissions.

Incinerators, especially if used for controlling spray booth emissions, use a great deal of fuel even with heat recovery in many cases. This constraint is considered very sensitive in this era of energy shortages.

5.4. REFERENCES

1. Holley, W. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), phone call to PPG Industries, Inc. August 25, 1977.
2. Oge, M.T. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.), Trip Reports and Guidelines 41,72,86,100,103, and 108.

6. EMISSION CONTROL SYSTEMS

The purpose of this chapter is to identify alternative emission control systems and finishing processes for typical metal furniture finishing lines. In Chapter 4 the performance of available emission control technology for coating operations in the metal furniture industry was discussed and evaluated.

Eleven alternatives (A-2 through A-7, and B-2 through B-6) for controlling or reducing emissions for metal furniture coating operations have been identified and are listed in Tables 6-1 and 6-2.

There are a variety of sizes of coating lines used in the metal furniture industry and therefore it would be impossible to show these systems in place for all sizes of lines. To illustrate the application of these systems it was necessary to design model coating lines where emission reductions could be quantified in terms of percent relative to base cases using organic solvent-borne coatings. In one base case a solvent-borne coating spray method was used and in another base case a solvent-borne coating dip method was used.

The two model lines discussed in this chapter are; a line with a yearly output of 333,333 metal shelves, spray coated, and another line with a yearly output of 2,496,000 metal shelves dip coated. The 333,333 metal shelves represent a yearly coated surface area of 3,000,000 square feet (278,707 square meters), the 2,496,000 metal shelves represent 22,464,000 square feet of coated area.

It was assumed for all cases that the coating lines for metal shelves were operating 1920 hours per year (240 days, 1 shift).

It is the task of this chapter to select a realistic number of alternative emission control systems in order to analyze the range of environmental (Chapter 7) and economic (Chapter 8) impacts associated with various alternative controls. For this reason, several of the most viable of the various alternatives have been selected for further consideration. These are presented - in order of decreasing emission reduction - in Table 6-1 for the smaller line producing 333,333 metal shelves per annum, and in Table 6-2 for the line with an output of 2,496,000 metal shelves per year.

Table 6-1. METAL FURNITURE EMISSION CONTROL SYSTEMS

Size of Line: 3,000,000 Square Feet Coated Area Per Year

<u>Process</u>	<u>Alternative (Case) Number</u>	<u>Solvent Emitted^a Metric Tons/Year</u>	<u>Reduction^a Percent</u>
Powder coating, electrostatic spray	A-5	0 ^b	95-99 ^b
Conventional solvent-borne coating, electrostatic spray			
Carbon adsorber on spray booth, and incinerator on cure oven (in- cinerator with primary heat re- covery)	A-7 ^c	1.7	90
High solids coating, electrostatic spray	A-4	2.8	83
Water-borne coating, electrostatic spray	A-6	3.6	79
Conventional solvent-borne coating electrostatic spray			
Carbon adsorber on spray booth	A-3	5.5	68
Incinerator on cure oven (with primary heat recovery)	A-2	13.2	22
No control (base case)	A-1	17.1	0

^a With the add-on controls it was assumed that all the solvents emitted from the application areas and flash-off and ovens went through the control unit.

^b For practical purposes, emission can be considered as zero; however, minute emissions can be caused (0.5 to 3.0 percent) by plasticizers from vinyl materials, and by curing agents used in conjunction with thermo-setting type resins.

^c This is actually a combination of A-2 and A-3.

With the add-on controls it was assumed that all the solvents emitted from application areas and ovens went through the control unit. Most water wash spray booths have recirculating water systems. Any solvent from overspray that is captured by the water curtain is eventually evaporated into the air exhaust system³⁴. Both incinerators and carbon adsorbers were figured as operating at an average efficiency of 90 percent.

Table 6-2. METAL FURNITURE EMISSION CONTROL SYSTEMS

Size of Line: 22,464,000 Square Feet coated Area Per Year

<u>Process</u>	<u>Solvent Alternative (Case) Number</u>	<u>Solvent Emitted^a Metric Tons/Year</u>	<u>Reduction^a Percent</u>
Water-borne electrodeposition	B-2	6.24	93
Solvent-borne dip coating with carbon adsorber on dip tank, and incinerator on cure oven	B-5 ^b	9.18	90
Water-borne dip coating	B-6	18.40	80
Solvent-borne dip coating			
Carbon adsorber on dip tank	B-3	42.23	54
Incinerator on cure oven (with primary heat recovery)	B-4	58.75	36
No control (base case)	B-1	91.80	0

^a With the add-on controls it was assumed that all the solvents emitted from the application areas and flash-off and ovens went through the control unit.

^b This is actually a combination of B-3 and B-4.

The decreased emissions and percent reduction are from the base cases (A-1 and B-1 respectively), which are uncontrolled organic solvent-borne coating systems.

6.1. ALTERNATIVE A-2

In this system, emissions from the curing oven of the model line (which amount to only about 20 to 30 percent of the total emissions) are discharged to an incinerator. Incineration is a process where compounds are combusted and reduced to other compounds. Organic solvents used in the industrial finishing industry, in general, can be converted by the incinerator into carbon dioxide and water vapor.

Incineration is the most universally accepted technique for reducing solvent emissions from industrial processes. The value of this technology has been demonstrated in the can manufacturing industry^{1,2,3,4}, in the coil coating industry^{5,6,7,8,9} and the automotive industry^{10,11}, etc.

By discharging the emissions of the curing oven to an incinerator, the emissions of the model line A-1 can be reduced to 13.2 metric tons per year - a reduction of 22 percent.

A flow diagram of this system is shown in Figure 6-1.

6.2. ALTERNATIVE A-3

Activated carbon gained some attention mostly in the paper and fabric coating industry for the removal of organic compounds from gaseous streams by adsorption^{12,13,14,15}.

In alternative system A-3, emissions from the spray booth and flash-off of the model line (which amount to about 70 to 80 percent of the total emissions and flash-off) are discharged to a carbon adsorption unit. A flow diagram of this system is presented in Figure 6-2.

By the use of this technology, the emissions of the model line are reduced from 17.1 metric tons per year to 2.8 tons - a reduction of 68 percent.

6.3. ALTERNATIVE A-4

In this alternative, the conventional solvent-borne paint is replaced with a high solids coating material. Otherwise, the process is identical with the base case (A-1). Due to the high solids content of the coating composition (therefore, low solvent content) the emissions are reduced.

Figure 6-1. FLOW DIAGRAM - ALTERNATIVE A-2
APPLICATION OF SOLVENT-BORNE COATING BY ELECTROSTATIC SPRAY
BASE CASE WITH INCINERATOR ON OVEN

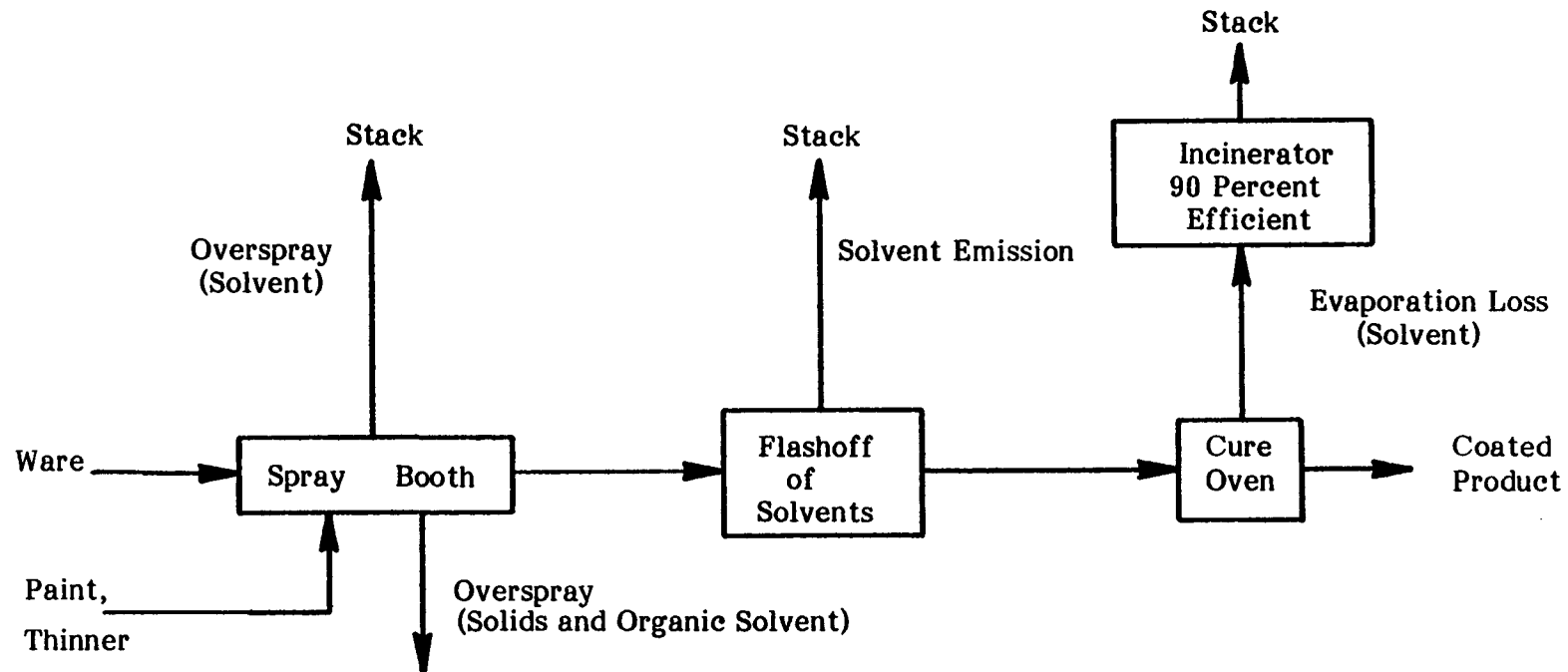
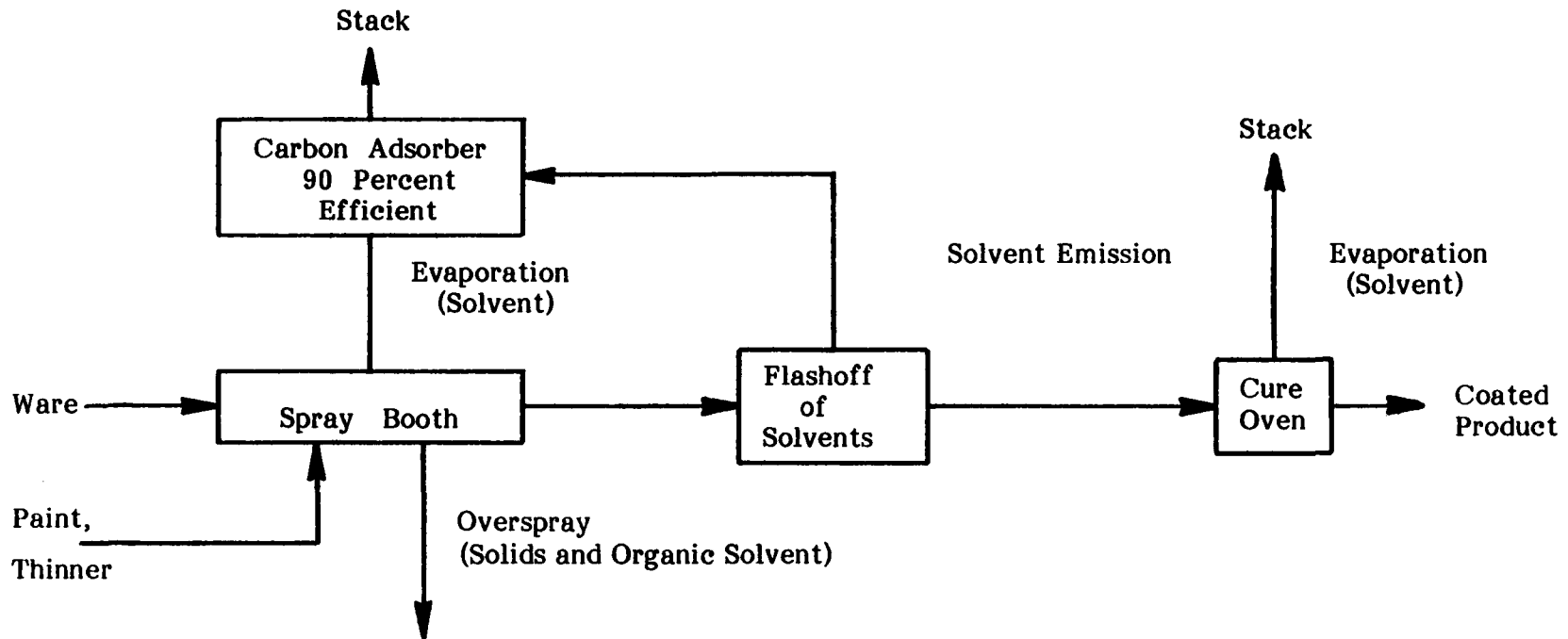


Figure 6-2 . FLOW DIAGRAM - ALTERNATIVE A-3
APPLICATION OF SOLVENT-BORNE COATING BY ELECTROSTATIC SPRAY
BASE CASE WITH CARBON ADSORBER ON SPRAY BOOTH



High solids coatings are currently investigated in the coating industry, (including the metal furniture industry, for the reasons of energy savings and pollution control)^{16,17}.

By the use of high solids coating material, the emission of the model line (A-1) can be reduced from 17.1 metric tons per year to 2.8 tons - a reduction of 83 percent.

A flow diagram of this process (see base case) is shown in Figure 6-3.

6.4. ALTERNATIVE A-5

In this alternative the solvent-borne coating material is replaced on the model line by powder coating. The reduction is 95 to 99 percent with a minimum emission (minute emissions can be caused by plasticizers from vinyl materials, and by some of the curing agents used in conjunction with thermosetting resins).

Of the control techniques presently in use in the metal furniture finishing industry, powder coating is the most common^{18,19,20,21,22,23,24} on outdoor and institutional furniture. Also, other coating industries, like the automobile industry investigate this technology on large scale production²⁵.

A flow diagram of this process is shown in Figure 6-4.

6.5. ALTERNATIVE B-2

Of the control techniques presently in use in the metal furniture industry, water-borne coatings are in widespread use. Most of the water-borne coatings are applied by electrodeposition (EDP)^{26,27,28,29,30,31,32,33}.

Changing from an uncontrolled organic solvent-borne coat to an EDP system for the metal furniture model line (base case or case B-1) would reduce the solvent emissions from 91.8 metric tons per year to 6.24 tons - a reduction of 93 percent.

A typical electrodeposition system diagram is shown in Figure 4-4 of Chapter 4. A simplified flow diagram of this system is presented in Figure 6-5.

Figure 6- 3. FLOW DIAGRAM - BASE CASE, ALTERNATIVES A-4 AND A-6
APPLICATION OF COATING BY ELECTROSTATIC SPRAY CONVENTIONAL (BASE CASE),
OR HIGH SOLIDS (A-4) SOLVENT-BORNE COATINGS OR WATER-BORNE COATINGS (A-6)

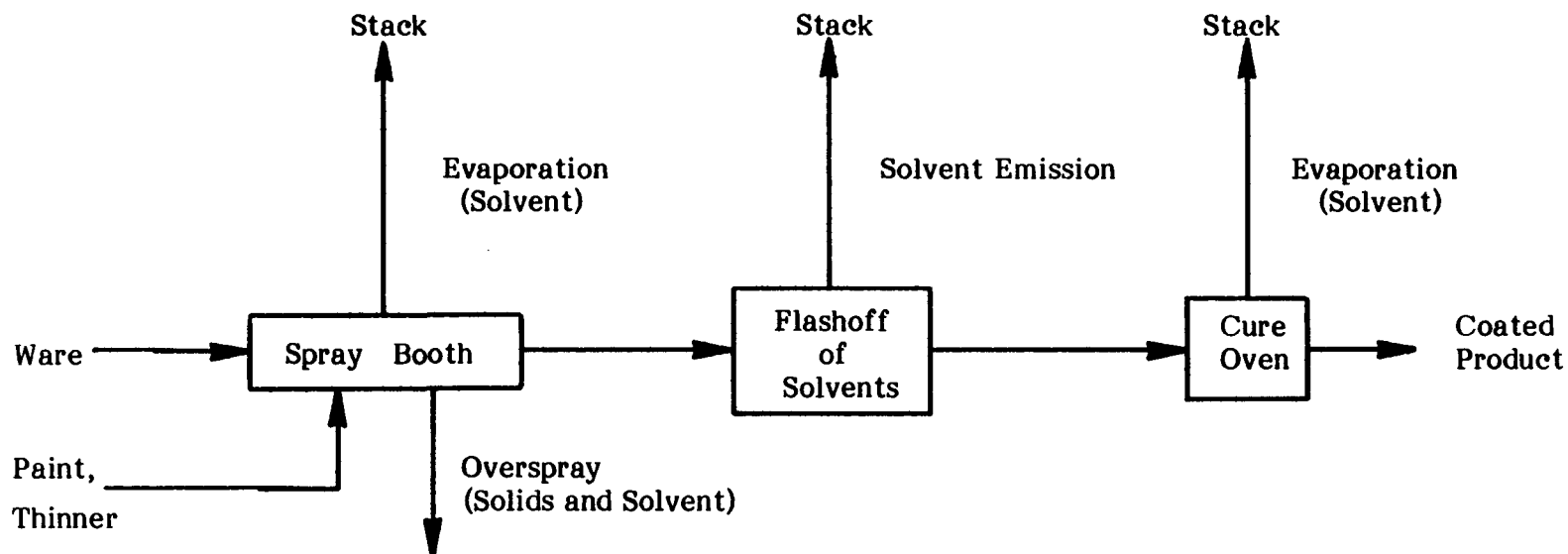


Figure 6- 4 . FLOW DIAGRAM - ALTERNATIVE A-5
APPLICATION OF POWDER COATING - ELECTROSTATIC SPRAY

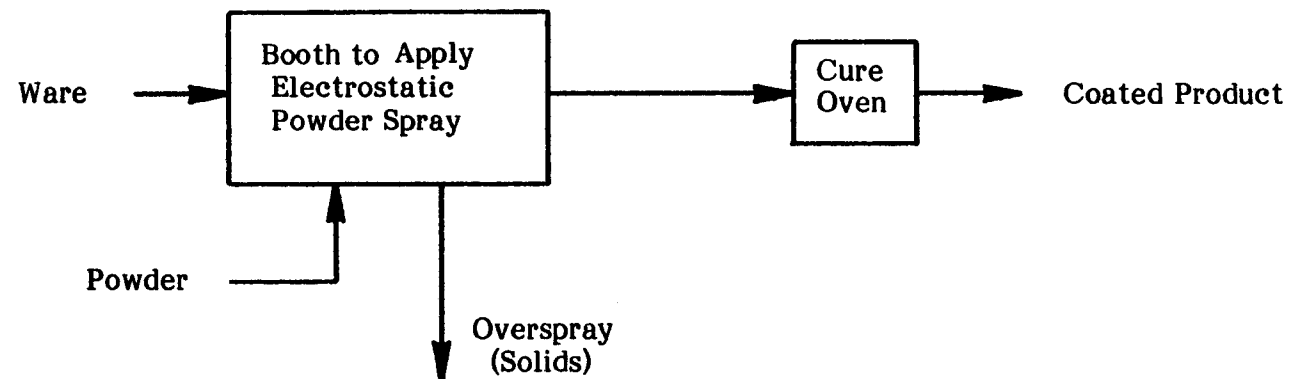
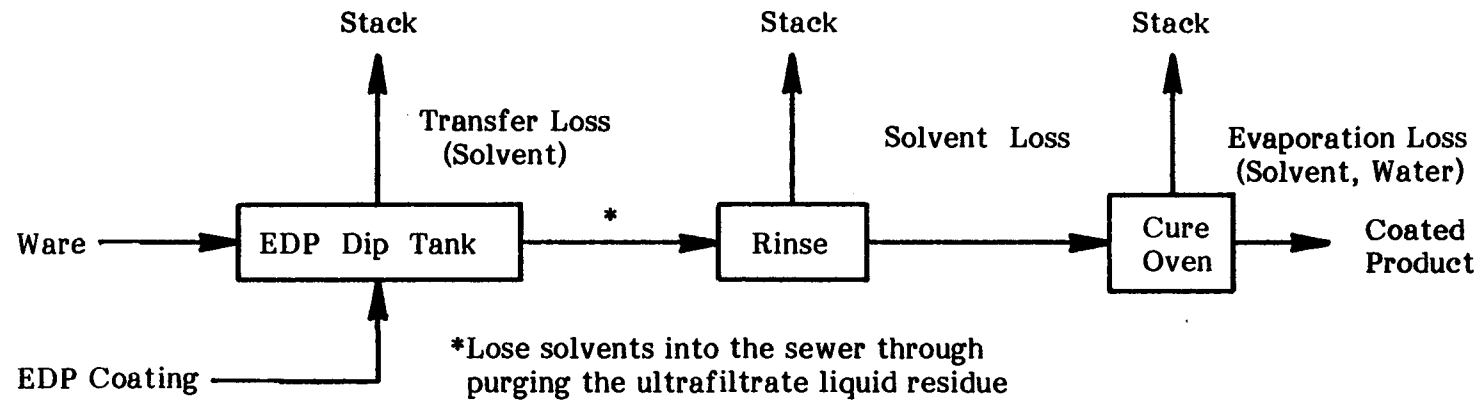


Figure 6-5. FLOW DIAGRAM - ALTERNATIVE B-2
APPLICATION OF WATER-BORNE COATING BY ELECTRODEPOSITION (EDP)



6.6. ALTERNATIVE B-3

Activated carbon is used in paper and fabric coating industries for the removal of organic compounds from gaseous streams by adsorption. Applications include recovery of solvent from various industrial operations, including industrial finishing operations (see Chapter 4 and also the references listed under A-3).

In this system, emissions (which amount to approximately 50 percent of the line) from the dip tank and flash-off of the model line are discharged to a carbon adsorption unit. A flow diagram is shown in Figure 6-6.

This control system reduces dip tank emissions of the metal furniture model line (B-1) from 91.8 metric tons per year to 42.23 metric tons - a reduction of 54 percent.

6.7. ALTERNATIVE B-4

In this system, emissions from the curing oven of the model line (which amount to about 40 to 50 percent of the total line emissions) are discharged to an incinerator. Incineration process was already discussed under alternative A-2. Therefore, no details are discussed here.

By discharging the emissions of the curing oven to an incinerator, the emissions of the model line B-1 can be reduced to 58.75 metric tons per year - a reduction of 36 percent.

A flow diagram illustrating this system is shown in Figure 6-7.

6.8. ALTERNATIVE B-5

This alternative is actually a combination of alternatives B-3 and B-4: the emissions from the dip tank and flash-off are discharged to a carbon adsorption unit, and the emissions of the curing oven are channelled to an incinerator. This combined carbon adsorber/incinerator system reduces total emissions from the model line (B-1) to 9.18 metric tons per year - a reduction of 90 percent.

6.9. ALTERNATIVE B-6

In this system, the solvent-borne dip coating material is replaced by a water-borne composition. By this, the emissions of the model line B-1 can be reduced to 18.4 metric tons per year - a reduction of 80 percent.

Figure 6-6. FLOW DIAGRAM - ALTERNATIVE B-3
APPLICATION OF SOLVENT-BORNE DIP COATING
BASE CASE WITH CARBON ADSORBER ON DIP TANK

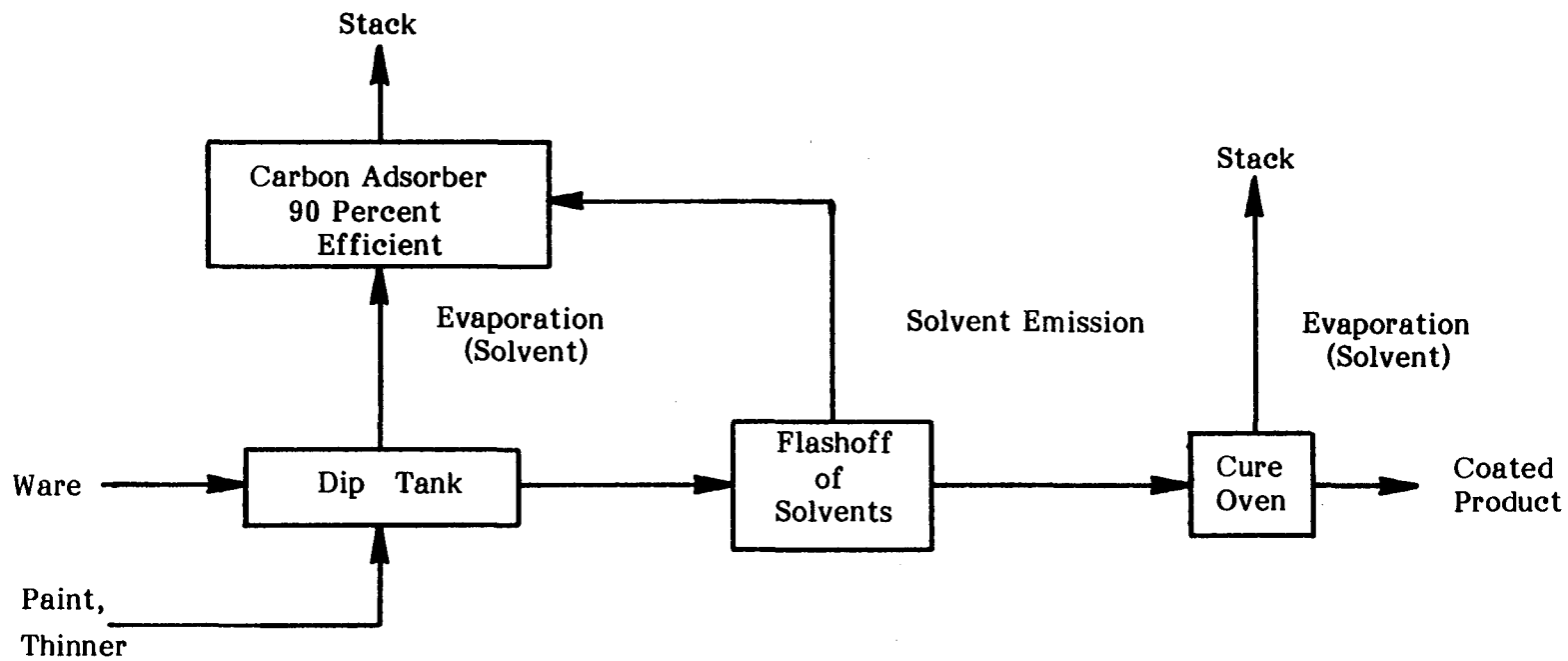
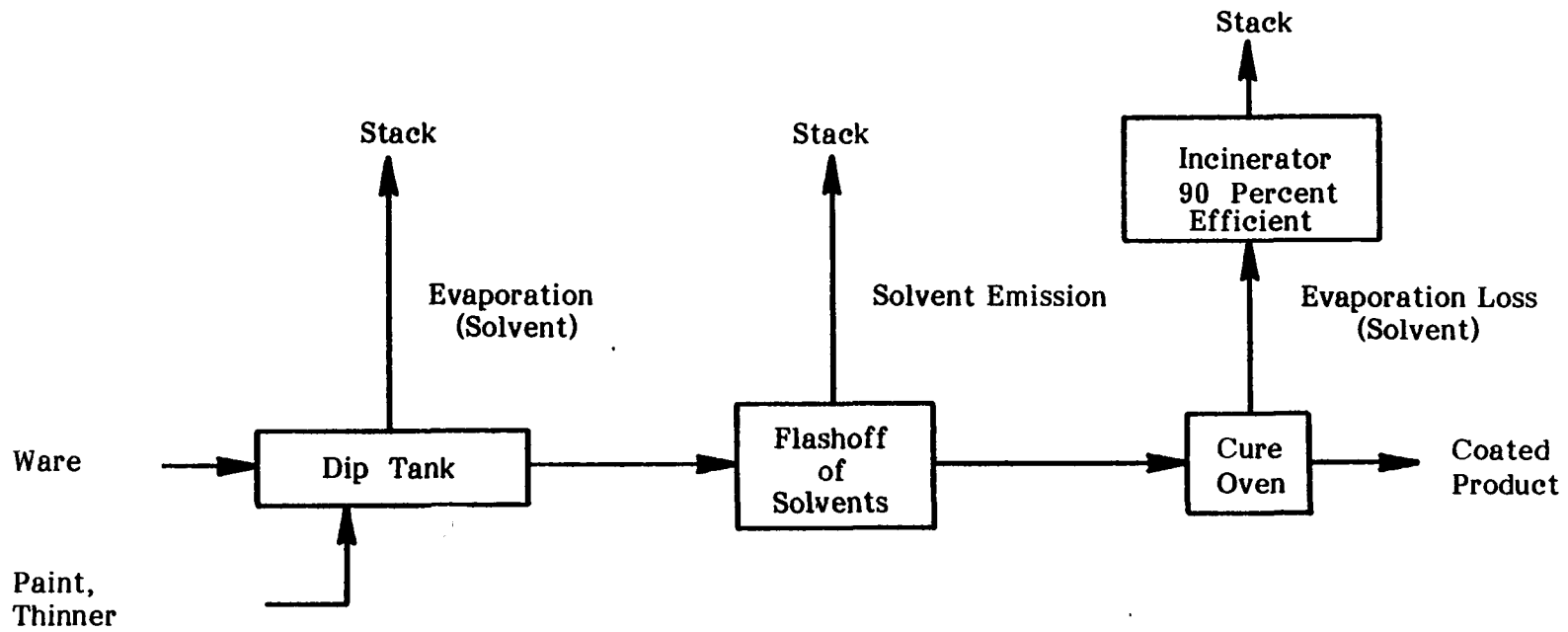


Figure 6-7. FLOW DIAGRAM - ALTERNATIVE B-4
APPLICATION OF SOLVENT-BORNE DIP COATING
BASE CASE WITH INCINERATOR ON OVEN



6.10. REFERENCES

1. Gabris, T. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.). Trip Report 5. December 2, 1975.
2. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 6. December 2, 1975.
3. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 80. February 24, 1976.
4. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 128. March 24, 1976.
5. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 16. December 18, 1975.
6. Fisher, R. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 27. December 12, 1975
7. Fisher, R. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 31. December 12, 1975
8. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 35. January 8, 1976.
9. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 76. February 9, 1976.
10. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 112. March 12, 1976.
11. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 120. March 12, 1976.
12. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 89. February 27, 1976.
13. Oge, M. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 139. July 19, 1976.
14. Oge, M. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 140. July 20, 1976.
15. Oge, M. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 141. July 21, 1976.
16. Oge, M. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 41. January 14, 1976.
17. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 36. January 16, 1976.

18. Schrantz, J. Automatic powder systems coat lawn furniture. Industrial Finishing. April 1975, pp 32-38.
19. Oge, M. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 86. February 25, 1976.
20. Oge, M. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 57. December 10, 1975.
21. Oge, M. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 108. March 8, 1976.
22. Oge, M. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 72. February 4, 1976.
23. Oge, M. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 85. February 25, 1976.
24. Oge, M. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 100. March 23, 1976.
25. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 38. January 15, 1976.
26. Oge, M. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 103. March 9, 1976.
27. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 9. December 9, 1975.
28. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 102. March 10, 1976.
29. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 110. March 11, 1976.
30. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 112. March 12, 1976.
31. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 120. March 12, 1976.
32. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 13. December 12, 1975.
33. Gabris, T. Springborn Laboratories, Inc. Enfield, Connecticut. Trip Report 73. February 10, 1976.
34. Holley, W.H. Springborn Laboratories, Inc. Enfield, Connecticut. Telephone conversation with Binks Manufacturing Co., New Jersey, November 7, 1977

7. ENVIRONMENTAL IMPACT

7.1. AIR POLLUTION IMPACT

Metal furniture manufacturing lines are sources of organic solvent emissions. The bulk of these emissions is due to the solvent-borne coating materials used to protect and decorate the low carbon steel sheets, strips and tubings used in the manufacture of the furniture.

Coatings for metal furniture must resist abrasion scuffing and maintain good appearance. Institutional furniture is subjected to a more abusive environment and in addition must withstand regular cleaning with alkali type cleansers.

Presently, the metal furniture industry employs mostly organic solvent-borne coatings for spray, dip and flow coating processes. However, different techniques are available today for reducing organic solvent emissions from metal furniture coating facilities.

As an example for the use of conventional organic solvent-borne coating material, the following figures are of interest. A metal furniture line producing 22,464,000 square feet coated area per year, and applying said coating material by dip coating, causes an uncontrolled emission of approximately 92 metric tons per year. A line producing 3,000,000 square feet of coated areas per year, and using the electrostatic spray technique to apply the coating material, causes an uncontrolled emission of approximately 17 metric tons per year.

In 1973 (a very high production year), United States consumption of solvents in paints and coatings was 1,902,273 metric tons or 4,185,000,000 pounds^{1,2}. From these 4,185 million pounds, 805 million were used directly in the manufacture of the coating materials, while 1,365 million pounds of solvents were used as thinners and for some other miscellaneous uses².

In 1973, the metal furniture industry (including fixtures) consumed 71,136 metric tons or 156.5 million pounds of organic solvents². These 156.5 million pounds of organic solvents were used with 79.4 million pounds of resins² and 56 million pounds of pigments² to make coating materials. Thus, the total paint consumption of the metal furniture (and fixtures) industry in 1973 must have been 291.9 million pounds or 132,681 metric tons (a total of the solvent, resins and pigment consumption).

If we examine these figures, the average organic solvent content as computed is 54 percent by weight or 36 percent by volume. (We used 35 percent by volume for our base case).

According to a recent survey of the National Paint and Coating Association³, the metal furniture (and fixture) industry consumed 116 million pounds of organic solvents in 1975. The 116 million pounds exclude thinners. The survey also states that the solvent/resin weight ratio of these coating materials was 1.8.

It is also apparent from said survey that thinner and miscellaneous solvents accounted to 32 percent of total solvents consumed. According to this, the total solvent consumption of the 1975 metal furniture industry must have been close to 170 million pounds.

Based on the earlier cited solvent/resin weight ratio of 1.8, the 170 million pounds of solvent should have required some 94 million pounds of resin as compounding ingredients. Based on the 1973 consumption figures of the metal furniture industry², the pigment/resin ratio was 0.7. This ratio is now used for estimating the 1975 consumption.

In view of the above, the 1975 consumption of the metal furniture industry is estimated as follows:

	<u>Millions of Pounds</u>	<u>Percent by Weight</u>	<u>Percent by Volume</u>
Organic Solvent	170	52	62
Resin	94	28	38
Pigment	<u>66</u>	<u>20</u> }	<u>included in resin</u>
Total	330	100	100

The estimates for 1976, our base year for this study, are discussed under 7.1.2.3. Estimated Hydrocarbon Emission Reduction in Future Years.

The objectives of New Source Performance Standards are to limit the emission of organics by imposing standards which reflect the degree of emission reduction achievable through the application of the best adequately demonstrated system(s) of emission reduction, taking into consideration the cost of achieving such reduction. Several alternative organic solvent emission control systems (hereinafter referred to as "Alternative") have been identified as candidates for the best system of emission reduction.

In assessing the environmental impact and the degree of emission control achieved by each alternative which could serve as the basis for standards, these alternatives need to be compared. Also, other facets of environmental impact -such as potential water pollution and solid waste generation - needed to be assessed. Similarly, state regulations and controlled emissions should be considered. These are discussed in the following sections.

7.1.1. State Regulations and Controlled Emissions

In August of 1971, Los Angeles County in California adopted Rule 66, Section C, specifying that effective August 31, 1974, the maximum allowable organic nonphotochemical emissions per paint facility was to be 3,000 pounds per day. The rule allows only 40 pounds per day from sources using photochemically reactive solvent and 15 pounds per day from ovens. Emissions beyond this limit would require control.

The regulations also provided an exemption for water-borne coatings where the volatile content consists of 80 percent water and the organic solvent was a non-photochemically reactive solvent.

There are very few coating users other than automobile and some truck assembly plants which could consume enough coating product to aggregate 3,000 pounds of total organic solvent emission in a day. This is the reason why the Air Resources Board of the State of California scheduled some consultation meetings for October 1976⁴ to gather information for developing a model rule to limit emissions of volatile organic compounds from automotive coating operations.

Based on preliminary discussions with coating manufacturers, the Organic Solvent Regulation Study Group, composed of staff members of the California Air Resources Board and several local Air Pollution Control Districts has developed for discussion purposes, the following organic solvent content limits to be effective by October 1, 1980:

<u>Coating Use</u>	<u>Maximum Organic Solvent Content As Applied (by Volume)</u>
Original Equipment Manufacture	
Undercoats (primer, primer-surfacer, sealer, etc.)	30%
Top coat	
(by October 1, 1980)	37.5%
(by October 1, 1982)	30%
Final Repair	
Metallic Color	55%
Solid Color	45%

These specifications are proposed for automotive coating lines only. However, this thinking could serve as the guide line for the other industries.

Today only thirteen states have statewide regulations covering hydrocarbon emissions. Approximately half of these states have regulations that are the same as, or similar to, Rule 66 of Los Angeles. Such standards carefully limit the amount of photochemically reactive (PCR) solvent volatiles which may be emitted within a given time period from both baking ovens and curing operations and from coating applications in any plant.

There are difficulties in understanding and interpreting Rule 66. While many states have Rule 66 regulations, many have variations such as no maximum limit per day. Even those states that have the same regulation seem to interpret it differently. The interpretation of the definition of the affected facility has a great impact on the stringency of the standard. The situation is complicated even more by the current activity in rewriting state regulations.

As to stringency, the Connecticut regulation is the most stringent in terms of total daily organic solvent emission restrictions. The oven discharges of organic materials are limited to 15 pounds per day, unless the discharge of the oven has been reduced by at least 85 percent.

There are ten states in which state regulations are in force in designated counties only. There twenty-two states where no hydrocarbon emission controls are required on stationary sources. And, there are five states in which state regulations are in the process of formulation.

7.1.2. Uncontrolled and Controlled Emissions (Alternatives)

The objective of this chapter is to discuss and determine what control methods coupled with which processes will allow substantial reductions in solvent emissions over the base line situation without an extreme adverse effect on secondary pollution such as water and solid waste. This chapter should help to identify those control methods/processes which can result in significant emission reduction and should guide the selecting of candidates for NSPS.

7.1.2.1. Spray Coating

For our base case, we have assumed that the coating line, which produces metal shelves, has a yearly output of 3 million square feet coated area. It was also assumed that the coating line was operating 1920 hours per year by being on one shift (8-hour shift, 240 work days per year). The base case is representative of what might be found in the industry. This model line is using traditional organic solvent-borne finishes.

Our base case indicates that the uncontrolled organic solvent-borne coating operation results in a yearly emission of 17.1 metric tons (37,620 pounds). This translates into 157 pounds per day.

The following alternatives represent control technologies that could be used to reduce the emission of volatile organic solvents. Typical emissions from such alternative lines have been discussed and have been compared against the base case. With the add-on controls it was assumed that all the solvents emitted from the application areas and ovens went through the control unit.

(1) Incinerator on Cure Oven

Alternative A-2 (Table 7-1)

In this case an incinerator is treating the emissions from the cure oven (which amount to about 25 percent of the total line emissions) of the model line, which can reduce the yearly emission (17.1 metric tons) by 22 percent, yielding a yearly emission of 13.2 tons or 29,040 pounds. Converting this into daily emissions, the result is 121 pounds per day.

(2) Carbon Adsorber on Spray Booth and Flash-off

Alternative A-3 (Table 7-1)

In this Alternative a carbon adsorber is put on the spray booth and flash-off area of the model line. A reduction of 68 percent in emission is observed, bringing the 17.1 metric tons of emission down to 5.5 tons. This amounts to 50 pounds per day.

- (3) High Solids Coating
Alternative A-4 (Table 7-1)

In this Alternative, the conventional solvent-borne paint is replaced with a high solids coating material. Due to the high solids content of the coating composition (therefore, low solvent content) the emissions are reduced by 83 percent, yielding a yearly emission of 2.8 metric tons or 25 pounds per day.

- (4) Powder Coating
Alternative A-5 (Table 7-1)

In this Alternative the solvent-borne coating material is replaced on the model line by powder coat. The reduction is 95 to 99 percent with an emission of 1 to 5 percent.

- (5) Water-Borne Coating
Alternative A-6 (Table 7-1)

In this example, a water-borne coating material is substituted for the solvent-borne coating. This Alternative reduces the emission by 79 percent to 3.6 metric tons per year, or 33 pounds per day.

- (6) Carbon Adsorber on Spray Booth and Flash-off
and Incinerator on Cure Oven
Alternative A-7 (Table 7-1)

This is a combination of Alternatives A-2 and A-3. The reduction is 90 percent (22 percent for A-2 and 68 percent for A-3 or 90 percent total). The emissions are reduced from the uncontrolled 17.1 metric tons to 1.7 tons. Converting this into daily emissions, the model line has an emission of 16 pounds per day.

7.1.2.2. Dip Coating

For our base case, we have assumed that the coating line has a yearly output of 22,464,000 square feet coated area. Similarly to the spray coating line (7.1.2.1), the line operates on one (8-hour) shift, 240 days per year. This amounts to 1920 work hours per annum.

Table 7-1. METAL FURNITURE PAINTING OPERATION
 SPRAY COATING HYDROCARBON EMISSION FACTORS AND
 CONTROLLED AND UNCONTROLLED MODEL PLANTS

<u>Model Plant</u>	<u>Alternative</u>	<u>Tons/Year^a</u>	<u>Percent Reduction</u>
Uncontrolled	(A-1)	17.1 (19.2)	-
Controlled			
Incinerator on cure oven	A-2	13.2 (14.5)	22
Carbon adsorber on spray booth	A-3	5.5 (6.0)	68
High solids coating	A-4	2.8 (3.0)	83
Powder coating	A-5	0 ^b	95 - 99
Water-borne coating	A-6	3.6 (3.9)	79
Carbon adsorber on spray booth and flash-off and incinerator on cure oven	A-7	1.7 (1.9)	90

^a Units are metric tons; U.S. tons shown in parentheses. With add-on controls it was assumed that all the solvents emitted from the application areas and ovens went through the control unit.

^b For practical purposes, emission can be considered as zero; however, minute emissions (0.5 to 3.0 percent) can be caused by plasticizers from vinyl materials and by curing agents used in conjunction with thermosetting type resins.

Our base case (B-1) indicates that the uncontrolled organic solvent-borne coating operation results in a yearly emission of 91.8 metric tons (201,960 pounds). This amounts to 841 pounds per day.

The following alternatives represent control technologies that could be used to reduce the emission of this line. Typical emissions from such alternative lines are compared against the base case and presented in Table 7-2.

- (1) Water-Borne - Electrodeposition
Alternative B-2 (Table 7-2)

In this Alternative, a water-borne coating material is applied by electrostatic deposition. By using this technology, the emission of the line is reduced by 93 percent. Thus, from the 91.8 metric tons of yearly emission to 6.24 tons. This amounts to 57 pounds per day. (The uncontrolled line produces an emission of 841 pounds per day).

- (2) Carbon Adsorber on Dip Tank and Flash-off
Alternative B-3 (Table 7-2)

In this system, emissions from the dip tank of the model line are discharged to a carbon adsorber unit. Emissions of the line are reduced by 54 percent, or to 42.2 metric tons per year. This corresponds to 387 pounds per day.

- (3) Incinerator on Cure Oven
Alternative B-4 (Table 7-2)

In this example, an incinerator is treating the emissions from the cure oven (approximately 40 percent of the total line) of the model line. This can reduce the emission by 36 percent. Thus the yearly emissions are reduced to 58.75 metric tons, or 538 pounds per day.

- (4) Carbon Adsorber on Dip Tank and Flash-off
and Incinerator on Cure Oven
Alternative B-5 (Table 7-2)

This is a combination of Alternatives B-3 and Alternative B-4. The achievable emission reduction is 90 percent. The yearly emission of the line is reduced to 9.1 metric tons, or 83 pounds per day.

- (5) Water-Borne Dip Coating
Alternative B-6 (Table 7-2)

A water-borne coating material is replacing the solvent-borne material in the dip tank. The achievable emission reduction is 80 percent. The yearly emission of the line is reduced to 18.4 metric tons, or 168 pounds per day.

Table 7-2. METAL FURNITURE PAINTING OPERATION
DIP COATING HYDROCARBON EMISSION FACTORS AND CONTROL EFFICIENCY
CONTROLLED AND UNCONTROLLED MODEL PLANTS

<u>Model Plant</u>	<u>Alternative</u>	<u>Tons/Year^a</u>	<u>Percent^b Reduction</u>
Uncontrolled	(B-1)	91.8 (100.9)	-
Controlled			
Water-borne - electrodeposition	B-2	6.2 (6.8)	93
Solvent-borne dip coating			
Carbon adsorber on dip tank	B-3	42.2 (46.4)	54
Incinerator on cure oven and flash-off	B-4	58.7 (64.6)	36
Carbon adsorber on dip tank and incinerator on cure oven	B-5	9.1 (10.0)	90
Water-borne dip coating	B-6	18.4 (20.2)	80

^a Units are metric tons; U.S. tons shown in parentheses.

^b With the add-on controls it was assumed that all the solvents emitted from the application areas and ovens went through the control unit.

7.1.2.3. Estimated Hydrocarbon Emission Reduction in Future Years

The household furniture industry from 1973 to 1980 is expected to grow at an annual rate of 2.4 percent⁵. Other branches of the furniture industry, like office metal furniture, public building furniture, and metal partitions and fixtures, expect to grow at a rate of 4.4 percent⁵. Growth rates predicted for the period of 1980 to 1985 are 3.9 percent for household furniture⁵, and 3.0 percent per annum for other furniture⁵.

Employment statistics, and sales projections presented in Chapter 3, indicate that approximately 30 percent of the total furniture industry is constituted by household furniture. The remaining 70 percent are made up from furniture sold to offices, public buildings, and sold as partitions and fixtures. Since the predicted growth rates for these industries are not significantly different, it is reasonable to take proportional averages for our work.

In view of the above, the metal furniture industry in the period of 1973 to 1980 is expected to grow at a rate of 3.8 percent per year (0.3 times 2.4 plus 0.7 times 4.4), and from 1980 to 1985, at an average rate of 3.3 percent.

We have estimated (see earlier pages of this chapter) that the solvent consumption of the metal furniture industry in 1975 was 170 million pounds (77,272 metric tons). Based on this figure, and the discussed estimated growth rates, the hypothetical emissions from uncontrolled metal furniture coating operations in the United States are estimated under A-1 in the tables which follow.

The adoption by the metal furniture industry of programs for the reduction of emissions is a long-range consideration. In 1973, from the 79.4 million pounds of resins consumed by the metal furniture industry, only 2 percent was used of new technology coating materials: 0.5 million pounds in water-borne, and 1.1 million pounds in powder coats².

Six control options for spray coating, and five options for dip coating are available to the industry to control emissions over a projected growth period up to the year 1985. Tables 7-3 and 7-4 encompasses the effectiveness of alternate control options on the reduction of annual emissions assuming that each year 5 percent of the industry would be affected by the use of pollution control systems. Tables 7-5 and 7-6 show the effectiveness at 10 percent yearly penetration.

**Table 7-3. COMPARATIVE EFFECTIVENESS OF ALTERNATE CONTROL SYSTEMS
EXPRESSED IN ANNUAL ORGANIC EMISSIONS
CONTROLS ON A SPRAY COATING OPERATION
ASSUMED ANNUAL PENETRATION: 5 PERCENT**

<u>Year</u>	<u>Emissions, Metric Tons/Year</u>						
	A-1 <u>Uncontrolled Emissions</u>	A-2 <u>Incinerator on Cure Oven</u>	A-3 <u>Carbon Adsorber on Spray Booth and Flash-off</u>	A-4 <u>High Solids Coating</u>	A-5 <u>Powder Coating</u>	A-6 <u>Water-Borne Coating</u>	A-7 <u>Carbon Adsorber on Spray Booth and Flash-off Incinerator on Oven</u>
1976	80,208	80,208	80,208	80,208	80,208	80,208	80,208
1977	83,256	82,339	80,425	79,800	79,093	79,967	79,509
1978	86,420	84,518	80,543	79,247	77,778	79,593	78,642
1979	89,704	86,742	80,553	78,535	76,248	79,073	77,593
1980	93,113	89,016	80,449	77,655	74,490	78,400	76,352
1981	96,186	90,894	79,834	76,226	72,139	77,188	74,543
1982	99,360	92,802	79,090	74,619	69,552	75,811	72,532
1983	102,639	94,734	78,210	72,882	66,715	74,259	70,307
1984	106,026	96,694	77,186	70,824	63,615	72,521	67,856
1985	109,525	98,681	76,009	68,616	60,238	70,588	65,166

**Table 7-4. COMPARATIVE EFFECTIVENESS OF ALTERNATE CONTROL SYSTEMS EXPRESSED
IN ANNUAL ORGANIC EMISSIONS CONTROLS ON A DIP COATING OPERATION
ASSUMED ANNUAL PENETRATION: 5 PERCENT**

<u>Year</u>	<u>Emissions, Metric Tons/Year</u>					
	B-1 <u>Uncontrolled Emissions</u>	B-2 <u>Water-Borne Electrodeposition</u>	B-3 <u>Carbon Adsorber on Dip Tank and Flash-off</u>	B-4 <u>Incinerator on Cure Oven</u>	B-5 <u>Carbon Adsorber on Dip Tank and Flash-off Incinerator on Oven</u>	B-6 <u>Water-Borne Dip Coat</u>
1976	80,208	80,208	80,208	80,208	80,208	80,208
1977	83,256	79,384	81,007	81,756	79,509	79,925
1978	86,420	78,383	81,753	83,309	78,642	79,506
1979	89,704	77,190	82,437	84,859	77,593	78,939
1980	93,113	75,793	83,056	86,408	76,352	78,214
1981	96,186	73,822	83,200	87,528	74,543	76,948
1982	99,360	71,638	83,263	88,629	72,532	75,513
1983	102,639	69,229	83,239	89,706	70,307	73,899
1984	106,026	66,584	83,123	90,757	67,856	72,097
1985	109,525	63,688	82,909	91,781	65,166	70,095

**Table 7-5. COMPARATIVE EFFECTIVENESS OF ALTERNATE CONTROL SYSTEMS
EXPRESSED IN ANNUAL ORGANIC EMISSIONS
CONTROLS ON A SPRAY COATING OPERATION
ASSUMED ANNUAL PENETRATION: 10 PERCENT**

Year	A-1	A-2	A-3	Emissions, Metric Tons/Year			
	Uncontrolled Emissions	Incinerator on Cure Oven	Carbon Adsorber on Spray Booth and Flash-off	A-4 High Solids Coating	A-5 Powder Coating	A-6 Water-Borne Coating	A-7 Carbon Adsorber on Spray Booth and Flash-off Incinerator on Oven
1976	80,208	80,208	80,208	80,208	80,208	80,208	80,208
1977	83,256	81,423	77,602	76,345	72,187	76,678	75,762
1979	89,704	83,783	71,404	67,368	58,471	68,444	65,484
1981	96,186	85,605	63,482	56,269	47,362	58,192	52,902
1983	102,639	86,832	53,783	43,006	38,363	45,880	37,976
1985	109,525	87,838	42,495	27,709	31,073	31,652	20,809

**Table 7-6. COMPARATIVE EFFECTIVENESS OF ALTERNATE CONTROL SYSTEMS EXPRESSED
IN ANNUAL ORGANIC EMISSIONS CONTROLS ON A DIP COATING OPERATION
ASSUMED ANNUAL PENETRATION: 10 PERCENT**

<u>Year</u>	<u>Emissions, Metric Tons Per Year</u>					
	B-1	B-2	B-3	B-4	B-5	B-6
	<u>Uncontrolled Emissions</u>	<u>Water-Borne Electrodeposition</u>	<u>Carbon Adsorber on Dip Tank and Flash-off</u>	<u>Incinerator on Cure Oven</u>	<u>Carbon Adsorber on Dip Tank and Flash-off Incinerator on Oven</u>	<u>Water-Borne Dip Coat</u>
1976	80,208	80,208	80,208	80,208	80,208	80,208
1977	83,256	75,512	78,759	80,258	75,762	76,595
1979	89,704	64,677	75,172	80,016	65,484	68,175
1981	96,186	51,459	70,216	78,872	52,902	57,711
1983	102,639	35,801	63,841	76,774	37,976	45,161
1985	109,525	17,852	56,295	74,038	20,809	30,666

Table 7-7. EFFECTIVENESS OF ALTERNATE CONTROL SYSTEMS - YEAR 1985
EXPRESSED IN ANNUAL ORGANIC EMISSIONS
CONTROLS ON A DIP COATING OPERATION
COMPARATIVE ANNUAL PENETRATION: 5 AND 10 PERCENT

<u>Control System</u>	<u>Alternative Number</u>	<u>Emissions, Metric Tons/Year</u>		
		<u>Uncontrolled^a</u>	<u>Annual Penetration 5%</u>	<u>Annual Penetration 10%</u>
<u>By Add-On Equipment</u>				
Carbon adsorber on dip tank and flash-off	B-3	109,525	82,909	56,295
Incinerator on cure oven	B-4	109,525	91,781	74,038
Carbon adsorber on dip tank and flash-off and incinera- tor on cure oven	B-5	109,525	65,166	20,809
<u>By Coating Composition</u>				
Water-borne coating electrodeposition	B-2	109,525	63,688	17,852
Water-borne dip coating	B-6	109,525	70,095	30,666

^a No add-on equipment with conventional solvent-borne coating material.

Table 7-8. EFFECTIVENESS OF ALTERNATIVE CONTROL SYSTEMS - YEAR 1985
EXPRESSED IN ANNUAL ORGANIC EMISSIONS
CONTROLS ON A SPRAY COATING OPERATION
COMPARATIVE ANNUAL PENETRATION: 5 AND 10 PERCENT

<u>Control System</u>	<u>Alternative Number</u>	<u>Emissions, Metric Tons/Year</u>		
		<u>Uncontrolled^a</u>	<u>Annual Penetration 5%</u>	<u>Annual Penetration 10%</u>
<u>By Add-On Equipment</u>				
Incinerator on cure oven	A-2	109,525	98,681	87,838
Carbon adsorber on spray booth and flash-off	A-3	109,525	76,009	42,495
Carbon adsorber on spray booth and flash-off and incinerator on cure oven	A-7	109,525	65,166	20,809
<u>By Coating Composition</u>				
High solids coating	A-4	109,525	68,616	27,709
Powder coating	A-5	109,525	60,238	31,073
Water-borne coating	A-6	109,525	70,588	31,652

^a No add-on equipment with conventional solvent-borne coating material

7.2. WATER POLLUTION IMPACT

When solvent-borne coatings are applied by spraying, the spraying operation is carried out in the spray booth. With the increased attention to air pollution, the efficiency of particulate removal from the spray booth is of great importance to the metal furniture coating lines. As a result, water-wash spray booths of advanced design are coming into use. These booths have a grid in the floor through which the overspray is drawn before being exhausted.

In a spray booth, typically used in the industrial finishing industry, 95 percent of the paint particulates are captured by the water curtain, but most of the solvent escapes to the atmosphere, either up the stack due to evaporation from the water curtain, or as fugitive emissions by evaporation from the water collection tank⁷. For most paints used, the solvents are immiscible in the water which facilitates their discharge into the air⁷.

Water-borne electrodeposition coats are prepared by neutralizing highly acidic polymers with an alkali (like amines) so that these polymers can be dissolved or suspended in water. Small amounts of solvents are also added to increase the water dispersibility⁶.

In the coating process the paint solids coat the metal ware, leaving alkali coalescing solvents behind in the tank. These products must be removed. In modern installations, ultrafiltration is used to automatically remove the water-solubles and chemical agents which are left behind during the process (see details in Section 7.3. - Solid Waste Disposal).

If the effluent water originates from properly operating ultrafiltration only and is treated properly, it can be adequately handled in municipal or in-house sewage treatment facilities. On the other hand, if the electrocoating systems allows rinse water and/or paint to drip or be spilled on the floor and the rinsing and clean-up water is not automatically placed in a reservoir for treatment, this painting operation could cause pollution.

Especially important in this instance is the matter of "dragout." At the end of the coating operation the dipped ware becomes coated with an additional film of adhering paint called dragout. This film is more porous than the plated coating; therefore, it is usually rinsed off. Also, a dragout takes place as the ware leaves the tank for the next location. This dragout is reclaimed through an ultrafiltration system.

Water-borne spray-coating materials, in the metal furniture industry, do not represent demonstrated technology as yet. Nevertheless, water-borne coating materials are used by spraying both in the automotive industry^{8,9,10} and in the can industry¹¹. Water-borne spray-coat materials, however, are made with water-miscible solvents to assure good suspension of the resin binder in the water phase of the coating material. These various water-miscible solvents (glycols, and certain esters and alcohols) found in the water-borne coating materials are extremely miscible with water wash and actually act as coupling agents between the suspended particles and the water.

The problem with organic solvent in effluent water is the chemical oxygen demand (COD). COD is not a pollutant in itself; it is a problem only if it is discharged to a stream in sufficient concentration and quantity to deplete the oxygen in the stream and thereby affect fish life and other water life.

There are no water pollution impacts associated with the other alternative emission control systems; however, incineration or adsorption of spray booth exhaust - although technically feasible - have not been used at any plant. As far as carbon adsorption is concerned, it is to be noted that some solvents used in solvent-borne coating systems are sufficiently water-miscible to pose a water pollution problem if regeneration steam is condensed and discharged without being treated.

7.3. SOLID WASTE DISPOSAL IMPACT

Water-borne electrodeposition operations can have an impact on solid waste disposal. In older installations the dragout and rinse were discarded, resulting in a waste disposal problem. This also causes a paint loss. Improvements have been made, however, to reduce paint cost through the inclusion of some means of reusing this paint by returning it to the tank.

In modern operations, ultrafiltration is used to automatically remove the amine(s), solvents, and water-solubles which are left behind during the electrocoating. Consequently, it is possible to set up a completely closed system with practically no waste problem.

Once a year there is a regular cleaning of the filter system. Otherwise cleaning is not needed except on occasions such as, for example, when a paper cup or other foreign object is accidentally dropped into the tank. Such a minor cleaning job, however, does not involve more paint than a few gallons.

There are no serious solids waste disposal problems associated with electrocoating. Sludge may develop in the tank, leading to a minor solid waste disposal problem; however, sludge is generally a result of improperly controlled chemistry of the electrocoating tank or poor housekeeping (such as allowing parts to accumulate in the tank). In any case, the amount of such solid waste is not excessive.

While water-borne electrodeposition type coatings no longer present any serious sludge and solid waste problems, water-borne spray coats are more prone to do so. Water-borne spray coat materials, because they are partial or full suspension systems just as are dispersions and/or emulsions, display considerably less mechanical and storage stability than do organic solvent-borne topcoat materials, which are often actually true solutions. In a dispersion, fine particles (of the binder) are suspended in a continuous liquid phase, like water. In an emulsion the solids are liquified with the help of solvent(s), and droplets of this are suspended in a continuous liquid phase like water.

The stability of these suspension (also referred to as colloidal) systems is much dependent on the water-to-solvent ratio used. This is especially true when the water-to-solvent ratio of the water-borne topcoat material is disturbed, as it is when the overspray of the water-borne topcoat material hits the water wash. In the water wash the major portion of the water-borne topcoat overspray is thrown out of suspension, forming lumps consisting of agglomerated solids with locked-in water. This can seriously increase the amount of sludge formed in a plant^{9,10}.

For example, an automobile plant reported that the sludge tank had to be cleaned only once a year when using solvent-borne topcoats, and as the plant switched to water-borne topcoats, the sludge tank had to be cleaned every three months¹².

As a result of the above situations - the water being filtered at and recirculated from the sludge tanks to the spray booths of coating lines - the water must contain significant amounts of water-miscible solvents as well as colloidal particles of the coagulated binder and pigment. Particles which are of ultrafine size are impossible to filter out by conventional filtering methods.

As to the exact amounts and compositions of the sludge, estimates of the various industry spokesmen vary over a wide spectrum.

There are some basic differences between the treatment of sludge from solvent-based coatings and that of water-borne spray coating materials. Sludge from water-based spray coat materials, in order to break the suspension system and to remove the particles, is treated with slightly acidic compounds like calcium acetate at an actual pH of 3-4¹³. Ultrafiltration could be used eventually to remove the colloidal particles; but this method is labeled as an expensive approach to the problem¹³.

There is little solid waste impact associated with alternatives other than water-borne coatings. In the case of carbon adsorption (because of the high cost of the carbon), the carbon is returned to the supplier for regeneration. In the case of powder coats (because of the high cost of the powder), the oversprayed powder is recovered by means of cyclone(s) - with the possible additional help of tube or bag filters. Virtually no solid by-product is produced by incineration.

7.4. ENERGY IMPACT

With the exception of high solids, powder and water-borne spray-coat systems - all alternative emission control systems require some additional energy.

In contrast to the necessary exhausting method used for solvent-borne paint systems, the exhaust from a powder coating application booth usually can be filtered and returned to the room. This makes possible a considerable energy reduction - attributable to less makeup air, less oven exhaust no flashoff zone, and the elimination of heat-up zones in the oven¹⁴.

The energy impact associated with each of the alternative emission control systems outlined in Chapter 6 and discussed in this chapter is summarized in Tables 7-9 and 7-10; these tables are a compact representation and summary of energy balances prepared for the purpose of comparing the energy required for a base case finishing model with the energy required when pollution reduction coatings or add-on emission controls are utilized.

Table 7-9. ENERGY BALANCE - ON A SPRAY COATING OPERATION

<u>Model Description</u>	<u>Alternative Number</u>	<u>Energy Requirements Per Line</u>		<u>Total Energy Per Year 10⁶ BTU</u>
		<u>Electricity ^a KWH/Year</u>	<u>Gas ^b MCF/Year</u>	
Base case	A-1	192,000	3,840	4,495
Incinerator on cure oven	A-2	203,500	6,048	6,743
Carbon adsorber on spray booth and flash-off	A-3	306,600	3,820 ^c	4,867
High solids coating	A-4	192,000	2,690	3,345
Powder coating	A-5	192,000	2,400	3,055
Water-borne coating	A-6	230,400	2,572	3,359
Carbon adsorber on spray booth and flash-off and incinerator on cure oven	A-7	318,100	6,331 ^c	7,417

^a Conversion factor: KWH = 3,415 BTU

^b Conversion factor: 1 cubic foot = 1,000 BTU

^c Adjusted for energy credit (303 MCF/year) due to solvent recovery

Table 7-10. ENERGY BALANCE ON A DIP COATING OPERATION

<u>Model Description</u>	<u>Alternative Number</u>	<u>Energy Requirements Per Line</u>		<u>Total Energy Per Year 10⁶ BTU</u>
		<u>Electricity^a KWH/Year</u>	<u>Gas^b MCF/Year</u>	
Base Case	B-1	153,600	6,720	7,244
Water-borne coating electrodeposition	B-2	960,000	4,500	7,778
Solvent-borne dip coating -				
Carbon adsorber on dip tank and flash-off	B-3	210,900	6,670 ^c	7,390
Incinerator on cure oven	B-4	176,640	10,560	11,163
Carbon adsorber on dip tank and flash-off and incinerator on cure oven	B-5	233,940	11,320 ^c	12,119
Water-borne dip coating	B-6	153,600	4,503	5,027

^a Conversion factor: KWH - 3,415 BTU

^b Conversion factor: 1 cubic foot = 1,000 BTU

^c Adjusted for energy credit (810 MCF/year) due to solvent recovery

7.5. OTHER ENVIRONMENTAL IMPACTS

Electrodeposition (EDP) coatings contain amines that are driven off during the curing step. Some plants have found it necessary to incinerate the oven exhaust gas to eliminate the visible emission and mal odors associated with these amines¹⁵; some other plants have installed scrubbers for the same purpose¹⁶.

No environmental impacts other than those discussed above are likely to arise from standards of performance for metal furniture painting (coating) operations, regardless of which alternative emission control system is selected as the basis for standards.

7.6. OTHER ENVIRONMENTAL CONCERNS

7.6.1. Irreversible and Irretrievable Commitment of Resources

The alternative control systems will require the installation of additional equipment, regardless of which alternative emission control system is selected. This will require the additional use of steel and other resources. This commitment of resources is small compared to the national usage of each resource. A good quantity of these resources will ultimately be salvaged and recycled. With the exception of carbon adsorption, there are not expected to be significant amounts of space (or land) required for the installation of control equipment and/or new coating technology because all control systems can be located with little additional space required. Therefore, the commitment of land on which to locate additional control devices and/or application equipment is expected to be minor.

The increase in the use of activated carbon is also expected to be insignificant. In many cases the carbon can be regenerated and reused.

As can be noted, the use of primary and secondary heat recovery would enhance the value of incineration; here it is reasoned that without heat recovery, significant energy would be lost.

7.6.2. Environmental Impact of Delayed Standards

Delay of proposal of standards for the metal furniture industry will have major negative environmental effects on emission of hydrocarbon to the atmosphere and minor or no positive impacts on water and solid waste. Furthermore, there does not appear to be any emerging emission control technology on the horizon that could achieve greater emission reductions or result in lower costs than that represented by

the emission control alternatives under consideration here. Consequently, delaying standards to allow further technical developments appears to present no "trade-off" of higher solvent emissions in the near future against lower emissions in the distant future.

7.6.3. Environmental Impact of No Standards

Growth projections have been presented in earlier sections. It is obvious that the increased production of metal furniture will add to the national solvent emissions.

There are essentially no adverse water and solid waste disposal impacts associated with either of the alternative emission control systems proposed in this chapter. Therefore, as in the case of delayed standards, there is no trade-off of potentially adverse impacts in these areas against the negative result on air quality which would be inherent with not setting standards.

7.7 REFERENCES

1. Tess, Roy W. Chemistry and Technology of Solvents; Chapter 44 in Applied Polymer Science. American Chemical Society, Organic Coatings and Plastics Division. 1975.
2. Sources and Consumption of Chemical Raw Materials in Paints and Coatings - by Type and End-Use. Stanford Research Institute. November 1974.
3. Bruce Ocko. Modern Paint and Coating Magazine. March 1977. p 61.
4. Air Resources Board, State of California, Sacramento, California 95812. Ronald A. Friesen, Chief Industrial Project Evaluation and Control Strategy Development Branch. Public Consultation Meeting on Methods to Reduce Solvent Emissions from Automotive Coatings. Meeting announcement, September 16, 1977.
5. Monthly Labor Review, U.S. Department of Labor. November 1976. p 5.
6. Jones, F.N. What Properties Can You Expect from Aqueous Solution Coatings. SME Technical Paper, FC74-641:3-4, 1974.
7. Holley, William H. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.) and Andreola, M., Binks Manufacturing Company. Telephone conversation.
November 7, 1977.
8. Gabris, T. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.) Trip Report 56. February 5, 1976
9. Gabris, T. Springborn Laboratories Inc. (formerly DeBell & Richardson, Inc.). Trip Report 102. March 10, 1976.
10. Gabris, T. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.). Trip Report 110. March 11, 1976.
11. Gabris, T. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.) Trip Report 5. December 2, 1975.
12. Gabris, T. Telephone conversation with one of the California General Motors plants. October 29, 1976.
13. Gabris, T. Telephone conversation with Gerwert, Phil. General Motors Water Pollution Section. November 2, 1976.
14. Product Finishing. June 1976. p 166
15. Gabris, T. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.). Trip Report 112. March 12, 1976.
16. Gabris, T. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.). Trip Report 13. December 12, 1975

8. ECONOMIC IMPACT

8.1. INDUSTRY ECONOMIC PROFILE

8.1.1 Introduction

The metal furniture industry as defined here includes all establishments engaged in the manufacture of metal household furniture.

- | | |
|---|----------|
| 1. Metal Household Furniture | SIC 2514 |
| 2. Metal Office Furniture | SIC 2522 |
| 3. Public Building and
Related Furniture | SIC 2531 |
| 4. Metal Partitions and Fixtures | SIC 2542 |

Major products in the metal household classification include indoor dining and breakfast furniture, and porch, patio and outdoor seating and tables; main office furniture products are chairs, desks, and filing and storage cabinets. Public building and related furniture covers furnishings purchased by schools and institutions such as hospitals. Room dividers, shelves, lockers and storage bins are classified under metal partitions and fixtures.

8.1.2. Industry Size

Tables 8.1-1 through 8.1-5 present a time series of basic statistics on the industry stretching from 1958 to 1975.^a Tables 8.1-1 through 8.1-4 include metal household furniture, metal office furniture, public building and related furniture, and metal partitions and fixtures, respectively. Table 8.1-5 presents total statistics for the four classifications.

In 1975, the industry shipped products worth \$3.4 billion, employing 71,400 production workers and 22,900 other employees. Production workers earned an average annual salary of \$8,209 in 1975 or \$4.21 per hour for an average work week of 38 hours. Other employees earned an average annual wage of \$13,332.

^a Data for 1958 is not available for metal partitions and fixtures, until 1963 metal and wood partitions and fixtures were classified as one industry.

Table 8.1-1. BASIC INDUSTRY STATISTICS
METAL HOUSEHOLD FURNITURE
(SIC 2514)

Year	Establish- ments	All Employees		Production Workers			Value Added by Manu- facture	Cost of Materials, Fuel	Value of Industry Shipments	Capital Expendi- tures, New	Gross Value of Fixed Assets
		Number	Payroll	Number	Man-Hours	Wages					
	(Number)	(Thousands)	(Million Dollars)	(Thousands)	(Millions)	(Million Dollars)	(Million Dollars)	(Million Dollars)	(Million Dollars)	(Million Dollars)	(Million Dollars)
1975	NA	28.1	233.5	22.5	41.5	155.4	436.6	478.2	930.6	14.7	NA
1974	NA	35.4	257.5	28.8	53.8	176.9	483.6	529.4	1,003.0	18.2	199.2
1973	NA	36.9	253.6	30.6	58.9	177.9	508.8	506.6	999.8	25.5	193.7
1972	467	34.4	222.5	28.6	53.7	157.6	447.2	452.4	890.4	16.9	174.3
1971	NA	31.5	194.2	25.8	49.7	133.7	386.3	380.4	763.9	10.8	146.6
1970	NA	32.4	188.1	26.7	50.4	131.3	365.8	360.7	724.9	13.8	148.6
1969	NA	32.8	181.4	27.6	52.4	132.6	346.2	352.8	697.1	12.9	129.2
1968	NA	32.1	169.4	26.5	51.2	120.5	333.9	333.2	664.3	10.1	127.6
1967	486	31.0	155.5	25.8	50.3	109.6	291.3	312.0	605.3	10.1	125.8
1963	517	29.3	128.8	24.3	47.9	92.0	247.0	280.7	524.3	6.8	91.7
1958	626	30.3	124.6	24.6	48.2	89.2	218.7	274.7	496.1	6.3	NA

Source: U.S. Census of Manufacturers, 1972: Annual Survey of Manufactures, 1973, 1974, and 1975.

NA -- Not Available

Table 8.1-2. BASIC INDUSTRY STATISTICS
METAL OFFICE FURNITURE
(SIC 2522)

	Establish- ments	All Employees		Production Workers			Value Added by Manu- facture	Cost of Materials, Fuel	Value of Industry Shipments	Capital Expendi- tures, New	Gross Value of Fixed Assets
		Number	Payroll	Number	Man-Hours	Wages					
		(Thousands)	(Million Dollars)	(Thousands)	(Millions)	(Million Dollars)	(Million Dollars)	(Million Dollars)	(Million Dollars)	(Million Dollars)	(Million Dollars)
1975	NA	25.2	272.0	18.5	36.5	183.1	589.5	399.4	981.9	23.9	NA
1974	NA	31.1	313.3	24.1	49.0	221.1	645.2	436.4	1,069.4	25.2	304.4
1973	NA	30.1	286.4	22.7	46.5	192.4	638.9	394.8	1,023.7	39.6	302.4
1972	192	27.6	248.2	20.6	42.6	166.7	508.6	349.8	853.7	24.5	261.5
1971	NA	25.0	201.8	18.1	37.5	134.2	415.5	263.7	682.5	14.2	251.2
1970	NA	27.6	205.6	20.4	42.4	136.3	425.2	254.2	682.1	14.2	248.8
1969	NA	30.5	219.4	23.1	46.5	151.7	478.6	304.2	764.5	20.3	252.9
1968	NA	27.1	186.3	20.9	42.7	128.3	398.9	262.6	654.2	32.6	231.4
1967	187	27.0	178.5	21.1	42.9	125.3	389.3	239.5	622.9	31.5	207.7
1963	170	19.9	112.1	15.8	31.5	81.4	228.3	160.1	390.0	14.2	151.5
1958	151	17.5	86.0	13.9	26.9	62.7	173.7	109.7	286.0	5.3	NA

Source: U.S. Census of Manufacturers, 1972; Annual Survey of Manufactures, 1973, 1974, and 1975

NA -- Not Available

Table 8.1-3. BASIC INDUSTRY STATISTICS
PUBLIC BUILDING AND RELATED FURNITURE
(SIC 2531)

	<u>Establish- ments</u>	<u>All Employees</u>		<u>Production Workers</u>			<u>Value Added by Manu- facture</u>	<u>Cost of Materials, Fuel</u>	<u>Value of Industry Shipments</u>	<u>Capital Expendi- tures, New</u>	<u>Gross Value of Fixed Assets</u>
		<u>Number</u>	<u>Payroll</u>	<u>Number</u>	<u>Man-Hours</u>	<u>Wages</u>					
<u>Year</u>	<u>(Number)</u>	<u>(Thousands)</u>	<u>(Million Dollars)</u>	<u>(Thousands)</u>	<u>(Millions)</u>	<u>(Million Dollars)</u>	<u>(Million Dollars)</u>	<u>(Million Dollars)</u>	<u>(Million Dollars)</u>	<u>(Million Dollars)</u>	<u>(Million Dollars)</u>
1975	NA	20.0	173.6	15.6	28.0	115.8	330.3	317.1	657.5	15.8	NA
1974	NA	21.6	186.1	16.9	31.7	124.5	338.7	305.8	643.1	15.6	154.8
1973	NA	22.2	169.1	17.4	33.0	112.0	299.6	265.6	564.9	13.0	150.5
1972	422	21.4	157.8	16.3	31.6	103.8	295.9	245.9	535.3	13.0	143.6
1971	NA	21.0	135.5	16.3	30.9	89.0	254.5	218.5	471.8	8.8	121.3
1970	NA	23.1	149.9	18.2	36.0	101.2	255.3	214.2	462.6	18.1	126.5
1969	NA	23.4	154.5	18.3	37.0	104.6	267.4	214.2	468.5	12.1	109.5
1968	NA	21.0	127.7	16.4	33.1	83.1	241.3	191.3	432.3	7.6	96.4
1967	438	22.6	132.2	17.5	36.3	89.2	233.6	194.7	421.2	10.0	94.5
1963	429	16.9	83.4	13.3	26.8	57.4	141.8	127.9	268.6	4.4	66.3
1958	390	16.0	69.3	12.6	25.8	48.4	112.9	98.0	208.4	4.9	NA

Source: U.S. Census of Manufactures, 1972; Annual Survey of Manufactures, 1973, 1974, and 1975

NA - - Not Available

Table 8.1-4. BASIC INDUSTRY STATISTICS
METAL PARTITIONS AND FIXTURES
(SIC 2542)

Year	Establish- ments	All Employees		Production Workers			Value Added by Manu- facture	Cost of Materials, Fuel	Value of Industry Shipments	Capital Expendi- tures, New	Gross Value of Fixed Assets
		Number	Payroll	Number	Man-Hours	Wages					
		(Thousands)	(Million Dollars)	(Thousands)	(Millions)	(Million Dollars)					
1975	NA	21.0	212.3	14.8	29.6	131.8	448.2	406.2	868.3	21.6	NA
1974	NA	25.6	237.9	18.4	37.6	150.1	546.8	458.3	987.6	22.2	239.3
1973	NA	26.3	231.3	19.5	38.7	149.1	444.8	367.8	805.6	22.7	242.7
1972	507	26.2	215.7	19.9	38.5	143.1	412.4	326.3	734.5	19.4	237.5
1971	NA	22.2	167.7	16.7	30.9	107.0	328.5	256.8	580.1	13.3	NA
1970	NA	22.7	166.0	16.8	32.7	105.8	324.9	257.4	579.0	14.9	NA
1969	NA	25.2	177.4	18.8	37.5	110.1	334.6	251.0	583.8	12.5	172.5
1968	NA	23.4	163.9	17.6	35.7	102.0	309.6	220.2	524.1	13.4	156.6
1967	500	22.7	152.9	17.0	35.1	96.0	302.5	213.0	512.0	19.9	150.6
1963	513	20.3	119.3	14.9	31.7	79.2	214.3	165.7	377.8	8.5	117.8
1958	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Source: U.S. Census of Manufactures, 1972; Annual Survey of Manufactures, 1973, 1974, and 1975

NA - - Not Available

Table 8.1-5. BASIC INDUSTRY STATISTICS
METAL FURNITURE INDUSTRY
(TOTAL FIGURES FOR SIC 2514, 2522, 2531, 2542)

	Establish- ments	All Employees		Production Workers			Value Added by Manu- facture	Cost of Materials, Fuel	Value of Industry Shipments	Capital Expendi- tures, New	Gross Value of Fixed Assets
		Number	Payroll	Number	Man-Hours	Wages					
Year	(Number)	(Thousands)	(Million Dollars)	(Thousands)	(Millions)	(Million Dollars)	(Million Dollars)	(Million Dollars)	(Million Dollars)	(Million Dollars)	(Million Dollars)
1975	NA	94.3	891.4	71.4	135.6	586.1	1,804.6	1,600.9	3,438.3	76.0	NA
1974	NA	113.7	994.8	88.2	172.1	672.6	2,014.3	1,729.9	3,703.1	81.2	897.7
1973	NA	115.5	940.4	90.2	177.1	631.4	1,892.1	1,534.8	3,394.0	100.8	889.3
1972	1,588	109.6	844.2	85.4	166.4	571.2	1,664.1	1,374.4	3,013.9	73.8	816.9
1971	NA	99.7	699.2	76.9	149.0	463.9	1,384.8	1,119.4	2,498.3	47.1	NA
1970	NA	105.8	709.6	82.1	161.5	474.6	1,371.2	1,086.5	2,448.6	61.0	NA
1969	NA	111.9	732.7	87.8	173.4	499.0	1,426.8	1,122.2	2,513.9	57.8	664.1
1968	NA	103.6	647.3	81.4	162.7	433.9	1,283.7	1,007.3	2,274.9	63.7	612.0
1967	1,611	103.3	619.1	81.4	164.6	420.1	1,216.7	959.2	2,161.4	71.5	578.6
1963	1,629	86.4	443.6	68.3	137.9	310.0	831.4	734.4	1,560.7	33.9	427.3
1958	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Source: Derived From Data in U.S. Census of Manufactures, 1972, and in Annual Survey of Manufactures, 1973, 1974, and 1975.

NA - - Not Available

In 1972, the last year for which data is available, 1,588 establishments were listed by the U.S. Census of Manufacturers as engaged in metal furniture manufacturing. The number of establishments devoted to metal furniture manufacturing has declined, but only slightly, from the 1967 level of 1,611 establishments for the industry as a whole. The number of establishments involved in metal household and public building and related furniture manufacturing decreased slightly from 1967 to 1972, and increased slightly for metal office furniture and metal partitions and fixtures. Generally, the number of establishments in the metal furniture industry has been relatively stable with only moderate rates of exit and new entry.

8.1.3. Industry Growth: Past and Projected

The metal furniture industry, as a manufacturer of capital goods and consumer durable goods, is quite volatile relative to changes in the United States economy as a whole. Table 8.1-6 presents the value of metal furniture industry shipments in current and constant 1972 dollars, as well as real gross national product, also expressed in 1972 dollars. Figure 8.1-1 presents the industry's shipments in constant dollars and real GNP graphically. As is readily evident, activity in the metal furniture industry expands more rapidly than GNP during the growth phase of the business cycle, and contracts more quickly during a period of decline (or even slow growth). Figure 8.1-2 presents a graph of a more direct measure of this phenomenon: annual percentage changes in real GNP and real shipment of metal furniture.

In addition to the volatility of the metal furniture industry, Figure 8.1-2 also illustrates a lag in the industry's reaction to shifts in the economy. In 1971, GNP grew at a real rate of increase of 3.0 percent, but metal furniture shipments continued the decline of the economic downturn in 1970; in 1972, however, the industry made up for lost time by growing by almost 19 percent over 1971. The industry did not lag the arrival of the recession of 1974 to 1975, however, as shipments dropped by more than 7 percent in 1974.

Table 8.1-6. VALUE OF METAL FURNITURE INDUSTRY
SHIPMENTS IN CURRENT AND CONSTANT DOLLARS,
1967 - 1975

<u>Year</u>	<u>Value of Industry Shipments (Millions of Current Dollars)^a</u>	<u>Wholesale Price Index for Commercial Furniture (1972=100)^b</u>	<u>Value of Industry Shipments (Millions of 1972 Dollars)^c</u>	<u>Gross National Product (Billions of 1972 Dollars)^d</u>
1975	3,438.3	138.7	2,478.9	1,191.7
1974	3,703.1	126.8	2,920.4	1,210.7
1973	3,394.0	107.7	3,151.3	1,233.4
1972	3,013.9	100.0	3,013.9	1,171.1
1971	2,498.3	98.3	2,541.5	1,107.5
1970	2,448.3	95.3	2,569.4	1,075.3
1969	2,513.9	89.9	2,796.3	1,078.8
1968	2,274.9	86.4	2,633.0	1,051.8
1967	2,161.4	83.2	2,597.8	1,007.7

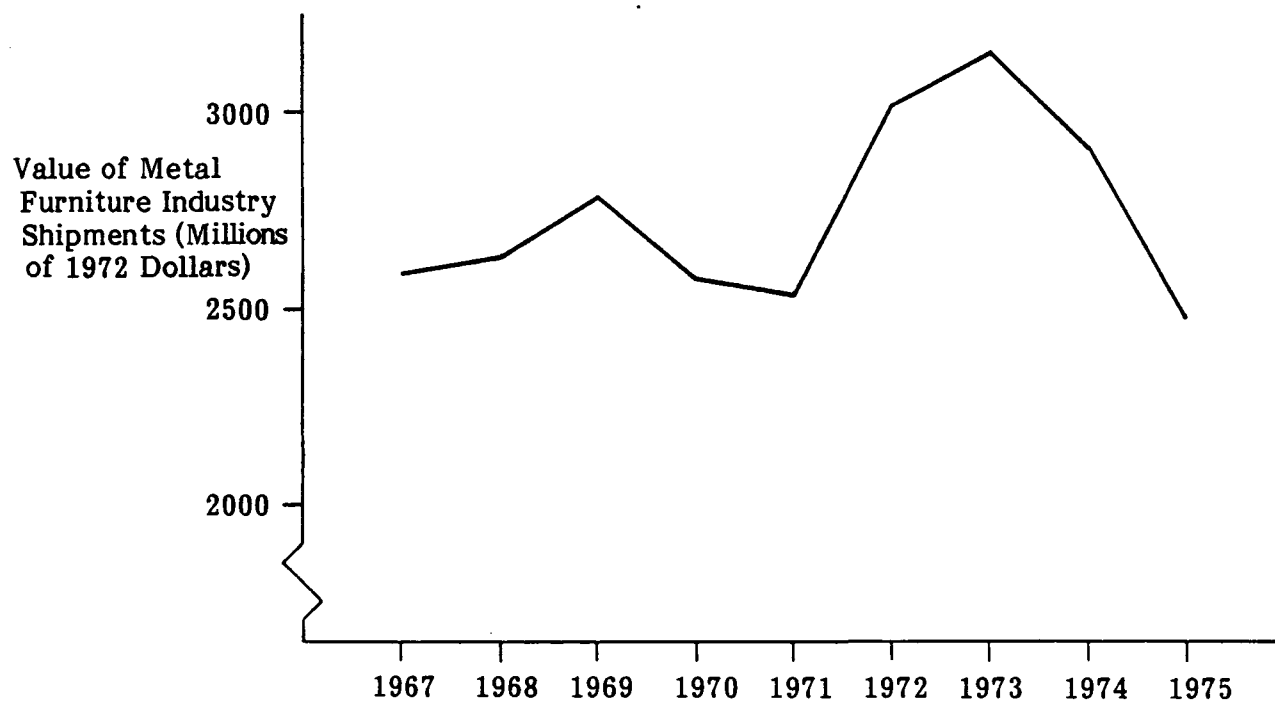
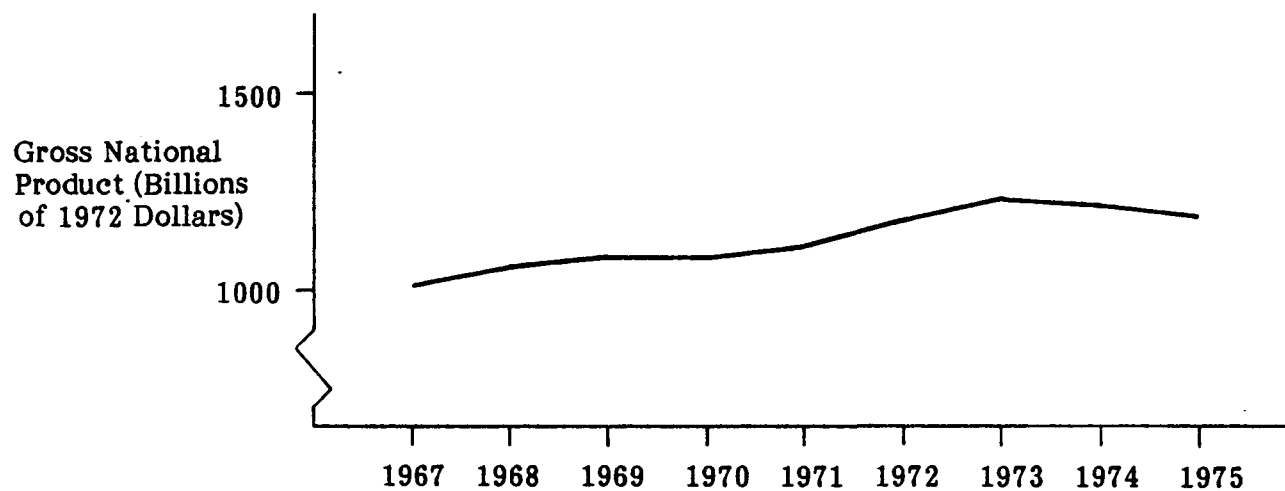
^a Source: Table 8.1-5.

^b Source: U.S. Bureau of Labor Statistics, Wholesale Prices and Price Indexes.
Note: This index is published with 1967=100. It has been converted to 1972=100 to facilitate comparison with constant dollar GNP.

^c Equals value in current dollars divided by (Index \div 100).

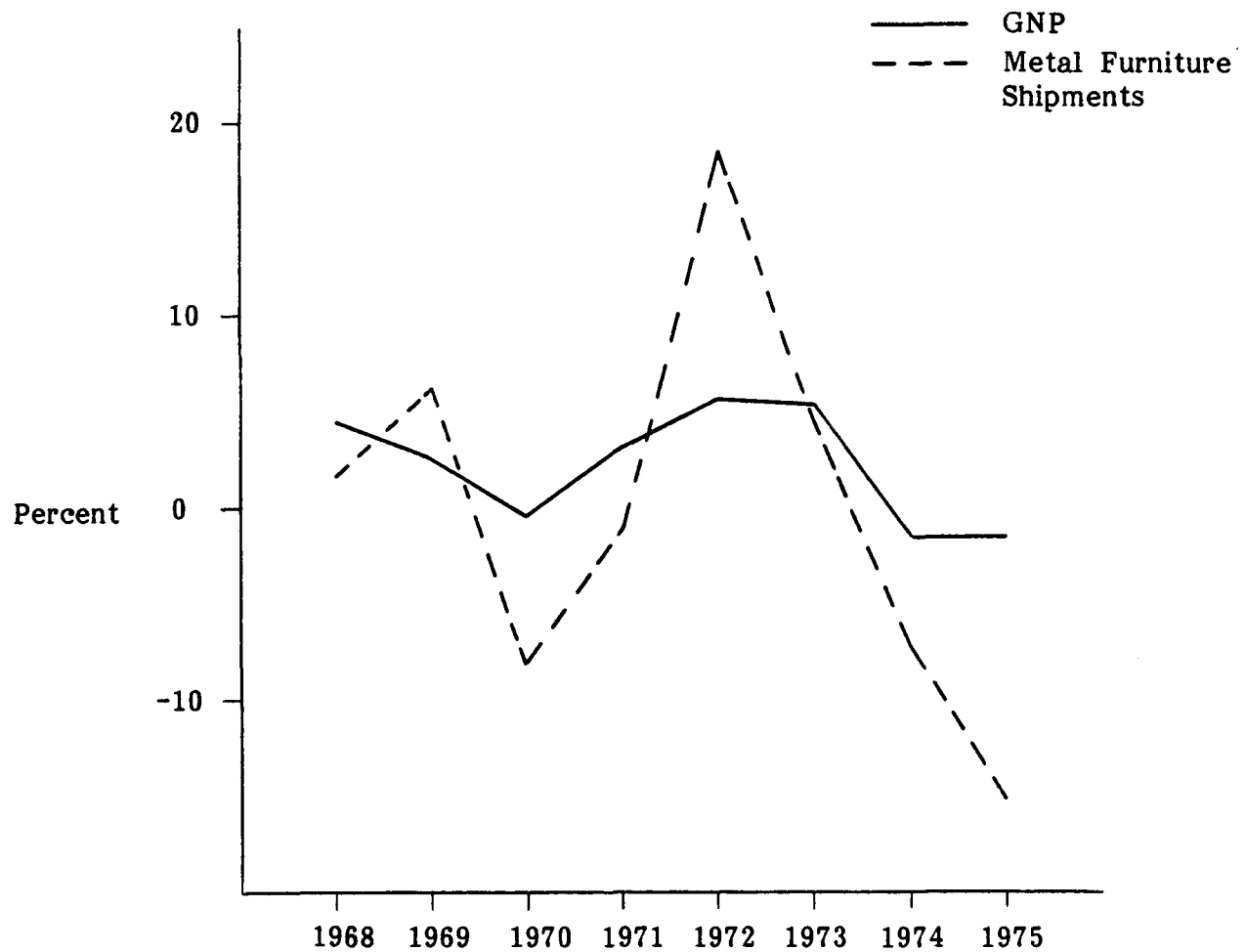
^d Source: Statistical Abstracts of the United States, 1976.

Figure 8.1-1. REAL GROSS NATIONAL PRODUCT AND METAL
FURNITURE INDUSTRY SHIPMENTS IN CONSTANT DOLLARS,
1967 - 1975



Source: Table 8.1-6.

Figure 8.1-2. PERCENT CHANGE FROM PREVIOUS YEAR
IN REAL GROSS NATIONAL PRODUCT AND CONSTANT
DOLLAR METAL FURNITURE INDUSTRY SHIPMENTS



In an industry which exhibits such volatility, calculating historic growth rates can yield vastly different results depending on the span of years chosen for analysis. Specifically, growth correlations for the most recent available data for 1974 and 1975 probably understates the secular growth trend.^a To avoid this difficulty, the annual compound growth rate may be calculated between the two most recent shipment peaks, 1969 and 1973. During those four years, real shipments growth averaged 3.0 percent per year.

We estimate long-term growth of real industry shipments will average 2 to 3 percent per year. While data for the entire industry is not yet available for 1976, statistics for one segment of the industry indicate the industry is repeating its traditional pattern of recovering from a dip in the economy with growth faster than the economy as a whole, and in line with historic growth rates.

According to the Business and Institutional Furniture Manufacturer's Association, office furniture shipments increased at a real rate of 12 percent in 1976 over the 1975 level. And during the first eight months of 1977, shipments in real terms were 24 percent above 1976 levels. Applying those growth rates to the industry as a whole for 1976 and 1977^b implies shipments for 1977 (in 1972 dollars) of \$3,443 million. Growth of shipments from the 1973 peak to 1977, using that assumption, averaged 2.2 percent per year. Thus the recovery of the metal furniture industry sales from the most recent recession tends to support a secular growth trend of 2 to 3 percent, following the trends of the last decade.

^a For example, a least squares fit of real industry shipments versus time, using a constant growth rate model, results in a 1.4 percent annual real growth rate from 1967 to 1975. The latest years are heavily weighted in this model.

^b From 1969 to 1973, metal office furniture shipments grew at almost exactly the same rate as the metal furniture industry as a whole.

8.1.4. Industry Structure

The metal furniture industry is quite fragmented. Table 8.1-7 presents concentration ratios for the four appropriate SIC classifications and none of the four shows enough concentration in the top four firms to indicate market dominance by one or even a few firms.

Metal office furniture (SIC 2522) is the most concentrated of the four classifications, with the top four firms having accounted for 37 percent of the value of shipments in 1972. Concentration increased slightly from 1967 to 1972, but not enough to imply a trend.

Some increase in concentration has also occurred in metal household furniture, but the increase is very small. In public building and related furniture and in metal partitions and fixtures, concentration has actually decreased.

Table 8.1-8 offers a look at the role of small firms in the metal furniture industry. In the economy as a whole, single-unit firms^a accounted for only 19 percent of the value of shipments by all manufacturing establishments. But in metal household furniture, public building and related furniture, and metal partitions and fixtures, single-unit firms accounted for at least double that proportion of the value of shipments, 38, 44 and 42 percent respectively. Only in metal office furniture did the 17 percent of single-unit firms fall near the level of single-unit firms in the economy as a whole. Small manufacturers play a more important role in the metal furniture industry than in the economy as a whole.

A view of the economics of plant size in the metal furniture industry can be obtained from Table 8.1-9, which lists the percent of number of establishments, production worker man-hours, and value added by manufacture for establishments of various sizes, classified by the number of employees per establishment. Establishments with less than 20 employees account for more than 50 percent of the number of establishments in metal household furniture, public building and related furniture, and metal partitions and fixtures. The smaller establishments, of course, account for a much lower percentage of the value added by manufacture by the industry than for the number of establishments.

^a The U.S. Bureau of the Census defines single-unit firms as one with a single establishment for both manufacturing and administration.

Table 8.1-7. CONCENTRATION RATIOS IN
METAL FURNITURE MANUFACTURING

	Percent of Value of Shipments Accounted for by:			
	<u>4 Largest Companies</u>	<u>8 Largest Companies</u>	<u>20 Largest Companies</u>	<u>50 Largest Companies</u>
Metal Household Furniture (SIC 2514)				
1972	14	23	41	65
1967	12	21	35	56
1963	12	18	31	53
1958	12	19	33	52
Metal Office Furniture (SIC 2522)				
1972	37	49	70	88
1967	32	45	69	88
1963	29	45	69	88
1958	33	49	73	89
Public Building and Re- lated Furniture (SIC 2531)				
1972	18	26	40	59
1967	18	30	46	64
1963	21	32	45	62
1958	24	34	47	65
Metal Partitions and Fixtures (SIC 2542)				
1972	13	22	39	59
1967	19	27	43	64
1963	19	26	41	61
1958	(NA)	(NA)	(NA)	(NA)

Source: U.S. Census of Manufactures, 1972, Concentration Ratios in Manufacturing.

NA - - Not Available

Table 8.1-8. PERCENT OF VALUE ADDED IN METAL
FURNITURE MANUFACTURING BY MULTI-UNIT AND
SINGLE-UNIT COMPANIES, 1972

	<u>Multi-Unit Companies</u>	<u>Single-Unit Companies</u>
	<u>Percent</u>	
All Manufacturing Establishments	81	19
<u>Metal Household Furniture (SIC 2514)</u>	62	38
<u>Metal Office Furniture (SIC 2522)</u>	83	17
<u>Public Building and Related Furniture (SIC 2531)</u>	56	44
<u>Metal Partitions and Fixtures (SIC 2542)</u>	58	42

Source: U.S. Census of Manufactures, 1972, Type of Organization.

**Table 8.1-9. DISTRIBUTION BY FIRM SIZE IN THE METAL FURNITURE INDUSTRY
OF ESTABLISHMENTS, PRODUCTION WORKERS AND VALUE ADDED
BY MANUFACTURE, 1972
(Share of Total, Percent)**

Firm Size (Number of Employees per Establishment)	Metal Household Furniture (SIC 2514)			Metal Office Furniture (SIC 2522)		
	Number of Establishments (Percent)	Production Worker Man-hours (Percent)	Value Added by Manufacture (Percent)	Number of Establishments (Percent)	Production Worker Man-hours (Percent)	Value Added by Manufacture (Percent)
1 to 19	50.7	4.9	5.0	39.1	1.3	1.3
20 to 49	18.0	8.2	7.3	14.1	3.5	2.7
50 to 99	10.3	10.3	10.6	15.6	7.7	7.4
100 to 249	13.1	29.7	30.5	18.2	19.7	16.2
250 to 499	6.2	31.3	29.2	6.3	16.9	17.7
500 to 999	1.3	15.7	17.5	4.2	21.5	20.6
1,000 to 2,499	0.4	(NA)	(NA)	2.1	29.3	34.1
2,500 or More				0.5	(NA)	(NA)
	Public Building and Related Furniture (SIC 2531)			Metal Partitions and Fixtures (SIC 2542)		
1 to 19	53.8	6.6	6.8	52.3	7.3	7.1
20 to 49	20.9	13.6	11.1	22.5	14.0	13.3
50 to 99	11.4	18.0	16.2	12.0	17.7	14.6
100 to 249	10.2	30.9	31.1	8.9	31.2	29.4
250 to 499	2.8	18.3	19.0	2.4	13.8	16.5
500 to 999	0.7	12.6	15.7	1.4	16.1	19.2
1,000 to 2,499	0.2	(NA)	(NA)			
2,500 or More						

Source: U.S. Census of Manufactures, 1972

NA = Not Available

In the case of all four industry segments, the very largest plants in the industry have the greatest labor productivity. For instance, in metal office furniture, in the largest plants, 29.5 percent of production workers man-hours are able to produce 34.1 percent of the value added by manufacture. (See Table 8.1-9.) However, just because one plant is larger than another does not necessarily mean that the larger plant is more efficient; a threshold effect is evident. Some intermediate sizes of establishments, for example, those with 100 to 249 or 500 to 999 employees in metal office furniture, account for a lower percentage of value added by manufacture than of production worker man-hours. At present, no economies of scale are evident in the metal furniture industry which prohibit a small manufacturer from competing, especially in regional markets where lower labor productivity may be overcome by lower distribution costs.

8.1.5. Channels of Distribution

The four segments of the industry market through different outlets; the one common denominator is that a large number of outlets sell to end-users. The 1972 Census of Retail Trade reported that 32,987 establishments marketed furniture and sleep equipment. One manufacturer estimated that 25,000 outlets handle metal office furniture; another manufacturer of outdoor furniture estimated that 30,000 to 60,000 retail outlets offer outdoor furniture. No single manufacturer is represented in the majority of end-user outlets.

Furniture marts play a major role in the marketing of metal household, metal office and public building and related furniture. At these marts^a buyers gather to examine the products of a large number of manufacturers. Such marts are extremely competitive. The furniture mart provides a mechanism for smaller manufacturers to compete without maintaining regional showrooms which are characteristic of some larger manufacturers.

Metal partitions and fixtures are marketed primarily through locally owned distributors who usually carry or offer the products of a large number of manufacturers. Price competition in this market is therefore particularly keen, as end-users can compare prices of various manufacturers in one location. The number of such distributors is quite large; in addition to shelves, lockers, storage bins and other fixtures, such outlets often carry related products such as material handling equipment.

^a Two key marts are in Chicago and High Point, North Carolina.

8.1.6. Industry Markets

Table 8.1-10 presents the product mix of the metal furniture industry as a percent of the value of total industry shipments. No major changes in product mix have occurred since 1967.

The most important development in metal furniture marketing of the last decade has occurred in the office furniture market, which includes not only metal office furniture (SIC 2522) but also metal partitions and fixtures (SIC 2542). With the growing importance of white collar and service workers in the American economy, managers have turned their attention more and more to white collar productivity. A major issue has been, of course, the office environment. Metal furniture manufacturers have responded to this change in the marketing environment with increased attention to the need for systems - - not just desks and chairs and room dividers, but modular units that can be fitted together in a number of ways. As Hauserman Inc., stated in its 1977 annual report, "Our strategy has been to broaden our opportunities in the office furniture market by improving user productivity. We accomplish this through easy movability, our ability to reorganize the wiring, lighting, communications, and other services of the building, and our accommodating individual furniture needs of office people." Herman Miller Inc., in its 1977 10-K report to the Securities and Exchange Commission, also address the issue of systems marketing: "The principal business of the company is the research, design, development, manufacture and sale of modular space division, storage and materials handling furniture systems and other furniture products such as chairs, tables, desks and general purpose seating. Most of these products and systems are coordinated in design so that they may be used together and interchangeably."

8.1.7. Labor and Materials Costs

Labor and materials and fuel costs have represented roughly constant share of the value of industry shipments during the past decade.^a No major changes in the industry's cost structure are apparent. Table 8.1-12 offers a detailed view of labor productivity in the industry. With one exception - - the most recent period in the metal household furniture industry - - labor productivity has grown more rapidly than the average hourly earnings of production workers during the periods analyzed. The productivity gains in metal office furniture and metal partitions and fixtures in the 1972 to 1975 period are particularly noticeable.

^a Table 8.1-11 reveals a decline in labor costs to 1975, but this is difficult to interpret correctly due to the recession of that year.

Table 8.1-10. METAL FURNITURE PRODUCT MIX, 1963 - 1975
(As Percent of Value of Total Industry Shipments)

	<u>1975</u>	<u>1974</u>	<u>1973</u>	<u>1972</u>	<u>1967</u>	<u>1963</u>
<u>Metal Household Furniture (SIC 2514)</u>	28.1	28.1	29.9	30.1	28.3	33.9
Dining, breakfast	9.2	8.9	8.5	8.6	7.9	9.4
Kitchen	1.7	1.7	2.7	2.5	2.7	4.2
Porch, lawn, outdoor	6.8	6.8	6.1	6.2	5.3	6.8
Other	10.5	10.7	12.5	12.8	12.4	13.5
<u>Metal Office Furniture (SIC 2522)</u>	27.8	29.5	28.9	27.4	28.2	23.9
Office seating	7.0	7.7	7.5	6.8	6.4	4.9
Desks	4.5	5.5	5.5	5.4	7.3	5.9
Cabinets, cases	10.9	11.2	11.4	10.5	9.6	9.6
Other	5.4	5.1	4.5	4.8	4.9	3.6
<u>Public Building and Related Furniture (SIC 2531)</u>	19.5	17.4	17.3	17.4	18.8	17.6
School furniture	7.2	6.7	6.3	6.4	7.6	7.9
Non-school furniture	11.8	10.1	9.7	9.8	10.1	9.0
Other	0.5	0.6	1.3	1.2	1.0	0.7
<u>Metal Partitions and Fixtures (SIC 2542)</u>	24.7	25.0	24.0	25.0	24.7	24.6
Partitions	3.4	3.1	2.5	2.8	(NA)	(NA)
Shelving and lockers	8.0	7.8	8.2	8.3	(NA)	(NA)
Storage racks, accessories	4.7	5.5	3.4	3.3	(NA)	(NA)
Fixtures	6.6	6.6	8.3	7.6	(NA)	(NA)
Other	1.9	2.1	1.5	3.0	(NA)	(NA)

Source: Annual Survey of Manufactures, U.S. Census of Manufactures.

NA - - Not Available

Table 8.1-11. LABOR AND MATERIALS COSTS IN METAL
FURNITURE MANUFACTURING RELATIVE TO VALUE OF
INDUSTRY SHIPMENTS

<u>Year</u>	<u>As % of Value of Shipments</u>	
	<u>Production Workers' Wages</u>	<u>Cost of Materials, Fuel</u>
1975	17.0	46.6
1974	18.2	46.7
1973	18.6	45.2
1972	19.0	45.6
1971	18.6	44.8
1970	19.4	44.4
1969	19.8	44.6
1968	19.1	44.3
1967	19.4	44.4
1963	19.9	47.1
1958	20.2	48.7

Source: Derived from Table 8.1-5.

Table 8.1-12. TRENDS IN WAGES AND PRODUCTIVITY
IN THE METAL FURNITURE INDUSTRY,
1958 - 1975

Year	Metal Household Furniture (SIC 2514)		Metal Office Furniture (SIC 2522)		Public Building and Related Furniture (SIC 2531)		Metal Partitions and Fixtures (SIC 2542)	
	Average Hourly Earnings of Production Workers	Value Added per Man-hour of Production Workers	Average Hourly Earnings of Production Workers	Value Added per Man-hour of Production Workers	Average Hourly Earnings of Production Workers	Value Added per Man-hour of Production Workers	Average Hourly Earnings of Production Workers	Value Added per Man-hour of Production Workers
	(Dollars)							
1975	3.74	10.52	5.02	16.15	4.14	11.80	4.45	15.14
1974	3.29	8.99	4.51	13.17	3.93	10.68	3.99	14.54
1973	3.02	8.64	4.14	13.74	3.39	9.08	3.85	11.49
1972	2.93	8.32	3.91	11.94	3.28	9.36	3.72	10.71
1967	2.18	5.79	2.92	9.08	2.46	6.44	2.73	8.61
1963	1.92	5.16	2.58	7.24	2.14	5.29	2.50	6.77
1958	1.85	4.54	2.33	6.45	1.88	4.38	(NA)	(NA)
Average Annual Compound Growth Rates from: Percent								
1958-1975	4.20	5.10	4.60	5.50	4.80	6.00	(NA)	(NA)
1967-1975	7.00	7.70	7.00	7.50	6.70	7.90	6.30	7.30
1972-1975	8.50	8.10	8.70	10.60	8.10	8.00	6.20	12.20

Source: Bureau of Manufactures, Annual Survey of Manufactures
NA - - Not Available

Coating materials cost varies in importance among the four segments analyzed here, as shown in Table 8.1-13. Cost is relatively higher for metal office furniture and metal partitions and fixtures, as it to be expected, for in major, high-volume products in these segments, e.g., file and storage cabinets and industrial shelving, coating is more important in the manufacturing process, and metal processing is less important than in the production of, for example, wrought iron lawn chairs.

The relative importance of coating material costs detailed in Table 8.1-13 is borne out by direct industry estimates of total coating costs as a percentage of total manufacturing costs. A manufacturer of hospital beds (public building and related furniture) reports that coating costs, including both materials and the cost of their application, run about 4 percent of total manufacturing costs; a company specializing in industrial shelving, office desks and file cabinets reports that total coating costs average 10 to 12 percent of total manufacturing costs.

8.1.8. Financial Performance

A wide range of financial performance is to be expected in an industry as fragmented as metal furniture. Table 8.1-14 bears out this expectation for some of the largest manufacturers of metal furniture. There is a wide range of profitability even among these firms.

8.1.9. Imports and Exports

Imports and exports are extremely small in the metal furniture industry, and do not play a significant role in industry conduct in the United States.

Table 8.1-13. METAL FURNITURE COATING MATERIALS COST
VS. TOTAL MATERIALS COST AND VALUE OF SHIPMENTS,
1972 AND 1967

	<u>Coating Materials Costs</u>			
	<u>1972</u>		<u>1967</u>	
	<u>Percent of Cost of Materials</u>	<u>Percent of Value of Industry Shipments</u>	<u>Percent of Cost of Materials</u>	<u>Percent of Value of Industry Shipments</u>
<u>Metal Household Furniture (SIC 2514)</u>	1.7	0.8	2.1	1.0
<u>Metal Office Furniture (SIC 2522)</u>	3.2	1.0	4.1	1.3
<u>Public Building and Related Furniture (SIC 2531)</u>	1.9	0.8	1.9	0.8
<u>Metal Partitions and Fixtures (SIC 2542)</u>	3.6	1.4	4.7	1.8

Source: Census of Manufactures

Table 8.1-14. FINANCIAL RATIOS FOR SELECTED METAL FURNITURE MANUFACTURERS

(Date Indicates End of Fiscal Year)

	<u>G. F. Business Equipment Inc.</u>		<u>Hauserman Inc.</u>		<u>Herman Miller Inc.</u>		<u>Hon Industries Inc.</u>		<u>Lyon Metal Products Inc.</u>		<u>Virco Manufacturing Corp.</u>	
	<u>12/76</u>	<u>12/75</u>	<u>6/77</u>	<u>6/76</u>	<u>5/77</u>	<u>5/76</u>	<u>12/76</u>	<u>12/75</u>	<u>12/76</u>	<u>12/75</u>	<u>1/77</u>	<u>1/76</u>
Cost of Sales as Percent of Net Sales	83.4	80.1	77.3	77.9	59.2	56.5	65.0	66.2	68.5	69.5	71.1	69.2
Net Income as Percent of Net Sales	0.0	0.8	1.7	4.1	5.1	5.3	7.2	6.6	5.0	4.2	2.4	2.7
Return on Equity Percent	0.0	1.8	5.9	14.3	19.6	15.5	23.3	20.6	7.5	6.0	14.9	15.9

Source: Annual reports, 10-K filings with the Securities and Exchange Commission.

8.1.10. Geographic Distribution

The metal furniture industry is not concentrated in any single area of the country, as Table 8.1-15 indicates. It should be noted that for metal office furniture, public building and related furniture, and metal partitions and fixtures, a preponderance of larger establishments are located in the North Central states. These states account for a much larger share of the value added by manufacture than for number of establishments. These states contain the largest manufacturing plants. Table 8.1-16 presents a more detailed breakdown on the location of establishments throughout the United States.^a

^a Data in Table 8.1-16 on the geographical distribution of the establishments must be used with care; as data in Table 8.1-15 on the North Central states indicates, percent of establishments do not necessarily coincide with percent of value added by manufacture (and thus with percent of employment). Due to the need to maintain confidentiality from census surveys, data on value added by manufacture and percentage of production workers is often not available for the finer geographic breakdowns in Table 8.1-16.

Table 8.1-15. GEOGRAPHICAL DISTRIBUTION OF
ESTABLISHMENTS AND VALUE ADDED BY MANUFACTURE,
METAL FURNITURE INDUSTRY, 1972

	<u>Share of Establishments (Percent)</u>	<u>Share of Value Added by Manufacture (Percent)</u>
Metal Household Furniture (SIC 2514)		
North East	33.8	(NA)
North Central	19.1	(NA)
South	28.5	35.2
West	18.6	17.2
Metal Office Furniture (SIC 2522)		
North East	33.2	27.7
North Central	32.6	51.8
South	15.8	12.6
West	18.4	7.9
Public Building and Related Furniture (SIC 2531)		
North East	19.0	14.7
North Central	32.5	43.5
South	30.6	28.7
West	18.0	13.0
Metal Partitions and Fixtures (SIC 2542)		
North East	39.3	27.5
North Central	30.0	49.5
South	16.6	15.3
West	14.2	7.7

Source: Derived from U.S. Census of Manufactures, 1972.

Note: North East includes New England and Middle Atlantic states; North Central states in East North Central and West North Central; South states in the South Atlantic, East South Central, and West South Central; and West states in the Mountain and Pacific regions. Individual states within the divisions are listed in Table 8.1-16.

NA -- Not Available

Table 8.1-16. GEOGRAPHICAL DISTRIBUTION OF METAL
FURNITURE INDUSTRY ESTABLISHMENTS, 1972
(In Percent of Number of Establishments)

	<u>Metal Household Furniture SIC 2514 (Percent)</u>	<u>Metal Office Furniture SIC 2522 (Percent)</u>	<u>Public Building and Related Furniture SIC 2531 (Percent)</u>	<u>Metal Partitions and Fixtures SIC 2542 (Percent)</u>	<u>Total Industry SIC 2514, 2522, 2531, 2442 (Percent)</u>
New England	5.1	3.1	4.5	4.3	4.5
Middle Atlantic	28.7	28.6	14.5	34.9	26.9
East North Central	16.3	25.0	24.9	23.3	21.9
West North Central	2.8	8.9	7.6	6.7	6.0
South Atlantic	16.1	7.3	11.4	6.9	10.8
East South Central	7.1	4.7	8.5	4.1	6.2
West South Central	5.4	4.2	10.7	5.5	6.7
Mountain	1.5	0.5	4.0	1.0	1.9
Pacific	17.1	17.7	14.0	13.2	15.1
Total Establishments (Number)	467	192	422	507	1,588

Source: 1972 Census of Manufactures.

Note: The above classifications contain the states indicated below:

New England: Main, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut; Middle Atlantic: New York, New Jersey, Pennsylvania; East North Central: Ohio, Indiana, Illinois, Michigan, Wisconsin; West North Central: Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas; South Atlantic: Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida; East South Central: Kentucky, Tennessee, Alabama, Mississippi; West South Central: Arkansas, Louisiana, Oklahoma, Texas; Mountain: Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada; Pacific: Washington, Oregon, California, Alaska, Hawaii.

8.2. COST ANALYSIS OF ALTERNATIVE EMISSION CONTROL SYSTEMS

Cost models were prepared as guides to show average costs for coating lines subject to new source performance regulations. A wide variety of coating line sizes and outputs are used in the metal furniture industry. To adequately cover this industry it was decided to construct two basic and distinct cost models. A relatively small line coating 3000,000 square feet per year (278,707 square meters), was chosen to compare solvent-borne, water-borne, high solids and powder coating all by electrostatic spray, and add-on controls. A larger output line capable of coating approximately 23,000,000 square feet per year (2,086,957 square meters) was selected to compare solvent-borne and water-borne dip coatings, electrodeposition and appropriate add-on controls. Such lines are used for high volume coating where high quality is not a prerequisite and where few colors are involved or for long runs of a single color¹. It is not the intent to show any cross comparisons between these two line sizes but to compare each on its own merits on a separate basis. The choice of lines should not be construed as limiting spray coating only to small lines or dip coating to very large lines. It is merely an attempt to show actual production situations.

Metal furniture manufacturers normally apply only one coat varying in thickness from .005" to .0015" depending on the product and the color -lighter colors tend to be applied thicker because of less hiding power. It is difficult to apply powder coatings much less than .002" in commercial production and get an acceptable finish. (See Table 4-1, Chapter 4 for typical thicknesses.) High solids coatings, because of their higher viscosities, also tend toward thicker coatings and are normally applied in the .001" to .0015" range². For the smaller electrostatic spray lines, a dry coating thickness of .001" was assumed for the conventional solvent-borne and water-borne coating models. For high solids coating, a thickness of .00125" was assumed and for powder coating, a thickness of .002" was assumed. For the dip coat and EDP lines, a coating thickness of .001" was assumed for the costing models. The majority of firms visited worked only one shift. The costing models, therefore, were based on one 8 hour shift, 240 days per year or 1920 hours per year. Capital costs include all equipment used in the coating operations except washing or other metal pretreatment equipment. Building space is included at 30¢ per square foot. Annual costs include labor, utilities, coating materials and fixed costs.

Capital costs used in the models reflect a typical installation where normal color changes are programed within the production cycle for efficient operation. Facilities requiring rapid color changes would have to be treated on an individual basis.

With the add-on controls it was assumed that all the solvents emitted from application areas and ovens went through the control unit. Most water wash spray booths have recirculating water systems. Any solvent from overspray that is captured by the water curtain is eventually evaporated into the air exhaust system³. Both incinerators and carbon adsorbers were figured as operating at an average efficiency of 90 percent.

For the smaller line, two add-on controls and three alternative painting methods were considered. Cost models are as follows:

Table 8.2-1. CASE CODES A-1 - A-7

<u>Code</u>	
A-1	Base Case - Solvent-borne coating electrostatic spray - no controls
A-2	Base Case - thermal incinerator on oven only
A-3	Base Case - carbon adsorber on spray booth and flash-off area
A-4	High solids coating - electrostatic spray
A-5	Powder coating - electrostatic spray
A-6	Water-borne coating - electrostatic spray
A-7	Base Case - carbon adsorber on spray booth and flash-off area and incinerator on oven

For the larger line, two add-on controls and two alternative coating methods were selected as follows:

Table 8.2-2. CASE CODES B-1 - B-6

<u>Code</u>	
B-1	Base Case - solvent-borne coating - dip coat
B-2	Water-borne coating - electrodeposition (EDP)
B-3	Solvent-borne dip coat - carbon adsorber on dip tank exhaust and flash-off area
B-4	Solvent-borne dip coat - thermal incinerator on oven exhaust. Primary heat recovery.
B-5	Solvent-borne dip coat - carbon adsorber on dip tank and flash-off area and incinerator on oven.
B-6	Water-borne coating - dip coat

Pertinent cost and emission data as developed from the cost models are shown in Table 8.2-3, Part I and Table 8.2-4, Part II, in order of increasing emission.

8.2.1. Cost Effectiveness Summarized -New Facilities

For new facilities the two most cost effective systems for the lower output lines are powder coating and high solids coating. The latter system achieves high emission reduction with no annual cost penalties in the model costed. The powder coating showed only a modest increase in annual costs (about 2 percent) over the conventional solvent-borne base case.

Powder coating of metal furniture is already an accepted practice, being used by many manufacturers for applying coating thicknesses of .0015" and above. Six of the metal furniture companies visited by Springborn Laboratories in the course of this study used powder coating for at least part of their coating operations. The majority of applications were by electrostatic spray although fluidized beds were also used for smaller parts and where heavy coating thicknesses (.006" and over) were desired. High solids coatings also show potential as a non-polluting, cost saving alternative to conventional coating methods. Although most work has been done in the medium solids range of 50 to 60 percent NVV, higher solids coatings are in use. The costing model was based on 80 percent solids. While considered high by many in the industry,

a major company visited by Springborn Laboratories is commercially applying an alkyd based coating at 80 percent solids after several years of development^{2,4}. Despite considerable interest in high solids coatings, there are very few lines in the metal furniture industry in commercial operation^{5,6}. Materials and application techniques are still undergoing development.

Water-borne coatings applied by electrostatic spray achieve a high emission reduction but are potentially more expensive than conventional solvent-borne coatings. Typical alkyd coatings in a water-borne formulation cost about \$1.00 per gallon more than their solvent-borne counterparts⁷. Coating lines are also more expensive as stainless steel is used in some areas to prevent rusting. There is very little action in the metal furniture industry with water-borne spray coatings^{6,8,9}.

As for control equipment, both carbon adsorption and incineration are expensive in proportion to amount of emission reduction and are more likely to be used in retrofit situations than in new facilities.

For the larger output line models, electrodeposition (EDP) is considerably more cost effective in terms of dollars per ton of reduced emissions than control options such as incineration or carbon adsorption. It is also more cost effective than water-borne dip coating primarily because of the cost of coating materials. Capital investment for EDP is higher than for dip coating, however. It should be noted that no water-borne dip coating operations were observed by Springborn Laboratories during industry visits. Water-borne coating materials suitable for dip coating, however, are available from major suppliers. Costs range 10 to 15 percent higher than for solvent-borne counterparts.

In the case of both the large and small lines controlling emissions by incineration on the oven is more expensive than by carbon adsorption on application and flash-off areas on a cost per ton of solvent removed basis.

Although both spray booth and dip tank emissions are below the 3000 pounds per day (assuming exempt solvents) allowed by the Los Angeles Rule 66 type regulations adopted by many states (as long as oven emissions are controlled), cost models were prepared controlling both application emissions and oven emissions of the solvent-borne spray line and dip coating line. As can be seen from Table 8.2-3, Case A-7 and B-5, emissions going into the control device can be reduced by 90 percent by these combinations but costs per ton of emissions reduced is considerably more than alternative coating methods.

**Table 8.2-3. ALTERNATIVE CASES - NEW FACILITIES
METAL FURNITURE - PART I**

**Model Size - Coating Capacity 3000,000 Square Feet
(278,707 square meters) Per Year**

Case No.		Total Annual Cost	Incremental Annual Cost Over Base Case	Total Coating Cost \$/Sq. Meter	Increased Cost Over Base Case \$/Sq. Meter	KG VOC Emitted Per Liter Coating (minus water)	Percent Reduction	Cost Per Metric Ton of VOC Controlled \$/Metric Ton
A-5	Powder coating	253,070	4,460	.910	.02	.01 ^a	99 ^a	261
A-7	Base - adsorber on spray booth, incinerator on oven	288,280	39,670	1.03	.14	.0545	90	2,576
A-4	High solids	243,810	(4,800)	.870	(.02)	.1678	83	0
A-6	Water-borne	278,080	29,470	.997	.11	.2272	79	2,195
A-3	Adsorber on spray booth	276,150	27,540	.990	.10	.1773	68	2,347
A-2	Incinerator on oven	260,740	12,130	.935	.04	.4226	22	3,110
A-1	Base case - solvent spray	248,610	--	.892	--	.5457	--	--

**Model Size - Coating Capacity 22,464,000 Square Feet
(2,086,957 square meters) Per Year**

B-2	EDP dip	517,200	3,900	.248	.002	.0987	93	45
B-5	Base - adsorber on application, incinerator on oven	572,940	59,640	.275	.029	.0348	90	722
B-6	Water-born dip	559,590	46,270	.268	.022	.2272	80	630
B-3	Adsorber on application	538,180	24,880	.258	.012	.2508	54	502
B-4	Incinerator on oven	548,060	34,760	.263	.017	.3490	36	1,052
B-1	Base case - solvent dip	513,300	--	.246	--	.5457	--	--

^a Some volatile organics can be emitted on the order of 0.5 to 3 percent from plasticizers or other additives. Thermoset resins which comprise the bulk of the market generally emit less than 1 percent.

**Table 8.2-4. ALTERNATIVE CASES - NEW FACILITIES
METAL FURNITURE - PART II**

**Model Size: Coating Capacity 3000,000 Square Feet
(278,707 square meters) Per Year**

<u>Case</u>	<u>Total Capital Investment</u>	<u>Increased Capital Over Base</u>	<u>Solvent Emitted</u>	
			<u>Metric Tons Per Year</u>	<u>Pounds Per Day</u>
A-5	370,000	(33,750)	<0.19 ^a	<1.7 ^a
A-7	531,410	127,660	1.7	15
A-4	350,000	(53,750)	2.86	26
A-6	496,000	92,250	3.67	34
A-3	495,750	92,000	5.5	51
A-2	439,410	35,660	13.22	121
A-1	403,750	--	17.1	157

**Model Size: Coating Capacity 22,464,000 Square Feet
(2,086,957 square meters) Per Year**

B-2	629,200	140,780	6.2	57
B-5	689,420	201,000	9.18	84.3
B-6	525,000	36,580	18.4	169
B-3	570,420	82,000	42.23	388
B-4	670,420	119,000	58.75	540
B-1	488,420	--	91.8	843

Cases correspond to codes on Tables 8.2-1 and 8.2-2

^a See footnote on Table 8.2-3

Only thirteen states currently have statewide regulations controlling organic solvent emissions from stationary sources, but eight other states with a total of twelve districts within these states have promulgated individual, non-statewide regulations. Most of these regulations are based on or are similar to Rule 66 of the Los Angeles County Air Pollution Control District.

This regulation limits oven emissions to 15 pounds per day per oven and all emissions of photoreactive solvents from any machine, equipment, or other contrivance to 40 pounds per day. The limit on "exempt" solvents is 3000 pounds per day. The law permits, however, these limits to be exceeded if the total emissions have been reduced by 85 percent or more. Most of the state and local regulations follow these limits closely.

The affected facilities in the coating line are assumed to be the application and flash-off area and the oven. As can be seen from Table 8.2-5 oven emissions from the smaller line are controlled to below the 15 pounds per day limit by incineration, high-solids coating and powder coating. Water-borne spray coatings exceed the 15 pound limit if one assumes that 50 percent of the solvents are emitted from the oven. This has found to be so in other industries (automotive) because higher boiling solvents are generally used in water-borne coatings than in conventional solvent-borne coatings where 10 to 30 percent of emissions are from the oven¹⁰. The use of water-borne coatings with a solvent content of not over 20 percent of the liquid contents, however, provides exemption from most state and local emission control laws.

For the large dip coat line only EDP coatings fall below the 15 pound level. As stated above, however, the Rule 66 type laws allow this limit to be exceeded provided emissions are reduced by at least 85 percent which is the case with incineration.

Four states and four districts have upper limits on the amounts of exempt (non-photoreactive) solvents emitted from sources other than ovens. These generally follow Rule 66, which places a limit of 3000 pounds per day - except for Connecticut, which has a limit of 800 pounds per day. In all of the model cases shown, these limits were not exceeded even with no controls, assuming of course, that exempt solvents are being used. It is the latest EPA purpose, however, to place limits on all solvent emissions not just those that are actively photoreactive^{11,12}.

**Table 8.2-5. METAL FURNITURE COATING
SOLVENT EMISSIONS FROM AFFECTED FACILITIES**

**Model Size: Capacity 3,000 Square Feet
278,707 square meters) Per Year**

<u>Model Case No.</u>	<u>Application Area</u>		<u>Oven</u>	
	<u>Metric Tons Per Year</u>	<u>Pounds Per Day</u>	<u>Metric Tons Per Year</u>	<u>Pounds Per Day</u>
A-1	12.83	118	4.27	39
A-2	12.83	118	.43	3.9
A-3	1.28	11.8	4.27	39
A-4	2.15	19.7	0.72	6.6
A-5	0	0	<0.19 ^a	<1.7 ^a
A-6	1.84	16.87	1.84	16.9
A-7	1.28	11.8	.43	4

**Model Size: Coating Capacity 22,464,000 Square Feet
(2,086,957 square meters) Per Year**

B-1	55.08	506	36.72	337
B-2	5.62	52	0.62	6
B-3	5.51	51	36.72	337
B-4	55.08	506	3.67	34
B-5	5.51	51	3.67	34
B-6	11.04	101	7.36	68

Cases correspond to codes on Tables 8.2-1. and 8.2-2.

^a See footnote on Table 8.2-3.

8.2.2. Reconstructed Facilities

Add-on controls for all intents and purposes will cost about the same as on new facilities providing space is available especially for large carbon adsorbers on spray booths and providing emissions are similar to a new facility using solvent-borne spray or dip coating. Since the latter could vary depending on the coating system chosen, it was assumed for costing purposes that the reconstructed lines had the same outputs and solvent emissions as the new facilities in Cases A-1 and B-1.

Add-on controls used are the same as those used in the new facilities as shown in Tables 8.2-6 and 8.2-7.

As for alternative coating systems such as water-borne or high solids, it is possible that a reconstructed facility could be altered to accommodate these. Each case will be different, however, depending on the degree of reconstruction. For example, it might be possible to switch to a high solids coating just by adding new guns at a cost of \$10,000 to \$20,000. A switch to powder coating on the other hand would require a recovery system as well as a new spray booth at considerable expense. Since costs to convert to a different coating system will be so variable only the add-on controls will be considered in this analysis.

Table 8.2-6. CODES A.1-1 - A.1-3

For smaller line:

Code

A.1-1	Thermal incinerator on oven exhaust
A.1-2	Carbon adsorber on spray booth exhaust
A.1-3	Incinerator on oven plus carbon adsorber on spray booth

For larger line:

Table 8.2-7. CODES B.1-1 - B.1-3

Code

B.1-1	Carbon adsorber on dip tank exhaust
B.1-2	Thermal incinerator on oven exhaust
B.1-3	Carbon adsorber on dip tank plus incinerator on oven

Pertinent cost and emission data as developed from cost models are shown in Tables 8.2-8 and 8.2-9. Costs shown are those for the control option only and are incremental to the cost of reconstructing the facility.

**Table 8.2-8. ALTERNATIVE CASES - RECONSTRUCTED FACILITIES
METAL FURNITURE - PART I**

**Model Size: Coating Capacity 3000,000 Square Feet
(278,707 square meters) Per Year**

<u>Case</u>	<u>Incremental Annual Cost</u>	<u>Incremental Cost \$/Sq. Meter</u>	<u>Kg VOC Emitted Per Liter Coating</u>	<u>Percent Reduction Total VOC</u>	<u>Cost Per Metric Ton of VOC Controlled</u>
A.1-3	39,670	.14	.0545	90	2,560
A.1-2	27,542	.10	.1773	68	2,374
A.1-1	12,130	.04	.4226	22	3,110

**Model Size: Coating Capacity 22,464,000 Square Feet
(2,086,975 square meters) Per Year**

B.1-3	59,640	.03	.0348	90	722
B.1-1	24,880	.01	.2508	54	502
B.1-2	34,760	.02	.3490	36	1,052

Cases correspond to codes on Tables 8.2-6 and 8.2-7

**Table 8.2-9. ALTERNATIVE CASES - RECONSTRUCTED FACILITIES
METAL FURNITURE - PART II**

**Model Size: Coating Capacity 3000,000 Square Feet
(278,707 square meters) Per Year**

<u>Case</u>	<u>Capital Investment of Add-on Controls</u>	<u>Solvent Emited</u>	
		<u>Metric Tons Per Year</u>	<u>Pounds Per Day</u>
A.1-3	92,000	1.7	15
A.1-2	56,340	5.5	50
A.1-1	35,660	13.22	121

**Model Size: Coating Capacity 22,864,000 Square Feet
(2,086,957 square meters) Per Year**

B.1-3	201,000	9.18	84
B.1-1	82,000	42.23	388
B.1-2	119,000	58.75	540

Cases correspond to codes on Tables 8.2-6 and 8.2-7

8.2.3. Water Pollution and Solid Waste Disposal

Control measures such as incineration and carbon adsorption do not contribute to solid waste disposal problems. Spent carbon is usually returned to the manufacturers and reprocessed. If steam is used to regenerate the carbon bed in the adsorber unit, any water miscible solvents remaining in the water can be dumped into the sewer. This can be avoided by incinerating the steam-solvent mixture.

In the electrodeposition process, water pollution and waste disposal of sludge was initially a problem but in today's modern operation a closed loop recirculating system is used whereby paint is filtered out using ultrafiltration methods and returned to the tank. The filtrate is used to rinse off excess paint from the part. A small amount of filtrate containing excess salts and solubilizers is normally dumped to the sewer and replaced with deionized water to keep the bath chemistry in balance. In a typical installation, this can amount to around 0.5 gallons per minute¹³.

With water-borne spray coatings sludge disposal problems increase compared to solvent-borne coatings. In the water wash the major portion of the overspray is thrown out of suspension forming gummy agglomerates requiring more frequent and more difficult cleaning of settling tanks. Based on information from the automotive industry, tanks had to be cleaned four times as often compared to solvent-borne coatings. In the cost model, liquid and sludge disposal costs were increased by 50 percent to reflect this. Disposal costs, however, play a relatively small part in the overall coating operation costs.

8.3. REFERENCES

1. Oge, M.T. Trip Report - Lyon Metal Products, Inc., Aurora, Illinois. Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.). Enfield, Connecticut. Trip Report 91. March 12, 1976.
2. Oge, M.T. Springborn Laboratories, Inc., Enfield, Connecticut. Telephone Conversation with Simmons Company, Charlotte, North Carolina. October 1977.
3. Holley, W.H. Springborn Laboratories, Inc. Telephone conversation with Binks Manufacturing, New Jersey. November 7, 1977.
4. Oge, M.T. Trip Report - Guidelines. Springborn Laboratories, Inc. Simmons Co., Munster, Indiana. Trip Report 41. January 28, 1976.
5. Holley, W.H. Springborn Laboratories, Inc. Telephone conversation with Ashland Chemical, Columbus, Ohio. August 24, 1977.
6. Holley, W.H. Springborn Laboratories, Inc. Telephone conversation with Hanna Chemical Coatings, Columbus, Ohio. August 25, 1977.
7. Holley, W.H. Springborn Laboratories, Inc. Telephone conversation with Lilly Industrial Coating, Indianapolis, Indiana. August 20, 1977.
8. Holley, W.H. Springborn Laboratories, Inc. Telephone conversation with Ransburg Corporation. Indianapolis, Indiana. August 29, 1977.
9. Holley, W.H. Springborn Laboratories, Inc. Telephone conversation with Lilly Industrial Coatings, Indianapolis, Indiana. August 24, 1977.
10. Air Pollution Engineering Manual, U.S. Department HEW 1967, p 711.
11. EPA declares exempt solvents will not be solution to air pollution. Industrial Finishing (magazine) April 1976, p 20.
12. EPA Solvent Game Plan, Industrial Finishing. December 1976, p 20.
13. Schrantz, W. UF Benfits Conveyorized Batch-Type EDP Systems, Industrial Finishing (magazine). November 1972, p 26.

9. RATIONALE FOR THE PROPOSED STANDARDS

This chapter presents the rationale for the selection of the emission sources, pollutants, and emission control systems for use in recommendations for an air quality standard for stationary sources in the metal furniture industry. Also discussed are modification and reconstruction considerations. The references for much of the data contained here are included in Chapters 3 through 8, which chapters develop the data for these recommendations.

9.1. SELECTION OF SOURCE FOR CONTROL

Section III of the Clean Air Act of 1970 and 1974 extends authority to EPA to regulate emissions by developing standards of performance for new stationary sources based on the degree of emission limitations achievable through the application of the best systems of emission reduction.

Section III (b), which allows EPA to limit emission of pollutants for which air quality criteria have been prescribed, is appropriate for the metal furniture industry a major source of hydrocarbon (HC) emissions. Hydrocarbon emissions from metal furniture finishing lines depend on the ratios of organic solvents to nonvolatile solids in the coatings used, the transfer efficiency of the method of applying the coatings and the quantities of coating materials used on the products. For example, lacquers having 15 to 17 volume percent solids are higher in organic solvents than enamels consisting of 30 to 35 volume percent solids. Powder coatings have volume percent volatiles ranging from less than 1 percent to 5 percent and water-borne coatings contain organic solvents in the range of 12 to 15 percent.

The sources studied are metal furniture and fixture assembly plants where the products of production are coated in a finishing operation. The coatings are applied to metal furniture or fixture pieces which will be assembled with other metal, wood, fabric, plastic or glass parts to form a furniture or fixture assembly. Included in this category are household furniture, office furniture, institutional furniture and fixtures. Household and office furniture includes tables, chairs, beds, desks, lockers, benches, shelving, file cabinets, lamps, room dividers and others. Institutional furniture is made for hospitals, schools, athletic fields, restaurants, governments offices, laboratories and other types of institutions.

Metal furniture assembly plants are generally medium to small in size with most of the companies employing 100 employees or less. The categories household, office furniture, institutional and fixtures employ nearly equal numbers of people. In terms of value of shipments, 50 largest companies had 65 percent of the metal household furniture market and in the metal office furniture 50 largest companies had 88 percent of the market. The location of about 3000 plants is distributed in the continental United States in this proportion: 43 percent in the East, 29 percent in the East Central Region, 12 percent in the West Central Region and 16 percent in the West and Pacific Coast Regions. Figure 9.1-1 shows this distribution.

The markets of the metal furniture industry are varied. Some companies sell directly to consumers through retail stores. Other companies do contract jobs for other manufacturers. Some companies specialize in certain functional furniture and purchase other pieces from outside sources which they provide to customers as an integrated suite of furniture.

Typical coating lines operate at speeds of 8 to 24 feet per minute at a continuous rate or intermittently. A plant may have more than one line. Plants operate single and multiple shifts depending on work loadings. Applications of coatings is done by the techniques of spray, dipping and flow coating which are described in detail in Chapter 4.

The major objective of new source performance standards is to obviate future air pollution problems rather than to correct them after the fact. The most practical time, from both an economic and technical viewpoint, to install pollution control equipment is during the construction phase of a new facility. Add-on systems or devices are more costly than those incorporated in the plant design, and they may not represent the application of the best technology due to constraints placed on them by existing structures and process considerations. Pollution control equipment, designed as an integral part of a process or operation, is the most effective means of reducing emissions at the least possible expense over add-on controls. New sources planned for the use of coatings low in organic solvents will avoid delays in production as the result of change-over from higher solvent systems avoiding economic benefits.

9.2. SELECTION OF POLLUTANTS AND AFFECTED FACILITIES

The pollutants for which New Source Performance Standards are being prepared are airborne organic solvents emitted from stationary sources such as metal furniture and fixture finishing lines.

100% = 3,036 Plants

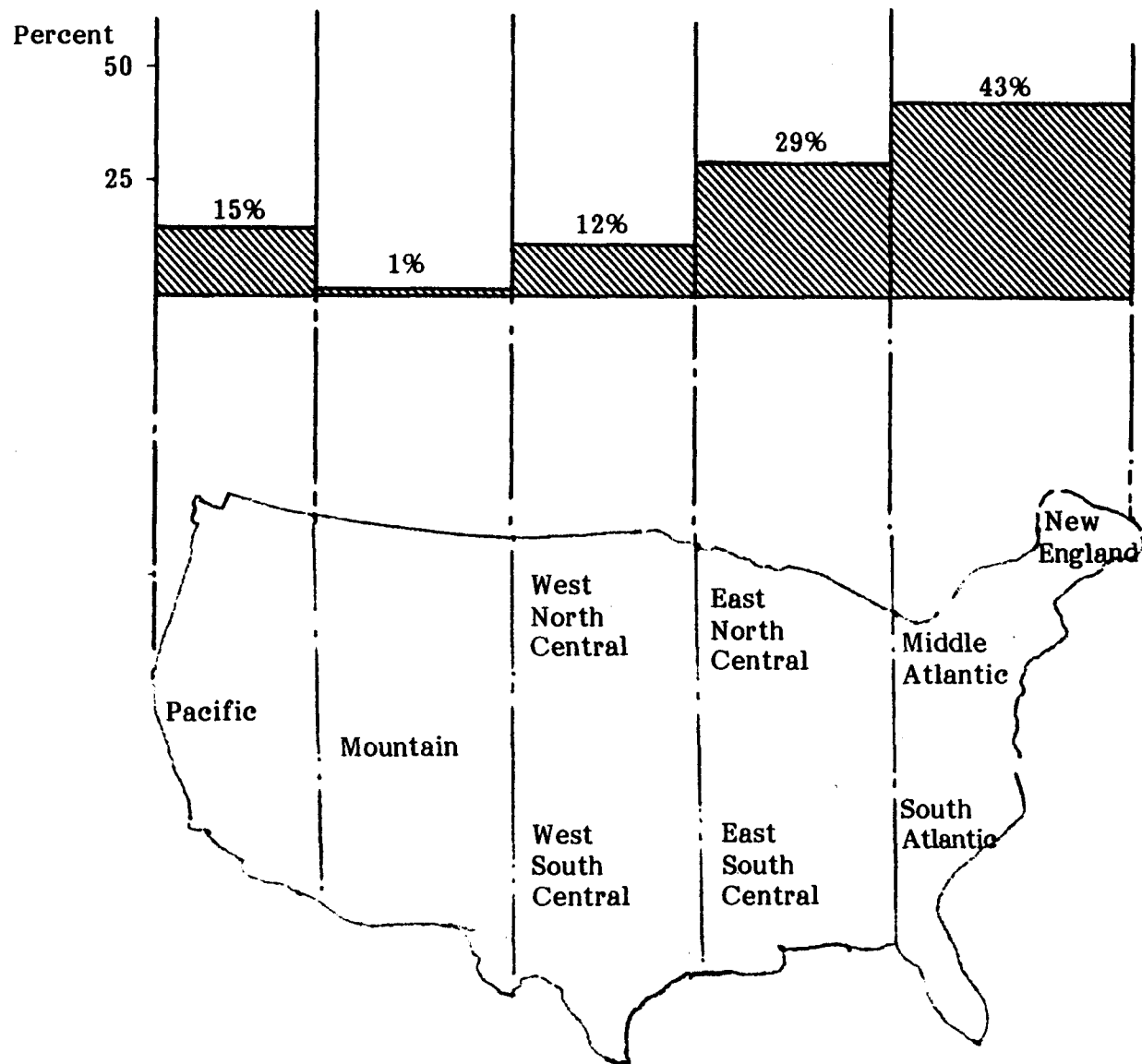


Figure 9-1. DISTRIBUTION OF 3000 PLANTS
MANUFACTURING METAL FURNITURE

The metal furniture industry uses two types of organic solvent-borne coatings: enamels and lacquers. Enamel is a type of paint consisting of an intricate dispersion of pigments in a varnish or resin vehicle. The vehicle may be an oil-resin mixture, or an entirely synthetic resin. The enamels containing drying oils are converted to film by oxidation; those comprised wholly of synthetic resins may be converted by either heat or oxygen or both.

Lacquers in contrast to enamels, do not undergo a chemical reaction when exposed to heat. Applied lacquers are dried by evaporation of the solvent to form the coating film.

The metal furniture industry uses organic solvent-borne coatings of quantity estimated to be 279 million pounds in 1975. The most widely used resins in these coatings are alkyd, others include acrylics, epoxies, polyesters, amines, vinyls and cellulose. The use of powder coatings is relatively small at this time. The organic solvents used in coatings for metal furniture are aliphatics, xylene, toluene ketones, and other aromatics. Solvents consumption of 170 million pounds annually in this industry amounts to 6 percent of the total industrial coating solvent usage.

The functions of coatings in the metal furniture industry are corrosion protection for the metal and esthetic decoration of the product. To provide these functions, coating films must be continuous with good adherence to the surface and they must be available in a variety of colors and glosses.

The process of finishing metal furniture may vary in detail from one plant to another, however, there are many features common to all plants. The application of coatings is done by spray coating, dip coating or flow coating. The process usually involves the following steps. The parts to be coated, unassembled, sub-assemblies and/or total assemblies, are loaded on a conveyor as they leave the metal fabricating shop. The parts are conveyed through a cleansing and degreasing station to prepare the surface for coating. These preparation steps are alkaline cleaning to remove light mill scale and oils, hot water rinsing, iron phosphatizing bath or spray to improve coating adhesion and prevent rusting during the process, and cold water rinsing. The parts are dried by passing them through an oven at temperatures of 121°C to 177°C (250°F to 350°C).

Some operations use a sandblasting chamber to remove mill scale, rust and other dirt and do not use the washing step.

The parts are next conveyed to the coating stations. Some parts, when required, are prime coated by one of the spray techniques applied in a spray booth or by dip or flow coating techniques. The spray booth, dip tank or flow coat nozzle enclosure are vented to the atmosphere to eliminate accumulation of organic solvents released from the coating.

The part is conveyed from the application station through an open area on its way to the bake oven. The area called the flash-off area is often necessary to allow time for the solvents in the coating to escape slowly from the wet film before it is cured. This step in the process avoids blistering the film from entrapped solvents during the bake cycle. This area is usually vented through roof fans.

The part is baked in an oven at temperatures ranging from 149°C to 204°C (300°F to 400°F).

The topcoating is applied next. In some cases this coating is the only coating applied when prime coats are not required. The topcoat is applied in a preferred color and in some plants many color changes are made which are best applied by one of the spray techniques. Flow coating and dip coating is usually restricted to the use of one or two colors where changes are infrequent.

The part to be topcoated is conveyed through the spray booth as described in the prime coat. In the case of dip coating and flow coating, conveyors carry multiple parts on holding fixtures through the application station at high unit rates of production.

Flash-off areas are in the process stream as previously described. The coated parts are baked in an oven at temperature ranges of 149°C to 232°C (300°F to 450°F).

A touch-up area may be located at the end of a line where repair of coatings is made. This work is usually done by spray application and air drying.

The affected facilities in the metal furniture coating lines are the coating application station such as a spray booth, dip tank or flow coating station which includes the flash-off area, and the curing station or bake oven or air drying location. The latter is used when ovens are not required. The touch-up area may not be considered an affected facility as the volume of solvents involved is expected to be very low.

The technology for controlling emissions at affected facilities was studied by visiting plant sites and gathering information from other metal coating operations. Emission reduction capabilities of various techniques and systems were compared for cost effectiveness. These systems are tabulated in Chapter 8.2. Such systems were selected for study on the basis that the technology to implement them was available or demonstrated to be in use in the industry or related metal fabricating industries. Emission reduction capability of add-on controls or coating systems, when compared to a model base case plant using organic solvent-borne coatings, ranges from 22 percent to nearly 100 percent.

The cost analysis of systems with these capabilities of emission reduction included all direct and indirect manufacturing costs, including an allowance for capital investment depreciation with interest charges on the capital. These emission reduction systems are based on two model plants scaled to produce, at an annual rate, 3,000,000 square feet and 22.4 million square feet of coated furniture. The smaller capacity plant model utilizes a spray application system and the larger plant model is a dip coating operation.

Cost effectiveness is measured in terms of annulized cost per metric ton of organic solvent emissions controlled. Energy effectiveness is measured in terms of British Thermal Units (BTUs) per metric ton of reduced emissions. Comparative values for control options studied are shown in Table 9.2-1 for a model operation using spray coatings and in Table 9.2-2 for a model operation using dip coatings.

The metal furniture industry organic solvent usage is estimated to be 80 thousand metric tons in 1976. The projected industry growth rate average per year is 3.8 percent for the period 1973 to 1980 and 3.3 percent for the period 1980 to 1985. If no controls on the discharge of organic solvents in the air are used over the growth forecast the organic solvent discharge could increase by approximately 37 percent in 1985 over the base year 1976. Fortunately, technology does exist that offers a means to reduce these emissions over the years to be applied to new or significantly modified sources as they become available each year in the industry.

Table 9.2-1. COMPARATIVE ENERGY AND COSTS
OF POLLUTION CONTROL SYSTEMS
FOR SPRAY COATING OPERATION

<u>Code</u>	<u>Case</u>	<u>Total Energy Usage 10⁶BTU</u>	<u>Percent Increase or (Decrease) Over Base</u>	<u>Ratio BTUx10⁶ Per Metric Ton of Reduced Emissions</u>	<u>Cost \$/Metric Ton Reduced Emissions</u>
A-5	Powder coating	3,055	(32)	178	261
A-4	High solids coating ^a	3,345	(26)	235	nil
A-6	Water-borne coating	3,359	(25)	251	2,195
	Base	4,495	--	--	--
A-3	Carbon adsorber on spray booth	4,867	8	420	2,374
A-2	Incinerator on cure oven	6,743	50	1,728	3,110
A-7	Carbon adsorber on spray booth and in- cinerator on oven	7,417	65	482	2,576

^a Estimated on high solids, 80 percent solids/volume coating used in a metal furniture.
Reference 1 in Chapter 8.2. Costs are lower in energy use and floor space.

Table 9.2-2. COMPARATIVE ENERGY AND COSTS
OF POLLUTION CONTROL SYSTEMS
FOR DIP COATING OPERATION

<u>Code</u>	<u>Case</u>	<u>Total Energy Usage 10⁶BTU</u>	<u>Percent Increase or (Decrease) Over Base</u>	<u>Ratio BTUx10⁶ Per Metric Ton of Reduced Emissions</u>	<u>Cost \$/Metric Ton Reduced Emissions</u>
B-6	Water-borne dip coating	5,027	(31)	68	630
B-1	Base	7,244	--	--	--
B-3	Solvent-borne dip coating, carbon ad- sorber on dip tank	7,390	2	149	502
B-2	Water-borne coating electrodeposition	7,778	7	91	45
B-4	Incinerator on cure oven	11,163	54	338	1,052
B-5	Carbon adsorber on dip tank and in- cinerator on oven	12,119	67	147	722

**9.3. SELECTION OF THE BEST SYSTEM OF EMISSION
REDUCTION CONSIDERING COSTS**

(To be prepared by EPA.)

9.4. SELECTION OF THE FORMAT OF THE PROPOSED STANDARD

The format for writing a standard is needed to uniformly measure performance of compliance to that standard. The term "format" is defined, for the purposed of this Chapter, as a ratio of emissions to a prescribed unit. The format could be chosen from any of the following approaches: concentration, mass/time, mass/unit of production, equipment standard, or mass/unit of coating material consumption. Each of these approaches has advantages as well as some disadvantages; however, most provide no long-range incentive to the user for energy reduction as required to abate emissions.

A brief discussion of each of these approaches will indicate why the best format for a standard is based on the mass/unit of coating material consumption.

9.4.1. Concentration - Airborne Emissions

The standards written in terms of concentration allowable in parts per million or whatever units by definition would govern the quantity of organic emissions discharged from the affected facility in terms of the quantity of air exhausted to the atmosphere from the affected facility. To enforce this format-standard would require constant monitoring of the discharge, which can be done with present technology. However, to reduce significantly the organic emissions from solvent-borne coatings, the use of add-on control equipment such as carbon adsorbers or incinerators is required. This is also possible within the present technology.

For compliance, another alternative would be to change coating formulation; but unless organic solvents were significantly reduced, the emission problem would persist.

The reduction in the use of energy by means of add-on controls required to abate organic emissions would most likely take place over a long period of time. This constitutes an indirect approach to the long-range solution of the organic emission problem.

9.4.2. Mass/Time - Airborne Emissions

This format suggests that a limitation be placed on the mass of organic emissions from an affected facility within a time period which is now in use within many states and localities within the states. The format is enforceable and requires monitoring equipment, as stated above. Also, add-on equipment involving the same

energy excesses for total abatement will be required to abate emissions from organic solvent-borne coatings. This format, as with the previous one, does not get at the root of the problem of providing an incentive to reduce the use of organic solvents and thinners in the coating.

9.4.3. Equipment Standard - Airborne Emissions

This format suggests that equipment used in the coating process be designed to meet an emission limitation. The burden of this requirement would fall on the equipment manufacturer, who probably could not comply without qualifying the type of coatings to be used with such equipment. The performance of the coating would dictate its selection by the end user, and the equipment manufacturer would want to place restrictions that would probably not be compatible with the performance of the coating. An unwieldy situation would develop and, as in the previous formats discussed, the long-range aspects of energy reduction in emission abatement would not be directly approached.

9.4.4. Mass of Emissions/Unit of Coating Material Consumed

The standards written in the format of liters or kilograms of organic emissions per liter of coating materials used by an affected facility is the most direct approach to a long-range solution to the problem of control of organic emissions from stationary sources. A programed approach to the application of this format to the industry will consider present technology availability in coatings. Each year or designated period the emission standards may be made more stringent according to a program for the industry to reduce emissions over a reasonable length of time. As a matter of interest graphic presentation of the effect on emission reduction through the use of higher solids coatings will be found in Chapter 4 - Emission Control Techniques - Figure 4-11, page 4-48

The energy consumption for emission abatement from present organic solvent-borne coatings will increase over the short-term in new stationary sources that must comply with performance standards. The use of incineration or adsorption techniques may have to be considered until higher solids coatings are used. The pressure to provide high solids coatings will be on the coating manufacturer who will respond to the industry. In the long-term, there will be in effect the incentive to use coatings with less volatiles in order to reduce energy costs of emission abatement.

There are some areas where some interpretation will be required in the use of this format. Also the format does not take into account volatile organic emissions caused by the reaction products during the curing of the coating, however, coating manufacturers may be able to supply this data.

A limitation of this format is possible under conditions where a coating facility is converted from, as an example, a conventional spray system to an electrostatic spray system improving transfer efficiency of the coating operation thereby using less coating material over a time interval resulting in less emissions. Another example of a limitation of this format would be when a different coating is used having better hiding power resulting in the use of thinner coating say changing 1.2 mils to 0.8 mils thickness. There is definitely a percentage reduction of organic emissions possible in these two examples that would not be recognized in this format. The latter case may be more prevalent in the modified or reconstructed facilities.

For the cases found in new sources and the majority of modifications reconstructions, the format will provide a straight forward means of measuring organic solvent emissions. The format will be easily measurable at the source, and the quantities of coating, volatiles, or organic solvents used per time period can be reported by the user and trade organizations. Routine monitoring tests and plant surveys will confirm compliance with new source performance standards.

9.5. SELECTION OF EMISSION LIMITS

(To be prepared by EPA.)

9.6. VISIBLE EMISSION STANDARDS

(To be prepared by EPA.)

9.7. MODIFICATION/RECONSTRUCTION CONSIDERATION

Modifications and reconstructions are discussed in Chapter 5 and are repeated here.

Proposed standards apply to all affected facilities constructed or modified after the date of proposal of the proposed standards. Provisions applying to modification and reconstruction were originally published in the Federal Register on December 23, 1971. Clarifying amendments were proposed in the Federal Register on October 15, 1974 (39 FR 36946), and final regulations were promulgated in the Federal Register on December 16, 1975 (40 FR 58416).

Modification is defined as "any physical change in, or change in the method of operation of, an existing facility which increases the amount of any air pollutant (to which a standard applies) emitted into the atmosphere by that facility or which results in the emission of any air pollutant (to which a standard applies) into the atmosphere not previously emitted". Reconstruction occurs when components of an existing facility are replaced to such an extent that:

- (1) The fixed capital cost of the new components exceeds 50 percent of the fixed capital cost that would be required to construct a comparable entirely new facility, and
- (2) It is technologically and economically feasible to meet the applicable standards.

There are certain circumstances under which an increase in emissions does not result in a modification. If a capital expenditure that is less than the most recent annual asset guideline repair allowance published by the Internal Revenue Service (Publication 534) is made to increase capacity at an existing facility and also results in an increase in emissions to the atmosphere of a regulated pollutant, a modification is not considered to have occurred.

An increase in working hours - i.e., from one to two-shift operation - or an extension from 8 hours to 10 hours per shift would also increase solvent emissions per day. This situation, however, is also not considered a modification under the definitions set forth in 40 FR 58416, December 16, 1975.

The purpose of this Chapter is to identify potential modifications and reconstructions of affected facilities, and any exemptions or special allowances covering changes in existing facilities that should be considered. Exemptions from the regulations may be based on availability of technology and economic considerations.

As will be seen, many of the possible changes do not qualify as modifications by strict definition. They are, however, potential causes of increased solvent emission and as such should be discussed.

9.7.1. Potential Modifications

The following changes in materials or formulations could cause increased solvent emissions but would qualify primarily as alternate raw materials, not as modifications, under the above definition unless capital expenditures are required to effect the change so as to qualify as a reconstruction.

(1) Lower Solids Coatings

If a change is made from a higher solids to a lower solids coating—e.g., from an enamel to a lacquer—more material, hence more solvent, will be used to maintain the same dry coating thickness. While a change in the direction of lower solids is unlikely, it could occur in any one plant as a result of changing paint systems or colors. It is unlikely, however, that any major capital expenditures to equipment would be required.

(2) Use of Higher Density Solvent

Regulations normally restrict the number of pounds of solvent which can be emitted. A change in the density of the solvents used, even if the volumetric amounts used were the same, would result in more pounds or kilograms being emitted. Again, this could be construed as a raw-material substitution and hence not a modification, as no major capital expenditures would be involved. Such substitutions might come about as a result of solvent shortages, attempts to cut paint costs, or efforts to incorporate less photoreactive solvents.

(3) Increased Thinning of Coatings

A change to a higher viscosity coating could result in an increased use of solvents for thinning the coating to proper application consistency.

While these three cases can be considered as raw material substitutions, they are not of themselves considered to be modifications. The phrase "bubble concept" has been used in Title 40 FR 58416, to refer to a trade-off of emission increases from one facility undergoing a physical or operational change with emission reductions from another facility in order to achieve no net increase in the amount of any air pollutant (to which a standard applies) emitted into the atmosphere by the stationary source as a whole.

Title 40 FR 58416 states: "In those cases where utilization of the exemptions under Paragraph 60.14 (e) (2), (3), or (4) as promulgated herein would effectively negate the compliance measures originally adopted, use of those exemptions will not be permitted."

Other changes that could be made that could result in increased solvent emission include:

(4) Change to Larger Parts

If part sizes were increased and the same production rates were maintained, more coating materials would be used. With the diversity of products produced by the metal furniture industry, it is somewhat difficult to see why this could occur unless a manufacturer began production of large parts such as desks or panels that he had not produced before.

Coating lines in this industry, however, are generally equipped to handle many size parts hence such a change would not qualify as a modification per se. If extensive capital expenditures were involved, such a change could be classified as a reconstruction.

(5) Change to Thicker Coatings

A change to a thicker coating, other factors remaining constant, could result in increased solvent emission. Such a change could result from a desire to increase durability or resistance to outdoor exposure. Most metal furniture manufacturers, especially of office furniture, apply as thin a coating as possible, however.^a

(6) Reduced Deposition Efficiency

Increased overspray because of a process modification such as a switch from electrostatic spray to conventional spray would result in increased emission. For economic reasons if for nothing else, however, a switch in such a direction is unlikely except possibly as a temporary measure.

(7) Additional Coating Stations

If for any reason additional coating stations were added, emissions would be increased. It is possible that new paint systems could result in such a change. This could involve a reconstruction or a new facility and, as such, would be subject to regulation.

9.7.2. Substitution of Equipment

There can be cases where in existing sources coating line configurations are of a temporary nature to perform custom jobs. Certain custom coaters in this metal furniture industry perform metal coating services only. These services are offered to metal furniture manufacturers on a contract basis. In the course of this type of business the coating line configuration may be changed to meet requirements of a specific contract job. For example, existing coating line components such as spray booths and dip tanks may be interchanged to accommodate different jobs. Another example, existing ovens may be lengthened or shortened for each job. The aforementioned changes do not constitute a modification. It is the intent to allow the custom coater to make changes of this nature for short-term contract business without invoking compliance with new source performance standards.

Installation of a line or affected facility previously used at another plant site however will require compliance to new source performance standards.

^a Chapter 5

9.7.3. Reconstruction

Spray booths and bake ovens used in coating metal furniture last ten to twenty years² and are not replaced before that time unless process changes dictate it. In some cases a line may be moved to another location within the plant and booths or ovens may fall apart necessitating some rebuilding.

Reconstructions would include replacement of spray booths either because of deterioration or because of more advanced design such as the addition of more automatic spraying or electrostatic spraying, if not already being used.

A line could be made longer or faster to permit increased production. This would be considered a reconstruction as long as the requirements outlined in the beginning of this chapter are met.

Ovens could be replaced with more efficient models or to accomodate new energy sources such as electricity.

Changing coating application methods such as from dip coating to electrostatic spray would qualify as a reconstruction, again if requirements were met.

It should be noted that according to 40 FR 58416 that an existing facility, upon reconstruction becomes an affected facility and hence subject to regulation irrespective of any change in emission rate.

It should also be noted that according to 40 FR 58416, Part 60, the decision as to whether a reconstructed facility can meet applicable standards both technologically and economically rests with the EPA Administrator. For example, if the equipment being replaced does not emit air pollutants, it may be determined that controlling the components that do emit air pollutants is not reasonable considering cost, and standards of performance for new sources should not be applied. As another example, if there is insufficient space after the replacements at an existing facility to install the necessary air pollution control system to comply with standards of performance, then reconstruction would not be determined to have occurred.

9.7.4. Constraints

Probably the greatest physical constraint to switching to new coating systems with lower solvent emissions is the added space requirements of some of the systems. The seriousness of this constraint will, of course, vary from line to line or plant to

plant. Plants with very tight space requirements might find it difficult to fit in the longer oven and flash-off area required by water-borne spray systems. Electrodeposition tanks are long to allow the necessary immersion time and rinse area.

Add-on controls for controlling bake oven emissions such as incinerators are relatively small and usually can be mounted on top of the oven. It could be difficult if space were tight to find room for a large carbon adsorber to handle spray booth emissions.

Incinerators, especially if used for controlling spray booth emissions, use a great deal of fuel even with heat recovery. This constraint is considered very sensitive in this era of energy shortages.

9.8. SELECTION OF MONITORING REQUIREMENTS

(To be prepared by EPA.)

9.9. SELECTION OF PERFORMANCE TEST METHODS

(To be prepared by EPA.)

APPENDIX A. EVOLUTION OF PROPOSED STANDARDS

June 27, 1975

EPA authorized Springborn Laboratories, Inc. (formerly DeBell & Richardson, Inc.) to conduct an Air Pollution Control Engineering and Cost Study on the General Surface Coating Industry including the Metal Furniture Industry. Springborn Laboratories Program Manager: Dr. Bernard Baum. EPA Contract Project Officer: David Patrick.

August 11, 15, 20, 1975

Springborn Laboratories conducted an equipment survey to review coating equipment, contacting manufacturers by telephone.

August 25, 1975

Springborn Laboratories visited Nordson Corporation in Amherst, Ohio to discuss powder coating application in the industrial coating industry.

August 27, 1975

Springborn Laboratories visited Interrad Corporation in Stamford, Connecticut to discuss powder coating technology and equipment.

August 28, 1975

Springborn Laboratories met with EPA representatives in Durham, North Carolina, to discuss progress of the study.

September 26, 1975

Office of Management and Budget approved the EPA questionnaire for distribution in the industrial finishing industry.

January 28, 1976

Springborn Laboratories visited the Simmons Company plant in Munster, Indiana to observe the high solids coating operation and to obtain related data.

February 11, 1976

Springborn Laboratories visited Virco Manufacturing Corporation plant in Gardena, California. The purpose of the visit was to observe a powder coating metal

furniture line and a solvent coating metal furniture line with an incinerator. Data on powder coating operations were obtained.

February 24, 1976

Springborn Laboratories visited the Steelcase Company plant in Grand Rapids, Michigan to observe the metal furniture coating operation. Information on powder coating was obtained.

March 8, 1976

Springborn Laboratories visited Goodman Brothers Manufacturing Company plant in Philadelphia, Pennsylvania to observe the powder coating operation.

March 8, 1976

Springborn Laboratories visited the Bunting Company plant in Philadelphia, Pennsylvania to observe the powder coating of outdoor household furniture. Information on powder coating was obtained.

March 12, 1976

Springborn Laboratories visited Lyon Metal Products, Inc. plant in Aurora, Illinois to observe the solvent-borne coating of metal office furniture and to collect related data.

April 2, 1976

Springborn Laboratories visited Herman Miller, Inc. plant in Zeeland, Michigan. The purpose of the visit was to observe the powder coating operation of metal furniture and to obtain related data.

April 5, 1976

Springborn Laboratories visited Angel Steel Company plant in Plainwell, Michigan to observe the electrodeposition coating operation for metal furniture and to obtain related data.

April 6, 1976

Springborn Laboratories visited U.S. Furniture Industries, Blacksmith Shop Division in Highpoint, North Carolina to observe the powder coating operation of metal furniture.

April 21, 22, 23, 1976

Springborn Laboratories attended Chemical Coatings Conference in Cincinnati, Ohio.

September 26, 1976

Springborn Laboratories visited Georg Koch & Sons, Inc., Evansville, Indiana to review available finishing technology.

July 15, 1976

The first interim report on Air Pollution Control Engineering and Cost Study of the Surface Coating Industry was sent to EPA, Triangle Park, North Carolina. Metal Furniture Coating Industry was included.

August 23, 1976

The second interim report on Air Pollution Control Engineering and last study of the Surface Coating Industry was sent to EPA, Triangle Park, North Carolina. Metal Furniture Coating Industry was included.

May 19, 1977

Springborn Laboratories met with EPA in Triangle Park, North Carolina to discuss general surface coating projects.

June 14, 1977

Springborn Laboratories was authorized to continue and complete the study to support New Source Performance Standards for metal furniture coating.

August 23, 1977

Springborn Laboratories made a telephone survey to resin suppliers to discuss present status of high solids coating for metal furniture.

August 25, 1977

Springborn Laboratories made a telephone survey to resin suppliers to discuss present status of powder coatings and water-borne coatings for metal furniture.

APPENDIX B. INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)

Location Within the Standards Support and Environmental Impact Statement

Background description of the domestic metal furniture industry (number of plants, location, production, trends, etc.).

Chapter 3, pages 3-1 through 3-4. Data are found also on pages 7-1 and 7-2.

General procedures, basic processes.

Chapter 3, Sections 3.2.1.1 and 3.2.1.2; pages 3-5 through 3-13.

Processes or facilities and their emissions

Chapter 3, Section 3.2.3; pages 3-15 through 3-16.

Affected facilities and types of sources.

Chapter 4, Sections 4.1.1 through 4.2.8; pages 4-1 through 4-49. Chapter 9, Section 9.1. and 9.2; pages 9-1 through 9-8.

Modifications and reconstructions.

Chapter 5, pages 5-1 through 5-5.

Emission control technology.

A discussion of the alternative emission control systems and their effectiveness is presented in Chapter 6; pages 6-1 through 6-13.

The various relationships between these alternatives are tabulated in Tables 6-1, and 6-2; pages 6-2 and 6-3.

Flow diagrams illustrating these alternative systems are presented in Figures 6-1 through 6-7; pages 6-5, 6-6, 6-8 through 6-10, 6-12 and 6-13.

Environmental impacts of suggested alternative control systems.

A discussion of the suggested alternative control systems is presented in Chapter 7.

Estimated hydrocarbon emission reduction in future years is discussed in Section 7.1.3. These are shown also in a tabulated form for 1976 through 1985 in Tables 7-3 through 7-8; pages 7-11 through 7-16.

**Agency Guidelines for Preparing Regulatory
Action Environmental Impact Statements
(39 FR 37419)**

**Location Within the Standards Support
and Environmental Impact Statement**

Secondary impacts associated with the suggested alternative control systems.

Secondary impacts are discussed under Chapter 7, Section 7.2 (water); pages 7-17 through 7-18. Section 7.3. (solid waste disposal); pages 7-18 through 7-20. Section 7.4. (energy); pages 7-20 through 7-22.

Tables 7-9 and 7-10 show energy balances and energy requirements of the various suggested alternative control systems.

Other environmental impacts and concerns.

Chapter 7, Sections 7.5 and 7-6 discuss impacts other than primary and secondary impacts associated with the suggested alternative control systems; pages 7-23 and 7-24.

Extension of time and effective date of standards.

Chapter 7, Sections 7.6.2 and 7.6.3, deal with impacts of delayed and no standards; pages 7-23 and 7-24.

Energy requirements for alternative control systems.

Chapter 7, Section 7.4, Tables 7-9 and 7-10 show energy balances in tabulated form; pages 7-21 and 7-22.

Economic impacts of alternative control systems.

Chapter 8, Section 8.1 and 8.2; pages 8-1 through 8-38.

Capital and operating costs for alternate control systems

Chapter 8, Section 8.1 and 8.2; pages 8-1 through 8-38.

Affected facilities and energy requirements.

Chapter 9, Section 9.2; pages 9-2 through 9-8.

Cost effectiveness for emission reduction

Chapter 9, Section 9.

State regulations and controlled emissions.

Chapter 7, Section 7.1.1, pages 7-3 through 7-5.

Uncontrolled emissions.

Chapter 7, Section 7.1.2; page 7-5.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-450/3-78-006		2.		3. RECIPIENT'S ACCESSION NO.	
4. TITLE AND SUBTITLE Study to Support New Source Performance Standards for Surface Coating of Metal Furniture				5. REPORT DATE April 1978	
				6. PERFORMING ORGANIZATION CODE	
7. AUTHOR(S) Springborn Laboratories, Inc.				8. PERFORMING ORGANIZATION REPORT NO.	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Springborn Laboratories, Inc. Enfield, Connecticut 06080 (Formerly DeBell & Richardson, Inc.)				10. PROGRAM ELEMENT NO.	
				11. CONTRACT/GRANT NO. EPA 68-02-2075	
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Protection Agency Office of Air Quality Planning & Standards Emission Standards & Engineering Division Research Triangle Park, N.C. 27711				13. TYPE OF REPORT AND PERIOD COVERED Final	
				14. SPONSORING AGENCY CODE 200/04	
15. SUPPLEMENTARY NOTES					
16. ABSTRACT The purpose of this report is to provide the information for EPA to establish Standards of Performance for New Stationary Sources under Section 111 of the Clean Air Act as amended. Included are descriptions of the industry, organic emission control techniques and their costs.					
17. KEY WORDS AND DOCUMENT ANALYSIS					
a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS		c. COSATI Field/Group	
Air Pollution Control Equipment Hydrocarbons Organic Solvents New Source Performance Standard Metal Furniture, Surface Coating Paint		Air Pollution Control Stationary Sources Hydrocarbons Organic Solvent Emission Control			
DISTRIBUTION STATEMENT Unlimited		19. SECURITY CLASS (This Report) Unclassified		21. NO. OF PAGES 212	
		20. SECURITY CLASS (This page) Unclassified		22. PRICE	