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Surface Coating of Metal Furniture - Background Information for Proposed Standards

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Surface Coating of Metal Furniture - Background Information for Proposed Standards

Emission Standards and Engineering Division

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

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ENVIRONMENTAL PROTECTION AGENCY

Background Information
and Draft
Environmental Impact Statement
for Surface Coating of Metal Furniture

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1. The proposed standards of performance would limit emissions of volatile organic compounds from new, modified, and reconstructed facilities for surface coating of metal furniture. Section 111 of the Clean Air Act (42 U.S.C. 7411), as amended, 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 proposed standards of performance are expected to affect all regions of the nation.

2. Copies of this document have been sent to the following Federal Departments: Labor; Health and Human Services; Defense; Transportation; Agriculture; Commerce; Interior; and Energy; the National Science Foundation; and Council on Environmental Quality; to members of the State and Territorial Air Pollution Program Administrators (STAPPA) and the Association of Local Air Pollution Control Officials (ALAPCO); to EPA Regional Administrators; and to other interested parties.

3. The comment period for review of this document is 60 days and is expected to begin on or about September 22, 1980.

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1. INTRODUCTION

1.1 BACKGROUND AND AUTHORITY FOR STANDARDS

Before standards of performance are proposed as a Federal regulation, air pollution control methods available to the affected industry and the associated costs of installing and maintaining the control equipment are examined in detail. Various levels of control based on different technologies and degrees of efficiency are expressed as regulatory alternatives. Each of these alternatives is studied by EPA as a prospective basis for a standard. The alternatives are investigated in terms of their impacts on the economics and well-being of the industry, the impacts on the national economy, and the impacts on the environment. This document summarizes the information obtained through these studies so that interested persons will be privy to the information considered by EPA in the development of the proposed standard.

Standards of performance for new stationary sources are established under Section 111 of the Clean Air Act (42 U.S.C. 7411) as amended, hereinafter 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 reduction achievable which (taking into consideration the cost of achieving such emission reduction, and any nonair quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated for that category of sources." 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 that apply to the process of establishing standards of performance.

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

a. 25 percent of the listed categories by August 7, 1980.

b. 75 percent of the listed categories by August 7, 1981.

c. 100 percent of the listed categories by August 7, 1982.

A governor of a State may apply to the Administrator to add a category not on the list or may apply to the Administrator to have a standard of performance revised.

2. EPA is required to review the standards of performance every 4 years and, if appropriate, revise them.

3. EPA is authorized to promulgate a standard based on design, equipment, work practice, or operational procedures when a standard based on emission levels 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- or non-polluting process or operation.

5. The time between the proposal and promulgation of a standard under section 111 of the Act may be extended to 6 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 nonair-quality health and environmental impacts, 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 that 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 Sections 111 or 112 of this Act. (Section 169(3))

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(j) 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 the public health, welfare, or safety; (4) the governor of the State where the source is located consents; and (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 3 years to meet the standards with a mandatory progress schedule.

1.2 SELECTION OF CATEGORIES OF STATIONARY SOURCES

Section 111 of the Act directs the Adminstrator to list categories of stationary sources. 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.

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 emitted by stationary sources. Source categories that emit these pollutants are 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 preselected future year by standards of performance for the source category. Sources for which new source performance standards were promulgated or 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 major source categories not yet listed by EPA. These are: (1) the quantity of air pollutant emissions that 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.

The Administrator is to promulgate standards for these categories according to the schedule referred to earlier.

In some cases it may not be feasible immediately to 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, inablility 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, the types of facilities within the source category to which the standard will apply must be determined. A source category may have several facilities that cause air pollution, and emissions from some of these facilities may vary from insignificant to 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.

1.3 PROCEDURE FOR DEVELOPMENT OF STANDARDS OF PERFORMANCE

Standards of performance must (1) realistically reflect best demonstrated control practice; (2) adequately consider the cost, the nonair-quality health and environmental impacts, and the 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 developing standards is to identify the best technological system of continuous emission reduction that has been adequately demonstrated. The standard-setting process involves three principal phases of activity: (1) information gathering, (2) analysis of the information, and (3) development of the standard of performance.

During the information-gathering phase, industries are queried through a telephone survey, letters of inquiry, and plant visits by EPA representatives. Information is also gathered from many other sources to provide reliable data that characterize the pollutant emissions from well-controlled existing facilities.

In the second phase of a project, the information about the industry and the pollutants emitted is used in analytical studies. Hypothetical "model plants" are defined to provide a common basis for analysis. The model plant definitions, national pollutant emission data, and existing State regulations governing emissions from the source category are then used in establishing "regulatory alternatives." These regulatory alternatives are essentially different levels of emission control.

EPA conducts studies to determine the impact of each regulatory alternative on the economics of the industry and on the national economy, on the environment, and on energy consumption. From several possibly applicable alternatives, EPA selects the single most plausible regulatory alternative as the basis for a standard of performance for the source category under study.

In the third phase of a project, the selected regulatory alternative is translated into a standard of performance, which, in turn, is written in the form of a Federal regulation. The Federal regulation, when applied to newly constructed plants, will limit emissions to the levels indicated in the selected regulatory alternative.

As early as is practical in each standard-setting project, EPA representatives discuss the possibilities of a standard and the form it might take with members of the National Air Pollution Control Techniques Advisory Committee. Industry representatives and other interested parties also participate in these meetings.

The information acquired in the project is summarized in the Background Information Document (BID). The BID, the standard, and a preamble explaining the standard are widely circulated to the industry being considered for control, environmental groups, other government agencies, and offices within EPA. Through this extensive review process, the points of view of expert reviewers are taken into consideration as changes are made to the documentation.

A "proposal package" is assembled and sent through the offices of EPA Assistant Administrators for concurrence before the proposed standard is officially endorsed by the EPA Administrator. After being approved by the EPA Administrator, the preamble and the proposed regulation are published in the Federal Register.

As a part of the Federal Register announcement of the proposed regulation, the public is invited to participate in the standard-setting process. EPA invites written comments on the proposal and also holds a public hearing to discuss the proposed standard with interested parties. All public comments are summarized and incorporated into a second volume of the BID. All information reviewed and generated in studies in support of the standard of performance is available to the public in a "docket" on file in Washington, D. C.

Comments from the public are evaluated, and the standard of performance may be altered in response to the comments.

The significant comments and EPA's position on the issues raised are included in the "preamble" of a "promulgation package," which also contains the draft of the final regulation. The regulation is then subjected to another round of review and refinement until it is approved by the EPA Administrator. After the Administrator signs the regulation, it is published as a "final rule" in the Federal Register.

1.4 CONSIDERATION OF COSTS

Section 317 of the Act requires 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, including the extent to which the cost of compliance varies depending on the effective date of the regulation and the development of less expensive or more efficient methods of compliance; (2) the potential inflationary or recessionary effects of the regulation; (3) the effects the regulation might have on small business with respect to competition; (4) the effects of the regulation on consumer costs; and (5) the effects of the regulation on energy use. Section 317 also requires that the economic impact assessment be as extensive as practicable.

The economic impact of a proposed standard upon an industry is usually addressed both in absolute terms and in terms of the control costs that would be incurred as a result of compliance with typical, existing State control regulations. An incremental approach is necessary because 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 economic impact from the cost differential that would exist between a proposed standard of performance and the typical State standard.

Air pollutant emissions may cause water pollution problems, and captured potential air pollutants may pose a solid waste disposal problem. The total environmental impact of an emission source must, therefore, be analyzed and the costs determined whenever 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 for proposed standards. It is also essential to know the capital requirements for pollution control systems already placed on plants so that the additional capital requirements necessitated by these Federal standards can be placed in proper perspective. Finally, it is necessary to assess the availability of capital to provide the additional control equipment needed to meet the standards of performance.

1.5 CONSIDERATION OF ENVIRONMENTAL IMPACTS

Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969 requires 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 decisionmaking 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 United States Court of Appeals for the District of Columbia Circuit has 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 Court of Appeals has determined that the best system of emission reduction requires the Administrator to take into account counterproductive environmental effects of a proposed standard, as well as economic costs to the industry. On this basis, therefore, the Court 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" (15 U.S.C. 793(c)(1)).

Nevertheless, the Agency has concluded that the preparation of environmental impact statements could have beneficial effects on certain regulatory actions. Consequently, although not legally required to do so by Section 102(2)(C) of NEPA, EPA has adopted a policy requiring that environmental impact statements 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 in this document 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 discussed.

1.6 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 is redefined as a new source if "modified" or "reconstructed" as 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).

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).

1.7 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 4 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.

1.8 EXECUTIVE SUMMARY OF REGULATORY ALTERNATIVE IMPACTS

Chapter 5 of this BID describes the selected regulatory alternatives. The bases of selection of these regulatory alternatives are presented in Chapters 2 through 4 of this document. Chapters 5, 6, and 7 contain information pertaining to the environmental and economic impacts for each of the regulatory alternatives, respectively. The regulatory alternatives selected for controlling volatile organic compounds (VOCs) from surface coating of metal furniture are:

Regulatory alternatives	Typical control option	Additional emission reduction from SIPs (percent)	Control options to meet regulatory alternative
I	(a) SIP - 60 percent solids coating	Baseline 0	(a) through (f)
II	(b) 60 to 70 percent solids coating	30	(a) through (f)
	(c) SIPs and Incineration	30 to 50	
III	(d) Waterborne coatings	50	(c), (d), (e), and (f)
IV	(e) Waterborne (electrodeposition)	85	(e) and (f)
	(f) Powder	≅100	

The environmental and economic impacts of each regulatory alternative are summarized in the next two sections.

1.9 ENVIRONMENTAL IMPACT

A summary of the environmental impacts for each regulatory alternative is contained in Table 1-1. These impacts are detailed in Chapter 6 of this BID. The most beneficial regulatory alternative from an environmental impact standpoint is Number IV.

1.10 ECONOMIC IMPACT

None of the regulatory alternatives cause an irreversible economic impact upon the metal furniture industry. However, the higher the emission reduction requirements (Regulatory Alternative III and IV), the more costly it becomes for the industry to comply.

Table 1-1. MATRIX OF ENVIRONMENTAL AND ECONOMIC IMPACTS OF THE PROPOSED SURFACE COATING OF METAL FURNITURE EMISSION LIMITS

Control option (regulatory alternative) \ Impact	Air	Water pollution	Solid waste	Energy	Noise	Economic	Inflationary
Powder, electrostatic spray (Regulatory Alternative IV)	+4**	+3**	+2*	+3**	0	+1** to -2**	+1** to -2**
Powder, fluidized bed (Regulatory Alternative IV)	+4**	+3**	-2**	+2**	0	-3**	-2**
Waterborne, Electrostatic Spray (Regulatory Alternative III)	+3**	-1*	-1*	+2**	0	-2**	-1*
Waterborne, Dip, and Flow (Regulatory Alternative III)	+3**	-1*	0	+2**	0	-1*	-1*
Waterborne, Electrodeposition (Regulatory Alternative IV)	+4**	-1*	+3**	+1**	0	-3*	-1**
High Solids (Regulatory Alternatives I or II)	+3**	-1*	-1*	+2**	0	+1*	0
Incinerator plus High Solids or Waterborne (Regulatory Alternatives I, II, or III)	+3**	-1*	-1*	+1*	0	-1*	0

Key:

+ Beneficial
- Adverse Impact

0 No Impact
1 Negligible Impact
2 Small Impact
3 Moderate Impact
4 Large Impact

* Short-term Impact
** Long-term Impact
*** Irreversible Impact

2. THE METAL FURNITURE INDUSTRY

2.1 GENERAL DESCRIPTION

The metal furniture industry consists of the following industry groups and subgroups:

<u>Metal household furniture (SIC 2514)</u>
Dining and breakfast furniture
Kitchen furniture
Porch, lawn, and outdoor furniture
Other metal household furniture
Metal household furniture, nsk (not specified by kind)

<u>Metal office furniture (SIC 2522)</u>
Metal office seating
Desks
Cabinets and cases
Other metal office furniture including tables, standard, etc.
Metal office furniture, nsk (not specified by kind)

<u>Public building and related furniture (SIC 2531)</u>
School furniture, except stone and concrete
Public building and related furniture, except school furniture
Public school furniture, nsk

<u>Metal partitions and fixtures (SIC 2542)</u>
Metal partitions
Metal shelving and lockers
Metal storage racks and accessories

Metal partitions and fixtures (SIC 2542) (continued)

Metal fixtures for stores, banks, offices and miscellaneous fixtures

Metal partitions, shelving, lockers, fixtures, nsk

The industry includes approximately 1400 establishments employing approximately 100,000 people. The term "establishment" means a plant, rather than a company; i.e., a company can consist of more than one establishment. In this industry, however, few companies actually have more than one establishment. In 1972, the average number of establishments per company in SICs 2522, 2531, and 2542 were 1.16, 1.04, and 1.05, respectively.[1] (No similar data for SIC 2514 are available).

Table 2-1 shows a distribution of establishments according to employment size classes. The four distributions are remarkably consistent with each other: all four show definite biases toward small plants. Fifty percent of the establishments in the metal furniture industry, viewed as a whole, have less than twenty employees, and eighty percent have less than 100 employees.

The industry size diversity is also demonstrated by a study of the annual paint consumption rates of the plants in existence.[2-16] This breakdown is shown in Table 2-2. These data were used to determine size categories for the model plants presented in Chapter 5 of this document.

2.2 PROCESSES OR FACILITIES AND THEIR EMISSIONS

2.2.1 The Basic Process

The metal furniture coating industry utilizes primarily solvent-borne coatings being applied by spray, dip, and flow coating processes. Dry coating thickness is generally in the area of 1 mil.[2-16] Coatings for metal furniture must be resistant to abrasion and maintain a good appearance. In addition, metal furniture must often be able to withstand regular cleaning with harsh detergents.

The coatings used in the industry consist primarily of solvent-borne resins. Other coatings include acrylics, amines, vinyls, and cellulosics. Some metallic coatings are also used on office furniture. The solvents used are mixtures of aliphatics, xylene, toluene, and other aromatics.

Table 2-1. DISTRIBUTION OF ESTABLISHMENTS BY EMPLOYMENT SIZE

SIC code	Industry group	Employment size class							
		Total	1-9	10-19	20-49	50-99	100-249	250-499	> 500
2514	Metal household furniture								
	Number of establishments	391	128	69	64	42	47	35	6
	Percent of establishments	100	33	18	16	11	12	9	2
2522	Metal office furniture								
	Number of establishments	177	42	25	23	25	38	12	9
	Percent of establishments	100	24	14	13	14	21	7	5
2531	Public building and related furniture								
	Number of establishments	377	133	52	92	44	43	12	1
	Percent of establishments	100	35	14	24	12	11	3	<1
2542	Metal partitions and fixtures								
	Number of establishments	449	167	71	102	49	45	11	4
	Percent of establishments	100	33	16	23	11	10	2	1
	Totals for four industry groups								
	Number of establishments	1394	470	218	281	160	173	70	20
	Percent of establishments	100	34	16	20	11	12	5	2
	Cumulative percent of establishments	100	49	49	69	80	92	Approx. 100	

Source: U. S. Department of Commerce, Bureau of the Census, County Business Patterns 1976, CBP-76-1.

Table 2-2. DISTRIBUTION OF ESTABLISHMENTS BY PAINT CONSUMPTION

SIC code	Industry group	Annual paint consumption (liters)						
		Total	0-2000	2001-7500	7501-40000	40001-115000	115000-190000	>190001
2514	Metal Household Furniture							
	Number of establishments	391	39	90	133	51	27	51
	Percent of establishments	100	10	23	34	13	7	13
2522	Metal Office Furniture							
	Number of establishments	177	9	35	53	9	44	27
	Percent of establishments	100	5	20	30	5	25	15
2531	Metal Office Furniture							
	Number of establishments	377	30	31	158	98	30	30
	Percent of establishments	100	8	8	42	26	8	8
2542	Metal Partitions and Fixtures							
	Number of establishments	449	67	45	135	67	45	90
	Percent of establishments	100	15	10	30	15	10	20
	Totals for Four Industry Groups							
	Number of establishments	1395	145	201	479	225	146	198
	Percent of establishments	100	10	14	35	16	11	14
	Cumulative percent of establishments	100	10	24	59	75	86	100

The metal furniture coating industry solvent emissions are directly related to the types of coating materials used and the technique with which they are applied. Typical coatings presently used contain 65 volume percent solvent and 35 percent solids.[2-16] Other types of coatings such as waterborne, high solids and powder are beginning to appear in the industry. These will be further discussed in Chapter 3.

Application, or transfer, efficiencies range from 30 to 95 percent depending upon the application technique and the configuration of the item being coated.[17,18] Application efficiency does not affect emissions from the curing oven; however, it is a major factor in emissions from the coating application step. It is important, therefore, to achieve the highest application efficiency possible. Application efficiency may be calculated by the following equation:

$$E = \frac{(A)(T)(1000) \div (S/100)}{Q}$$

where, E = Application efficiency

A = Area coated (square meters)

T = Dry coating thickness (meters)

S = Solids content of paint (volume percent)

Q = Quantity of paint applied (liters)

2.2.1.1 Spray Coating. Spray coating is the most common application technique used. Spray coating lines generally consist of six major steps. These may vary, however, from plant to plant. These steps are listed below:

1. Three- or five-stage washer
2. Oven
3. Manual touch-up spray
4. Electrostatic spray
5. Manual touch-up spray
6. Oven

Furniture pieces are loaded onto an overhead conveyor moving at speeds ranging from 2.5 to 7 meters per minute. This conveyor carries the pieces through all steps of the coating process. Figure 2-1 provides a block diagram of the steps involved in the process.

A five-stage cleaning process contains the following steps:

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

The alkaline cleaning removes oil and grease and the phosphate treatment improves the adhesion characteristics of the surface. Most metal furniture coating operations use only three stages eliminating the chromic wash and cold water rinse.

After washing, the parts pass through a dry-off oven and then into a touchup booth where manual spray guns apply a reinforcement coating to the parts prior to topcoat application. This step is generally eliminated in metal furniture coating operations and a one coat process is used.

The topcoat operation is, naturally, the most important step in the finishing process. The paint is applied by manual or automatic electrostatic spraying. Application efficiency for electrostatic spraying varies from 60 to 95 percent depending upon the type of application equipment and the configuration of the item being painted.[18] Application efficiency for flat surfaces is generally 85 percent and for complex shaped objects it is 65 percent. Because of the length of time that the item is in the spray booth and flash-off area, approximately 70 percent of the solvent evaporates prior to the curing step.[19]

Color changes present no great problem for electrostatic spraying. In manual operations, the operator purges the line with solvent, wipes the gun, and connects the line to the new color coating supply. In some larger operations different spray guns may be used, each attached to a different feed line. Automated systems may have several guns which are programmed for color sequence or there may be a single gun and line purging may be required as with the manual operation. Some larger operations perform color mixing compounding with computer programming. The color ingredients are selected in accordance with programs designed to meet customer requirements.

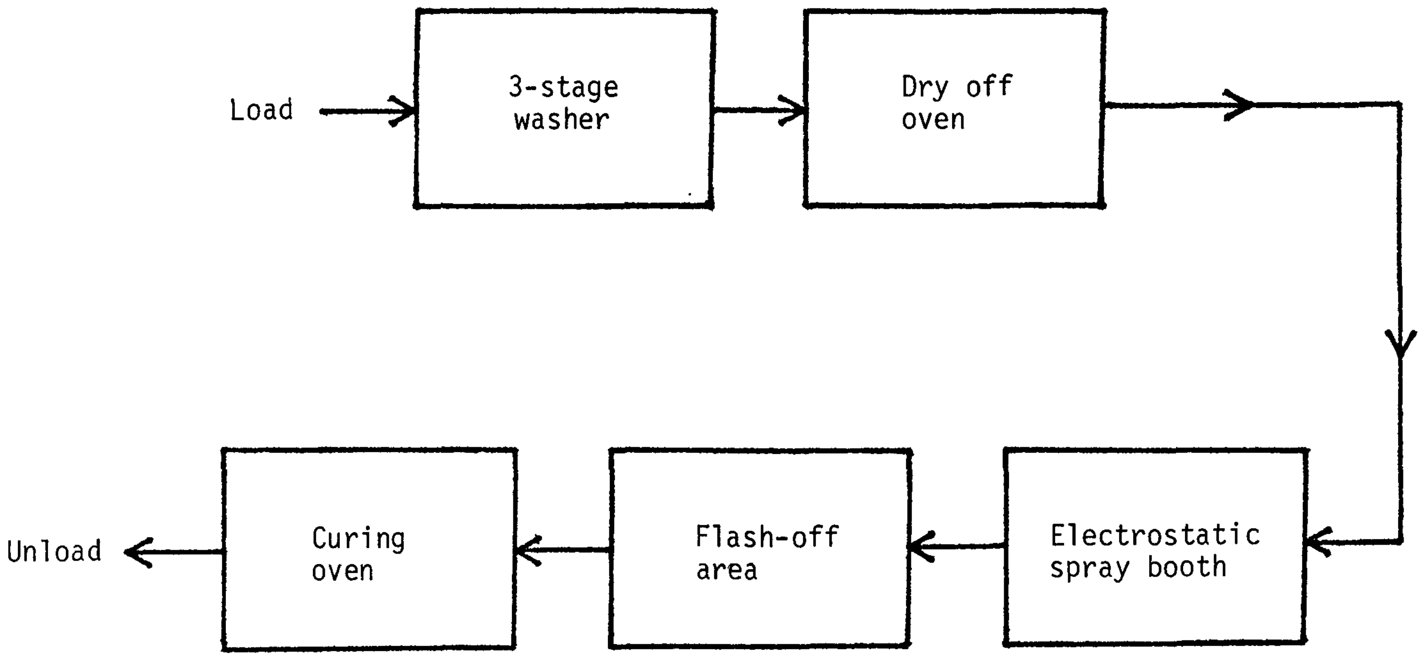

Figure 2-1. Flow diagram - electrostatic spray coating operation.

2.2.1.2 Dip Coating. Dip coating is the second most commonly used method of paint application. With this method, the wash stage is similar to that of spray coating.

Dip coating may be done manually or automatically. Items to be coated are loaded on an overhead conveyor which lowers them into the paint tank. They are then raised from the tank and suspended in a flash-off area over a drainboard. The items are then passed into the oven. Figure 2-2 shows the steps involved in the dip coating process.

Approximately 40 percent of the solvent emissions which occur during dip coating are released during application and flash-off.[19] Application efficiency is approximately 90 percent for dip coating and there is no appreciable difference resulting from differing object configurations.[18] Typical dry coating thickness is 2.54×10^{-3} cm (1 mil) and the paint is usually a solvent-based alkyd with 35 volume percent solids.

Color changes are not easily accomplished with dip coating. If an operation requires multiple colors, it will generally require several tanks, each filled with a different color paint.

2.2.1.3 Flow Coating. Flow coating is a method used to a much lesser extent in the metal furniture coating industry. The wash stage is the same as with spray and dip coating.

For topcoat application, furniture items are carried by an overhead conveyor into a flow coating chamber. In the chamber, paint is directed at the object from many angles through as many as 100 nozzles. These nozzles effectively form a curtain of paint through which the furniture items must pass. After application, the coated objects are held over a drain board in a flash-off area. They then pass into the curing oven. Figure 2-3 shows the steps involved in the flow coating process.[20] Approximately 80 percent of all solvent emissions are released in the application and flash-off areas.[19] Application efficiency is estimated at 90 percent for flow coating and there is no significant difference with varying object shapes.[18] Typical dry coating thickness is 2.54×10^{-3} cm (1 mil) and the paint is usually a solvent based alkyd with 35 volume percent solids.

Color changes are not easily accomplished with flow coating. If multiple colors are needed, several coating chambers are usually needed.

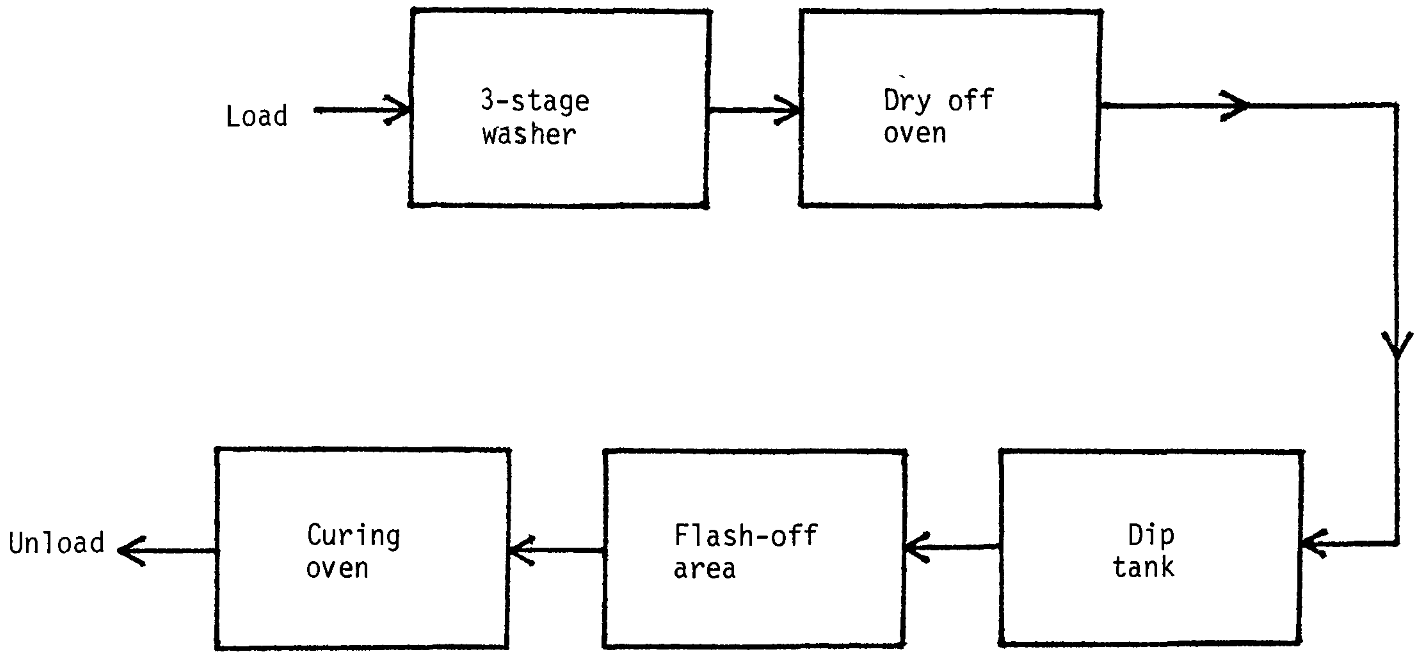

Figure 2-2. Flow diagram - dip coating operations.

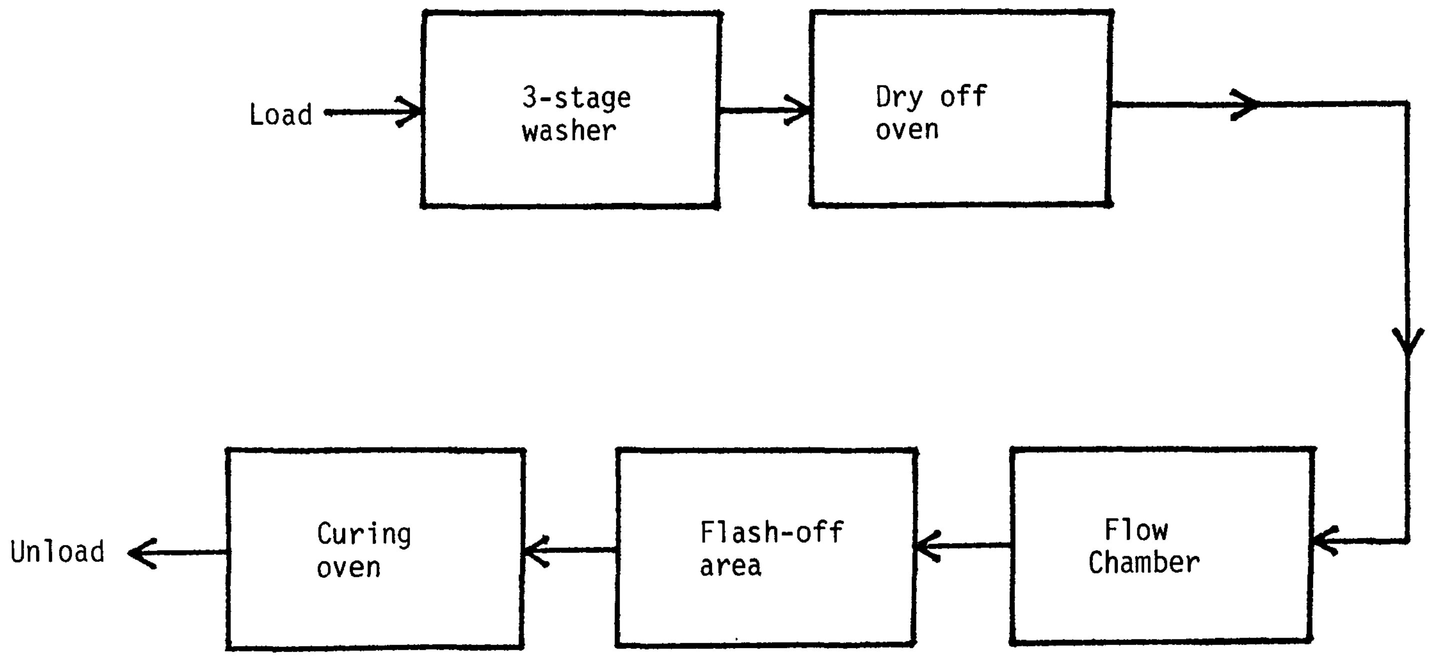

Figure 2-3. Flow diagram - flow coating operations.

2.3 BASELINE EMISSIONS

For the purpose of this study, the term "baseline emissions" refers to the level of emission control required of the metal furniture surface coating industry in the absence of a New Source Performance Standard (NSPS).

The metal furniture industry is located almost entirely in urban areas which are nonattainment areas for photochemical oxidants. State Implementation Plans (SIPs) have been developed to control volatile organic compound (VOC) emissions from various sources including the metal furniture industry within these areas. In addition to some existing facilities, all new, modified and reconstructed metal furniture coating facilities will be required to comply with these SIP regulations.

The method for control of VOC emissions by the SIPs is based on the Control Techniques Guideline (CTG) document published by the U. S. Environmental Protection Agency in December 1977.[21] This document presents an emission limit of 0.35 kg VOC per liter of coating applied (3.0 lb/gallon). This level is, therefore, considered to be the baseline emission rate and is used as the basis for comparison of regulatory alternatives in Chapter 5.

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3. EMISSION CONTROL TECHNIQUES

This chapter establishes control techniques that are available to the metal furniture industry to control volatile organic compound (VOC) emissions. In addition, it develops control efficiencies for each control technique. Control techniques which are evaluated include coating formulation changes, "add-on" air pollution control equipment, and process modifications. Coating formulation changes include powder, high solids, and waterborne coatings instead of conventional solvent-based coatings. The basic aim behind coating formulation changes is to reduce or eliminate the organic solvent concentrations present and to increase the solids content or the water content of the coating. These changes should in turn reduce VOC emissions to the atmosphere.

Add-on air pollution control equipment which is considered includes incinerators, process boilers, carbon adsorbers, condensers and absorbers. Both types of incinerators are evaluated: thermal and catalytic. Discussions relating to add-on control techniques are only applicable to paint lines that continue to use conventional organic solvent-based coatings.

Finally, emission reduction performance associated with process modification is discussed. Improving transfer efficiencies in applying solvent-borne coatings is emphasized for this control technique.

Each control technique is also evaluated to determine impact upon reducing or eliminating "fugitive" emissions of VOC. Without this evaluation, the exact control efficiency of a control technique cannot be determined.

Control techniques and their associated control efficiencies are applied in Chapter 5 to the model plants to establish regulatory alternatives. From the regulatory alternatives, the control techniques which will be recommended for economic analysis in Chapter 7 will be determined.

3.1 EMISSION CONTROL THROUGH COATING FORMULATION CHANGES

Topics regarding formulation changes which are discussed in the following sections are:

1. Discussion of which surface coating industries (metal furniture and other related) employ coating formulation changes as an air pollution control technique.
2. Chemical compositions.
3. Advantages and disadvantages of coating formulations.
4. Coating application techniques.
5. Process descriptions.
6. Process VOC emissions.
7. Operating parameters for new metal furniture lines.

3.1.1 Powder Coatings

A control technique often employed in the metal furniture industry is powder coating. Powder is applied to outdoor furniture as well as indoor products such as shelves, beds, and chair frames. Table 3-1 shows the type of metal furniture products being powder coated, the powder resin type, the application process, and the coating thickness.

In addition to the metal furniture industry, several other surface coating industries apply powder coatings to metal substrates. Table 3-2 lists some of these. The process steps for powder coating of metal products shown in Table 3-2 are the same or similar to process steps in the metal furniture industry. Since the application of powder coatings to metal substrates is a physical process, most comparisons between surface coating of metal furniture and surface coating of other metal products are applicable. Before powder can be applied as a coating, part size, part mass, part shape, paint thickness, color changing and matching, and "Faraday Effect" are the most important evaluations to be made.

Chemical compositions of powder coatings used in surface coating industries consist of synthetic resins, pigments, solid additives, and from 0 to 10 percent entrapped volatiles. The film formers are the synthetic resins (alkyd, vinyl, acrylic, epoxy, urethane, etc.). The surface coating industry classifies surface coatings by the resin type (e.g., alkyd paint, vinyl paint, etc.). Pigments consist of both inorganic and organic

Table 3-1. METAL FURNITURE PRODUCTS BEING POWDER COATED

Product	Application process[a]	Powder resin type	Coating thickness (10^{-3} cm)	Reference
Indoor metal furniture	ES-automatic	Epoxy resin	3.81 - 12.7	1
Outdoor metal furniture	ES-automatic	Cellulose acetate butyrate (CAB)	17.8 - 20.8	1
Outdoor metal furniture	FB	CAB	17.8 - 20.3	1
Lawn and patio furniture (17 and 22 guage mild steel)	ES	---	---	2
Patio and casual furniture	ES	Polyester	---	3
Steel file cabinets and desks	ES,ED	---	---	4
Metal furniture	ES-automatic	PVC polyester (thermoset)	6.35 2.54	5
Metal chairs	FB	Vinyl and polyester	38.1 - 40.6	6
Lawn furniture	ES	Polyester	3.81	7
Hospital bed frames and parts	ES-automatic	Epoxy	6.10	8
Chair bases, frames, and other parts	ES-automatic	Epoxy	6.10	9-11

(continued)

Table 3-1. (Concluded)

Product	Application process[a]	Powder resin type	Coating thickness (10^{-3} cm)	Reference
Chair bases and arms	FB	Nylon 11	25.5 - 50.8	10,11
Shop furniture	ES	CAB	8.89 - 10.2	12
Tubular metal furniture	ES-manual	Epoxy and thermoplastic polyester	3.81	13
Stadium seating	ES-manual	Polyester (thermoplastic)	7.62	14
Hospital beds	ES	Nylon II	---	15
Indoor and outdoor furniture	ES-automatic	Epoxy and polyester	2.54 - 7.62	16,17
Library shelves	ES-automatic	Epoxy	5.59	18
Dinette tables	ES	Epoxy	---	16
Metal finishing parts	ES-manual	Epoxy	6.35 - 10.2	19
Office furniture	ES-automatic	Epoxy	7.62 - 20.3	20
Hospital furnishing parts	FB and ES	Nylon	---	19

[a] ES refers to electrostatic application of powder.
FB refers to fluidized bed application of powder.
ED refers to electrostatic disk application of powder.

Table 3-2. OTHER METAL PRODUCTS BEING POWDER COATED

Metal product	Application process[a]	Powder type	Coating thickness (10^{-3} cm)	Reference
Bicycle parts	ES-automatic	CAB	7.62	21
Metal tubing	ES-automatic	Vinyl	---	5
Trailer hitches	ES-automatic	Epoxy	---	22
Lawn and garden equipment	ES-automatic and manual	Acrylic	---	23
Metal part for electrical equipment	--	Epoxy	---	16, 24
Metal parts for fan coils and ice makers	ES	Epoxy	6.10 - 10.2	25
Lawn and garden tractors	ES-automatic	Acrylic	---	26
Automobiles	ES-automatic		---	27
Oil filters	ES-automatic	Epoxy	2.54 - 5.08	28
Outside and floor panels of automobiles	ES-automatic	Epoxy	---	29
Refrigerator liners, shelving and kick plates		Epoxy	---	30
Components for electrical equipment	ES-automatic and manual	Epoxy	2.29	31

[a]ES refers to electrostatic application of powder.

compounds which are used for color and opacity. Additives are used to aid in production and improve application and performance properties of the film former.[32]

There are two general synthetic resin types of powder coatings: thermoset and thermoplastic types. Thermosetting powders harden during heating inside a bake oven as a result of cross-linking or polymerizing of the resin. Thermoplastic powders soften with the application of heat and resolidify during cooling.[16] Table 3-3 lists the powder coatings grouped by synthetic resins.[16,33] Thermosetting and thermoplastic coatings are usually applied by electrostatic spray and fluidized bed, respectively. Most thermoplastic coatings require a solvent or powder primer before the coating can be applied.[10,16] The most widely applied thermosets in the metal furniture industry are epoxies and polyesters.[10,16] These materials provide a tough, chemical and abrasive resistant coating which achieves excellent adhesion to almost any metallic substrate. Several of the thermoplastics listed in Table 3-3 are being applied successfully to metal furniture products. Most of the thermoplastics are applied in thick films for wear resistance in areas such as chair legs, bases and arms.

Both powder coating types offer several advantages and disadvantages (Tables 3-4 and 3-5). when compared to solvent-based coatings. The majority of advantages apply to outdoor type products where color matching is not as important. Some of the disadvantages mentioned in Table 3-5 are so critical that powder coating certain parts may not be possible, e.g., color matching and Faraday Effect. Color matching presents problems for facilities that coat parts with different paint types (metallics) and then assemble the parts into a finished product.[34,35] Lack of proper color match can result in a large number of rejected parts. The second disadvantage, Faraday Effect, applies to all types of coatings applied electrostatically. This phenomenon occurs for parts with recesses which are surrounded by metal. The electrostatically charged particles travel to the closest ground and as a result the recesses on the part are not coated. The Faraday Effect becomes a significant problem if the parts require a reinforcement spray or a touch-up spraying. This effect can sometimes be overcome by preheating the part, coating at a reduced voltage, or focusing the spray directly at the problem recess area.[3,10,16,36]

Table 3-3. POWDER COATING RESIN GROUPS

Thermosetting	Thermoplastics
Epoxy	Polyvinyl chloride or "vinyl"
Polyester	Polyethylene
Acrylic	Cellulose acetate butyrate (CAB)
	Nylon
	Polyester
	Acrylic
	Cellulose acetate propionate (CAP)
	Fluoroplastics

Table 3-4. ADVANTAGES OF POWDER COATINGS WHEN COMPARED TO ORGANIC SOLVENT-BASED COATINGS

Advantages	Reference
1. Provides tougher more abrasive resistant finish.	3, 5, 18, 24, 28, 36, 37
2. Fewer rejects and sags.	5, 14, 26, 28, 38, 39
3. Lower energy consumption.	2, 25, 28, 38, 40-42
4. Production rates can sometimes be increased.	26, 28, 38, 40
5. Less metal products are damaged during packing and shipping because coating is more abrasive resistant.	38, 40
6. Eliminates OSHA requirements for solvents.	24, 43
7. Usually no final refinishing required.	43
8. Less metallic preparation for parts to be coated.	10, 14, 18, 36, 40
9. Preferred for wire-type parts.	14, 36, 39
10. Superior for tubular parts.	36
11. No additional solvents for controlling viscosity or cleaning equipment required to be purchased or stored at facility.	24, 38
12. Less powder required to cover same surface area at same coating thickness.	24, 38, 42
13. Good coatings for electrical insulation and ambient temperature variations.	16
14. Significant reduction of VOC emissions.	44
15. No primer required for thermosets and some thermoplastics.	14
16. Problems associated with water usage are reduced or eliminated.	---
17. In many applications powder can be reclaimed and reused, providing a higher powder utilization efficiency than transfer efficiencies achieved with conventional solvent-based coatings.	38

Table 3-5. DISADVANTAGES OF POWDER COATINGS WHEN COMPARED TO ORGANIC SOLVENT-BASED COATINGS

Disadvantages	Reference
1. Color changes require that application area and powder recovery system be thoroughly cleaned.	1, 2, 10, 26, 28, 33, 36, 40, 44
2. Tapped holes in parts require masking.	26, 36, 45
3. Almost all thermoplastics presently require a organic or powder primer.	10, 16
4. Certain shapes cannot be electrostatically coated because of the "Faraday Effect."	10, 13, 28, 33, 40, 43, 44
5. Difficult to coat small numbers of parts.	11, 36
6. Powders are explosive, but minimum ignition temperature of powders is higher than for organic solvents.	10, 36
7. High capital costs for manufacturing and application equipment for powder coatings.	26, 33
8. Electrostatic gun hoses may plug frequently.	25
9. Difficult to touch-up complex surfaces.	3, 13, 38
10. Metallic and some other types of finishes available from organic solvent-based coatings have not been duplicated commercially in available powder coatings.	34, 35

The application of powder coatings to metal parts eliminates VOC emissions in the coating storage, application and flash-off areas. Also, VOC emissions from the bake oven are reduced significantly when compared to other coatings. The only exceptions are thermoplastic powders which require that the part be coated with an organic solvent-based primer. For this type of operation, VOC emissions can result from the primer application area and preheat oven. Control efficiencies developed for powder coatings are discussed in Section 3.3.1 of this chapter. The remainder of the discussion in this section concentrates on powder application techniques.

Powder coatings can be applied to metal parts by one of several coating techniques which include: (a) spray, (b) fluidized bed, and (c) electrofluidized bed.[11,36,44] Application techniques most common to the metal furniture industry are electrostatic spray and fluidized bed coating. Sections 3.1.1.1 and 3.1.1.2 discuss these two coating techniques in detail.

3.1.1.1 Electrostatic Spraying of Powder Coatings. Electrostatic spraying of powder is the most widely used application technique for powder coatings in the metal furniture industry. The basic principal of electrostatic spray is that opposite charges attract and like charges repel. Therefore, the metal part to be coated is grounded or given a positive charge, whereas the atomized powder particles (20 to 80 μm) receive a negative charge at the discharge point of a spraying gun. The electrical potential that results between the particles and the part causes the particle to be physically attracted to the part. As a result, the particles adhere uniformly to the surface of the metal part. As the powder film forms, the part becomes insulated and the powder charge is dispelled through the grounded part. A uniform film which is free of voids, is the final result.[37,44,46,47] Thermosets are the preferred powder for electrostatic application because not all of the thermoplastics can be ground to the required spraying particle size range.

If the powder is a thermoset, the film coating on the part is cured by baking in an oven at an elevated temperature. However, for thermoplastic powders, the part must be preheated before the powder is applied electrostatically. Post heating may be necessary even for the thermoplastic powders.

Usually, finished film thicknesses for electrostatically applied powder coatings vary from about 0.025 to 0.170 mm (1.0 to 8.0 mils), depending upon part temperature, powder particle size, electrical potential difference between part and particles, and spraying duration. It is much more common, however, to find film coating thicknesses of 0.025 to 0.106 mm (1.0 to 5.0 mils).[36,48,49]

The most common electrostatic spraying device used in the metal furniture industry is the manual electrostatic gun. Figure 3-1 shows schematically an electrostatic gun spraying a grounded part. The basic components of an electrostatic gun include a basic console, powder spray gun, spray booth, and powder recovery and recycling system. Each component is discussed below in detail.[7,12,16,25,50-53]

- Basic Console

The basic console or cabinet contains the powder supply for the gun and converts line current to high-voltage direct current. The unit contains the air supply which is used to atomize the powder particles. Moisture from the air supply is removed by a drier. The unit is usually equipped with a reservoir, vibrator, air fluidizer and hose. The control regulates air volume and pressure, voltage, amperage, vibrator frequency and powder flow rate.[11,37,50,51,53]

- Powder Spray Gun

The spray is activated by manually depressing a trigger switch which initiates powder flow and transfer of voltage. The pattern flow is determined by a deflector located inside the gun. The electrode on some guns is cleaned by an airstream.[11,54] This ensures that the gun provides a constant electrical discharge to the powder particles. Also a powder hose and a high-voltage cable are connected to the gun.

Automated electrostatic guns are mounted on vertical or horizontal reciprocators, and operation is controlled by a master switch on the control panel. The number of guns in an automatic system usually varies from 1 to 12 and is dependent upon part size and complexity, the extent and rate of travel of the reciprocating guns, and the conveyor speed. Most automated application lines require that more than one gun be employed because the operation of several guns at a moderate output rate provides a higher transfer efficiency than one gun operating at a high output rate.[2,35,38,50,52]

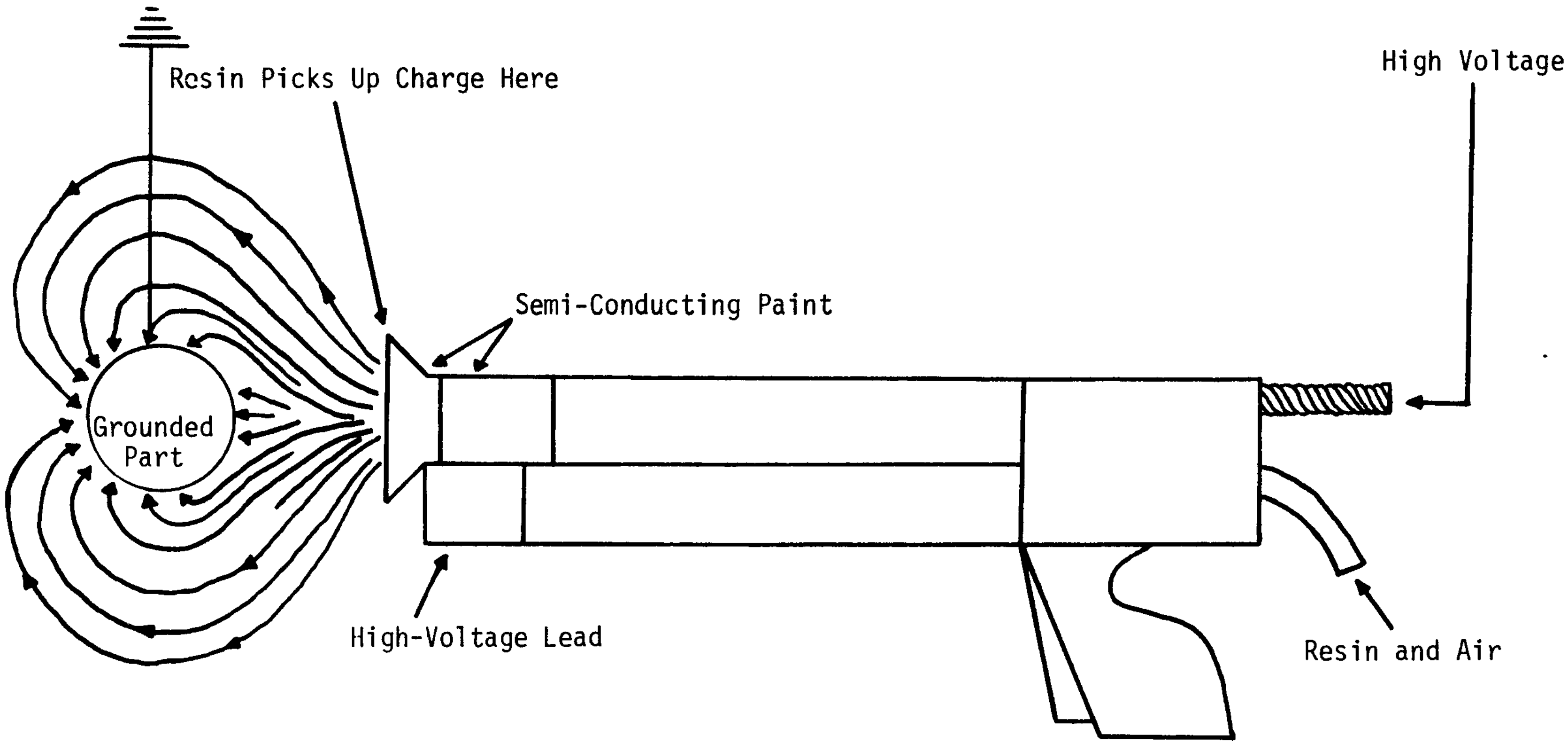


Figure 3-1. Electrostatic gun.

- Spray Booth

Powder spray booths are much simpler in design than spray booths employed for solvent-based coatings.[38] The floors are sloped downward to improve powder overspray collection and to allow for easier cleanout of the spray booths. The guns are mounted in the side of the walls of the booth, but sizes of openings are kept to a minimum to prevent powder loss. Guns can also be mounted on both sides of a booth to allow both surfaces of a part to be coated at one time. The interior walls are vertical and free of any type of projections to minimize hang-up of powder.

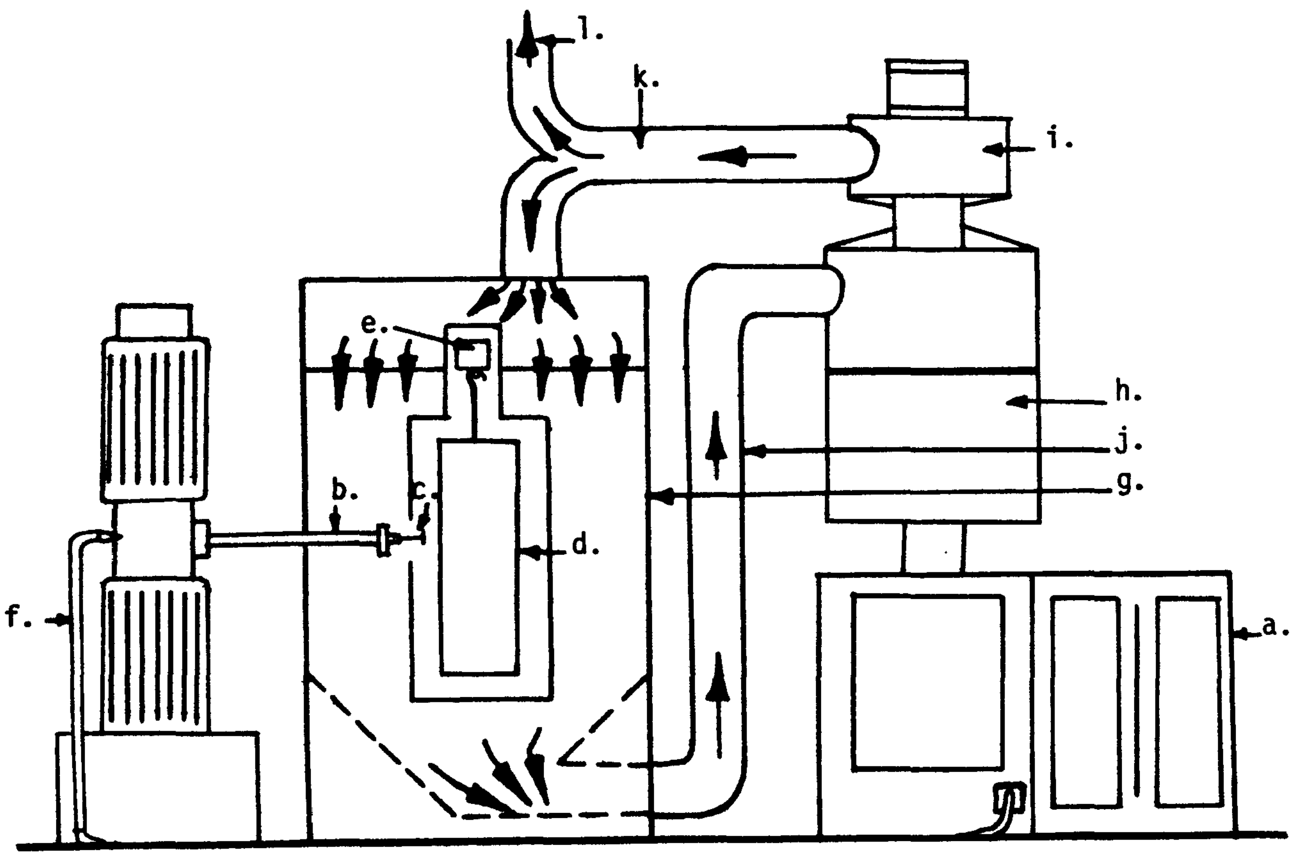
The dimensions of the booth are governed by part size, conveyor size, conveyor speed and the number of guns.[38]

- Recovery and Recycle System

Figure 3-2 shows a spray booth with a powder recovery system. Recovery and recycling of overspray powder is of economic significance when considering powder coating. Most recovery systems collect powder particles by filtration systems which are usually preceeded by cyclones. If cyclones are employed, the largest particles are removed from the spray booth exhaust air as a result of centrifugal action and collected in a hopper below the cyclone.[1,55] The smaller particles are removed from the exhaust air by filtration. Collection systems also include bag filters, tube filters, or a continuous moving belt of fabric filter.[37] The application of the belt filtration system reduces some of the problems associated with color changes because powder is removed after the belt leaves the spray booths.[37] Cyclones recover about 75 to 95 weight percent of the powder but the collection efficiency depends upon the powder particle size.[55]

After the airstream leaves the cyclone, particles of less than 2 μm in size remain in the airstream. The filtration system removes about 99 weight percent of these particles, whereas, if an "absolute" filter is employed, a total of 99.97 percent of the powder can be removed from the airstream. After the airstream has been adequately filtered, it can be exhausted back into the building.

For coating operations in which only one color is being used, powder particles recovered from the cyclone and filtration system can be recycled and about 98 percent of the overspray powder can be utilized.[55] However,



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

Figure 3-2. Powder spray booth equipped with powder recovery system.

if more than one color is required, only the powder collected by the cyclone can be reused because powder recycled from the filtration system can cause color contamination, a problem which can be overcome if a separate filtration system is employed for each color.[10] For operations in which color changes are required, powder utilization depends upon a combination of the efficiency of the powder recovery unit and the initial transfer efficiency in the spraying booth. The effect of these two variables is shown in Table 3-6.

Powder to be recycled is pneumatically or manually transported to the powder reservoir. This material is screened to remove oversized particles that will not carry a charge and is mixed with virgin powder in the reservoir.[1-3,7,16,37,38,51] The voltage for most electrostatic guns can be varied to 90 KV which provides a method of controlling powder film thickness. The polarity of the charging electrode in the guns can be varied but most powder particles are sprayed with a negative charge.

Transfer efficiency for electrostatic spraying of powders varies depending upon part shape and size. The transfer efficiencies for certain shapes and sizes are shown below.[52,55,56] However, powder utilization efficiency is much higher (90 percent or greater) than the transfer efficiencies shown since oversprayed powder is recycled.

Shape	Size	Transfer efficiency (percent)
Flat surface	Large	65-85
Wire racks and baskets	Variable	50-80

Table 3-7 lists the operating parameters of powder coating lines presently in use. This information may be representative of new coating lines that would fall under New Source Performance Standard (NSPS) regulations. These coating lines are considered to be both manually or automatically operated and apply only to the spraying of thermoset powders. The same coating lines may be employed for thermoplastics but either additional equipment for a primer or preheating of parts might be required. In some cases, both might be required. The coating line for powder thermosets does not require spray primer and flash-off areas as are needed for solvent-based

Table 3-6. OVERALL WEIGHT PERCENT OF POWDER UTILIZED[a]

Weight fraction	Weight fraction transfer[b]		
Powder recovery	50	65	80
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.

Table 3-7. PROCESS OPERATING PARAMETERS FOR POWDER COATING LINES USING ELECTROSTATIC SPRAY

Parameter	Operating range
Conveyor speed	1.5-14 m/min (5-45 ft/min)[1-4,7,13,15,40]
Spacing between furniture parts	0.31-0.61 m (1-2 ft)[3]
Number of cleaning stages for parts	3[1,3,5,7,16]
Dry-off oven	370-530 K (200-500°F) for 5-15 min.[1,4,11]
Application area	
Electrical output of guns	35-100 KV DC[1,3,11,35,49]
Number of guns	1-12[1-3,7,11,16,26,35]
Touch-up guns	0-2[1,26]
Polarity of charged particles[a]	Positive or negative[16]
Compressed air output	1420-7080 m^3/sec at 146-488 kg/m^3 (30-100 psig)[35,48,49]
Powder output	0-36 kg (0-80 lb)/hr/gun[1,35]
Powder overspray reuse	97 percent[1]
Flash-off	Not required for all thermosets and some thermoplastics.
Powder baking	436-505 K (325-450°F) for 4-30 min.[1,2,4,5,7,11-13]

[a]Usually negative.

coatings (Figure 2-1). The spray booths are also not equipped with water curtains. A powder recovery system on the spray booth is the only additional equipment required.

The remainder of this section details process descriptions of a coating line employing electrostatic spraying of powder and evaluates the process parameters shown in Table 3-7. The process involves five steps which include loading of parts on a conveyor, cleaning of parts, drying of parts, spraying of parts, and curing of the powder coatings on the parts (Figure 3-3).[16] Each is discussed in detail below.

- Conveyor

All of the coating facilities studied that employ electrostatic spraying of powder use a conveyor system (mainly overhead) which transports the parts through a cleaning rinse, dry-off oven, spray booth, bake oven, and unloading area. Parts are hung on hooks at specified intervals governed by part size. Conveyors are normally loaded and unloaded by hand, but automatic systems are available.[1-4,7-12,16,17,19,28]

- Cleaning

Usually, the metal parts are cleaned in a 3-stage iron phosphate rinse. From 1 to 3 stages of the cleaning system may consist of an iron phosphate rinse. The purpose of this rinse is to remove oil and dirt on the parts. This phosphatizing of the metal parts is followed by a water rinse stage. The last stage involves spray coating the parts with a chromic acid rinse.[1-4,16,26]

- "Dry-Off" Oven

The wet parts next travel through the "dry-off" oven to vaporize the liquid on the parts. Before the parts are sprayed with powder, they are cooled by traveling along on the conveyor in the open plant for 5 to 15 minutes.[1-4,7-12]

- Powder Spraying

Powder spraying of the parts can begin after parts have cooled, but this is not a requirement for thermoplastic powders. In some automated systems, the parts are indexed by an "electric eye" located at the entrance of the spray booth. The electric eye is part of the automatic control that starts and stops the powder flow to the electrostatic gun. The remainder of the spraying booth was discussed earlier in this section.[1-4,7-12,28]

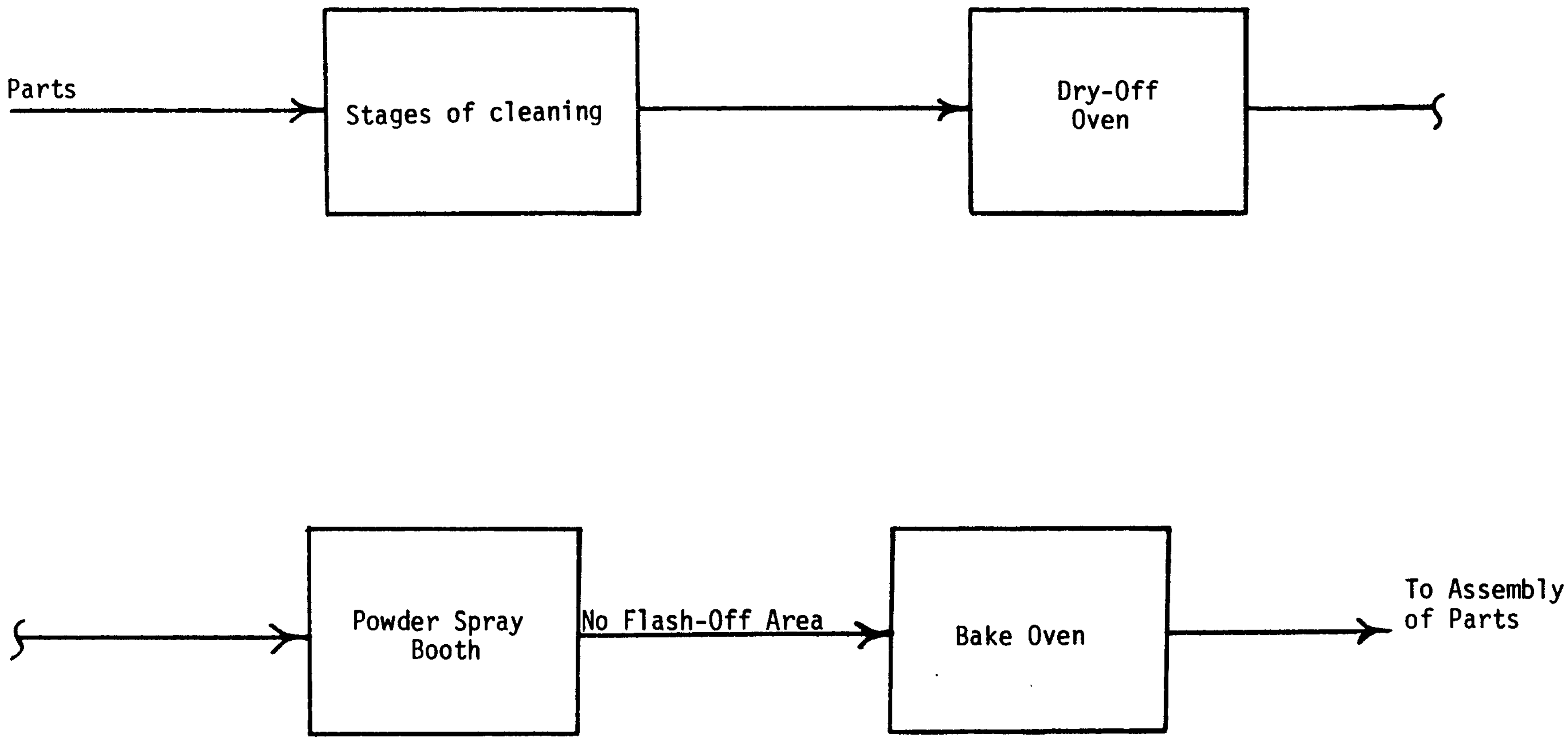


Figure 3-3. Flow diagram for a powder coating line.

Some coating lines are equipped with manual spraying in a smaller touch-up booth.[1]

- Baking

After the parts have been coated, the coating is cured in a bake oven. The oven itself is usually gas- or oil-fired and consists of more than one zone. One or more of the zones are used to bring the part to a specified temperature while the remainder of the zones maintains the part temperature. Curing time depends upon the mass of these parts, the type of powder, and the coating thickness. This process on the coating line is the only source of VOCs on a powder coating line employing thermosetting powders.[1-3,11,44,48,57]

The flow diagram in Figure 3-3 shows the equipment that would be needed for powders that require parts to be prime coated first. Emissions of VOCs would also result from the primer application, the preheat oven, and the post heat oven (if required).[10]

In the area of new developments in application techniques, a high speed rotating disk has been used to powder coat office cabinets and desks.[4] The disk is a spraying device that could replace the electrostatic gun on a powder coating line. Powder particles are discharged from the disk which rotates at high centrifugal speeds (30,000 rpm), and the particles are atomized by a combination of centrifugal and electrostatic forces. The disk offers higher transfer efficiencies and is considered to be an improvement over the electrostatic gun.[4,28,46]

Section 3.1.1.2 discusses the second application technique (fluidized bed) employed in the metal furniture industry. This application technique is used when an extra thick coating is desired.

3.1.1.2 Fluidized Bed Application of Powder Coatings. Figure 3-4 is a schematic of a metal part to be powder coated in a fluidized bed. The metal part is cleaned by the same iron phosphate system discussed in Section 3.1.1.1. For parts to be coated with a thermoplastic powder, an organic primer (or sometimes a powder) is added to the surface of the part. Next, the part is preheated above the fusion point of the resin particles and is dipped manually or automatically into the fluidized bed where the particles melt onto the part. Loose powder is blown or shaken from the formed film. For thermoplastics, the coating solidifies as the part cools

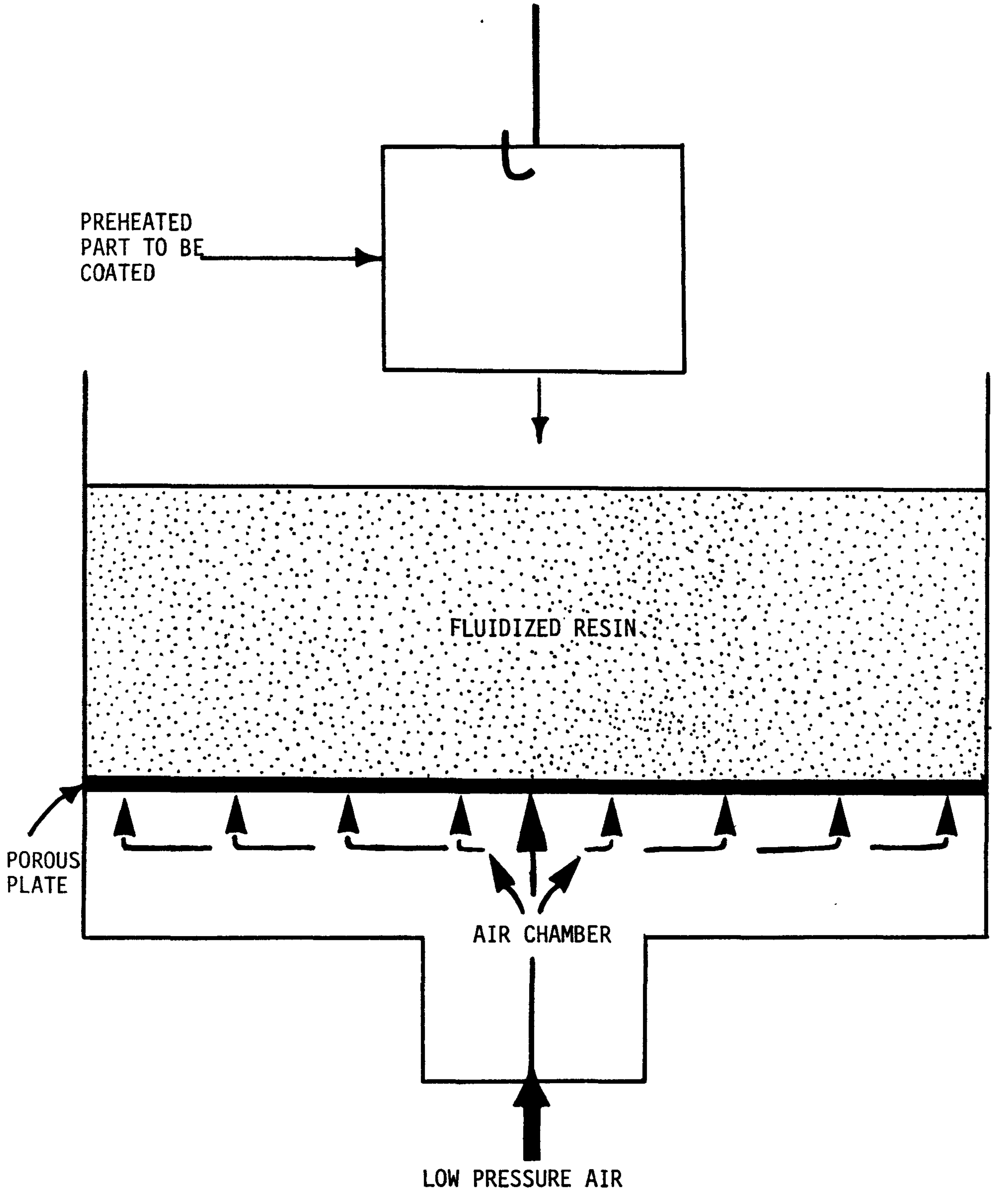


Figure 3-4. Part coating in a fluidized bed of powder.

on the conveyor line. However, for some thermoplastics and all thermosets, post heating is required. The post heating of some thermoplastics is employed to provide a more uniform film. After the coating has cured and the part is sufficiently cool, each part is removed manually from the conveyor line.[1,10,14,28,33,36,38,39]

A particle recovery system much like those employed for electrostatic spraying systems can also be used to collect resin particles from the top of the fluidized bed. Resin particles, because of the decreasing particle size, are elutriated from the fluidized bed. A slightly negative pressure is maintained across the top of the fluidized bed of resin particles to collect this elutriated material. The resin particles are collected by either a cyclone and filtration system, or both.[1,10]

The fluidized bed application technique is preferred in the metal furniture industry for thermoplastics coating operations. Thicker protective films can result from this application technique. Coating thicknesses can range from 0.15 to 1.5 mm (6 to 60 mils); they depend upon mass and temperature of the part and part residence time within the fluidized bed of resin particles.[10,28,36,58] In fact, two different coatings (vinyl and polyester) have been applied with this application technique to the same chair parts.[6]

Emissions of VOCs can result from the following processes when applying either a thermoset or thermoplastic:[10,29]

Coating	Process source of VOC emissions
Thermoset	Bake oven
Thermoplastic (no primer)[a]	Bake oven
Thermoplastic (organic primer)[a]	Primer application area, preheat oven, and bake oven

[a]Emissions of VOCs from the bake oven only result if post heating is required.

Table 3-8 contains process operating parameters for fluidized bed coating lines presently operating in the metal furniture industry. These data are representative of the new coating lines that would fall under NSPS regulations.

Table 3-8. PROCESS OPERATING PARAMETERS FOR POWDER COATING LINES USING FLUIDIZED BED

Parameter	Operating range
Conveyor speed	2.4-4.9 m/min (8-16 ft/min)[11,59]
Spacing between furniture parts	0.31-0.61 m (1-2 ft)[3]
Number of cleaning stages for parts	3-6[11]
Dry-off oven	370-530 K (290°F-500°F) for 5-15 min.[11]
Primer application[a]	One coat[11]
Flash-off[a]	8 min.[11]
Preheat oven[b]	400-615 K (275°F-650°F) for 4-6 min.[11,39,59]
Particle resin size	200 μ and above.[60]
Air flow through fluidized bed	15-61 m^3/hr per m^2 of plate (50-200 ft^3/hr per ft^2 of plate)[38]
Bake oven[c]	440-500 K (340°F-450°F) for 4-30 min.[11,58]
Cool down time[d]	5-15 min.[10]

[a]Only required for certain thermoplastic powders.

[b]Temperature will vary depending upon resin type.

[c]Bake oven required for all thermosets and some thermoplastics where film uniformity is a problem.

[d]Applies only to thermoplastics that cure as a result of cooling.

3.1.2 High Solids Coatings

A second coating formulation change currently employed in the metal furniture industry to reduce VOC emissions is high solids coatings. This group of coatings is oligomeric and includes such general categories as radiation curable systems, "high solids coatings" (anything greater than 50 percent by volume solids is being considered) and the already discussed powder coatings (see Section 3.1.1). The radiation curable systems are not discussed. These types of coatings are not being used in the metal furniture industry since there is a potential health hazard associated with the isocyanate emissions from these coatings, and the difficulties involved in curing these coatings.[61,62]

Table 3-9 shows the types of metal furniture products being coated with higher solids coatings. All coatings are being applied by electrostatic guns unless specified otherwise in the table. Other industries which require surface coating and which are investigating and using high solids include the automotive, can, coil, and appliance industries.[68-75] Surface coating of appliance parts with high solids has been very successful. The metal furniture industry is studying everything from 50 to 100 percent by volume solids.[76]

The chemical composition of high solids coatings consists of modifications of their solvent-based counterparts. High solids coatings are categorized into two general groups: two-component/ambient curing and single-component/heat-converted materials. The general chemical composition of both groups includes synthetic resins, pigments, additives, and solvents at a reduced concentration (when compared to solvent-based coatings). The general properties of pigments and additives have been mentioned in Section 3.1.1. The synthetic resin types that have been developed for single-component/heat-converted materials include epoxy, acrylic, polyester and alkyd. The two-component systems include acrylics, polyesters, epoxys, urethanes, and others.[69,70,73,77-86] The single- and two-component coatings offer several advantages and disadvantages which are presented in Table 3-10 and 3-11, respectively.

Three spraying techniques can be employed to apply single- and two-component high solids coatings: (1) air atomization, (2) airless atomization, and (3) electrostatic methods.[44,81,97,101,102]

Table 3-9. METAL FURNITURE PRODUCTS BEING COATED WITH HIGH SOLIDS

Product	Resin type	Solids content by volume (%)	Coating thickness (10^{-3} cm)	Reference
Panel and desk parts	Acrylic/ polyester	54	3.05	10
Metal drawers	Alkyd	--	2.54-3.81	63
Metal furniture parts	Alkyd	55	--	64
Shop furniture and shelving	Alkyd	--	--	65
Office furniture	Acrylic/ polyester	--	--	65
Metal furniture parts	--	--	--	66
Metal furniture parts	--	56	--	67
Lighting fixtures, shelving, and office furniture[a]	Alkyd enamel	66-80	--	68
Metal furniture shelving and fixtures[b]	Alkyd-amine	62	--	68

(continued)

Table 3-9. Concluded

Product	Resin type	Solids content by volume (%)	Coating thickness (10^{-3} cm)	Reference
Steel office furniture[c]	Polyester	60	--	68
Steel shelving[d]	Alkyd	67	--	68
Steel shelving[d]	Polyester	65	--	68

[a]The low range of solids coating applied by disc and the high range of solids coating applied by high speed disc.

[b]Coating applied by disk.

[c]Coating applied by high speed bell or disk.

[d]Coating applied by high speed disk.

Table 3-10. ADVANTAGES FOR HIGH SOLIDS COATINGS WHEN COMPARED TO CONVENTIONAL ORGANIC SOLVENT-BASED COATINGS

Advantage	Reference
1. Reduction of VOC emissions.	44, 86-109
2. Reduced shipping costs, inventory, and handling of drums containing the coatings.	44, 87, 88, 94, 95
3. Potential for reduction of energy usage to cure coatings.	44, 69, 79, 81, 87-92, 94, 100
4. Reduced air flow rates through spray booths and bake ovens.	81, 89, 105
5. Less coating is applied to obtain same dry film thickness.	67, 70, 80, 87, 90, 104
6. Two-component systems can cure under ambient conditions.	77
7. Higher production rates can be achieved.	69
8. Color matching comparable to solvent-based paints.	69
9. Utilization of paint heaters, high speed disks and bells can result in the application of coatings that contain more solids.	93-97, 101-103, 110

Table 3-11. DISADVANTAGES FOR HIGH SOLIDS COATINGS WHEN COMPARED TO ORGANIC SOLVENT-BASED COATINGS

Disadvantage	Reference
1. Higher viscosity in application area.	44, 88, 97
2. Reduced shelf-life for two-component coating.	44
3. Less latitude with in-plant formula modifications.	44
4. Short pot lives for some two-component coating systems.	81
5. Elaborate feeding equipment required for two-component coating systems.	81
6. Premature loss of solvent caused by preheating.	97
7. Possible requirement of careful metal preparation.	10, 67, 69, 90
8. Decrease in quality of mechanical properties of a coating as the molecular weight of the resin decreases.	93
9. More difficult spray booth cleaning due to tackiness of some high solids coatings.	10, 67, 80
10. "Faraday effect" is a problem for certain shapes.	33, 34
11. Metallic finishes from organic solvent-based coatings have not been matched with other high solids coatings.	

Air atomization uses its own air supply which may be heated, filtered, humidified, or a combination thereof. Airless atomization is accomplished by forcing the coating through spray nozzles under a pressure of 6.9 to 13.8 MPa (1,000 to 2,000 psig). Both the air and airless spraying techniques exhibit poor transfer efficiencies.[97,111] As a result, these spraying techniques are not common for applying high solids coatings in the metal furniture industry. These two spraying techniques are mainly employed for touch-up work for parts that exhibit the Faraday Effect. Therefore, the spraying technique this section concentrates on is spraying by electrostatic methods.

The three basic types of electrostatic spraying techniques that have been successful in applying high solids coatings at acceptable transfer efficiencies (greater than 50 percent) are listed below and shown schematically in Figure 3-5:[81,93,94,101,102]

Type of Spray Equipment	Mechanical Energy for Atomization
Air atomization - electrostatic guns	Compressed air
Airless or hydraulic atomization - electrostatic guns	Hydraulic
Electrostatic atomizing - electrostatic disks and bells	Centrifugal and electrostatic

For electrostatic guns using air and airless atomization, the coating is atomized by compressed air or mechanical forces and charged electrostatically. In the disk or bell systems, a combination of mechanical force (centrifugal) and electrostatic means are used to atomize, charge, and deposit the coating. Transfer efficiencies achieved by applying high solids (60 to 70 percent by volume solids) with the disks and bells range from 80 to 90 percent regardless of part shape. These systems are schematically shown in Figure 3-5.[81,94]

Each electrostatic system is equipped with coating handling equipment. The air and airless electrostatic guns are supplied from a pressure fed device with a fluid regulator or metering valve, and an air driven piston pump with a fluid regulator, respectively. Two-component coating systems present additional equipment problems associated with the varying pot lives of the coatings. The pot lives of certain two-component coatings and mixing requirements of equipment located before the electrostatic spraying device are listed below:[81]

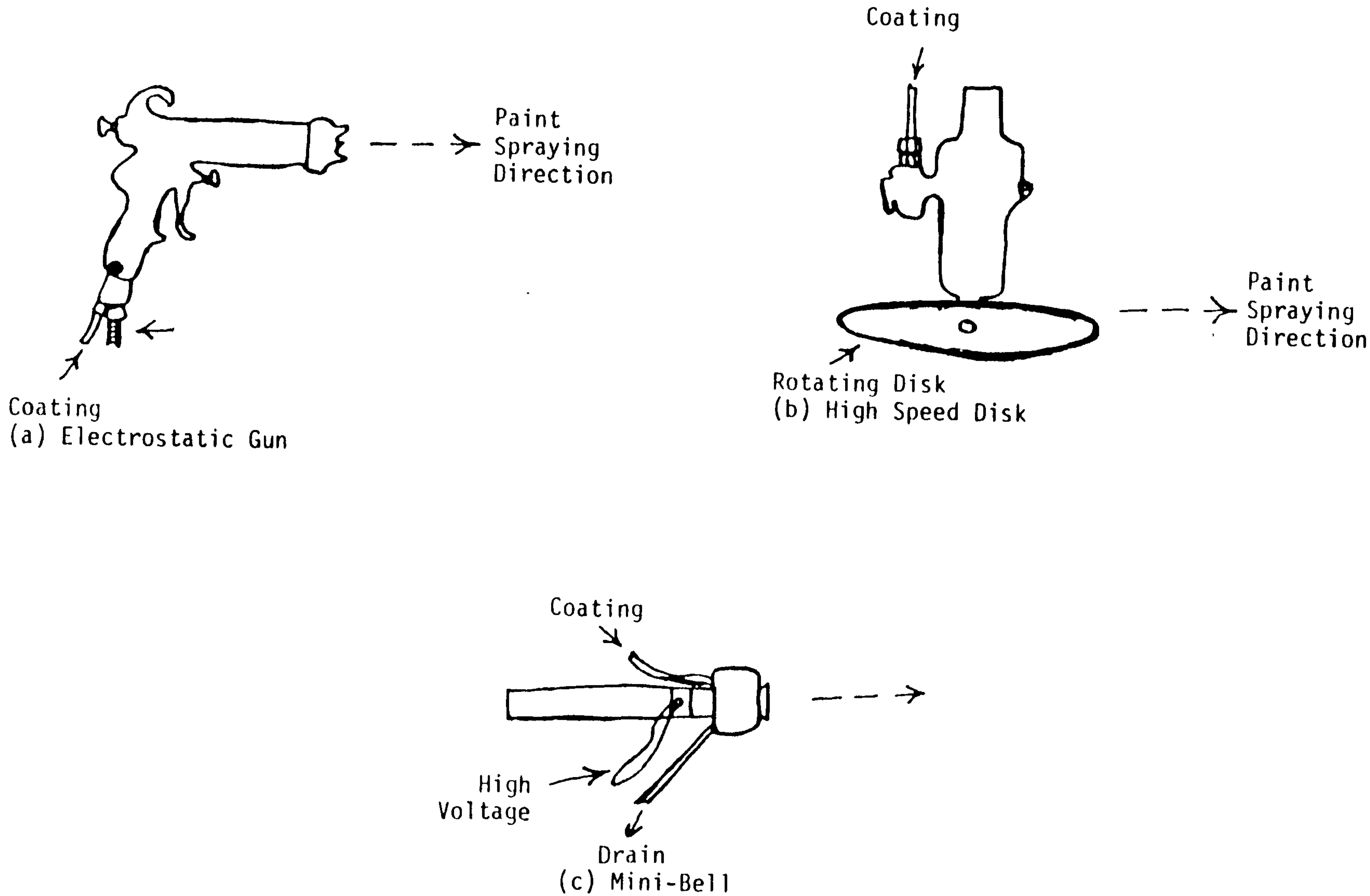


Figure 3-5. Schematic of high solids coatings spraying equipment.

Pot Life	Mixing Equipment
One to five minutes	External mix at the site of atomization
Five minutes to eight hours	Static mixers located close to the spray device
Eight hours	Static mixers or premixers in fluid supply tanks

Figure 3-6 shows how electrostatic equipment is fed with static mixers depending upon pot lives that are associated with two-component coatings. All of the feeding systems in Figure 3-6 are automatically controlled to maintain a close relationship (± 5 percent) between the coating and the catalyst. This is done to avoid the coatings' curing in the spraying device, or at some other earlier stage of processing before the baking ovens. Paint heaters constitute additional equipment which may be necessary for electrostatic guns. Some single- and two-component coatings must be heated to a flowable viscosity. Paint heaters, however, are not always necessary for disk or bell systems. These systems seem to be particularly well suited to the application of high solids coatings.[81,94,101,102]

The remainder of this section discusses the process description of a representative high solids coating line, and describes the various sources (including fugitive) of VOC emissions. The process description of a coating line is very similar to that of an organic solvent-based coating line. The line consists of a conveyor and cleaning, dry-off, application, flash-off, and baking areas. The conveyor, cleaning, and dry-off areas are basically the same as the powder coating lines and are not discussed in this section. The application, flash-off, and baking areas are discussed below:

- Application Area

This area includes the spray booth, electrostatic spraying device, possibly a paint heater, and paint mixing equipment. Of these, only the spray booth has not previously been discussed.

Spray booths on high solids coating lines are downdraft or sidedraft design and can be smaller in size when compared to conventional solvent-based spray booths because less makeup air is required to handle VOC

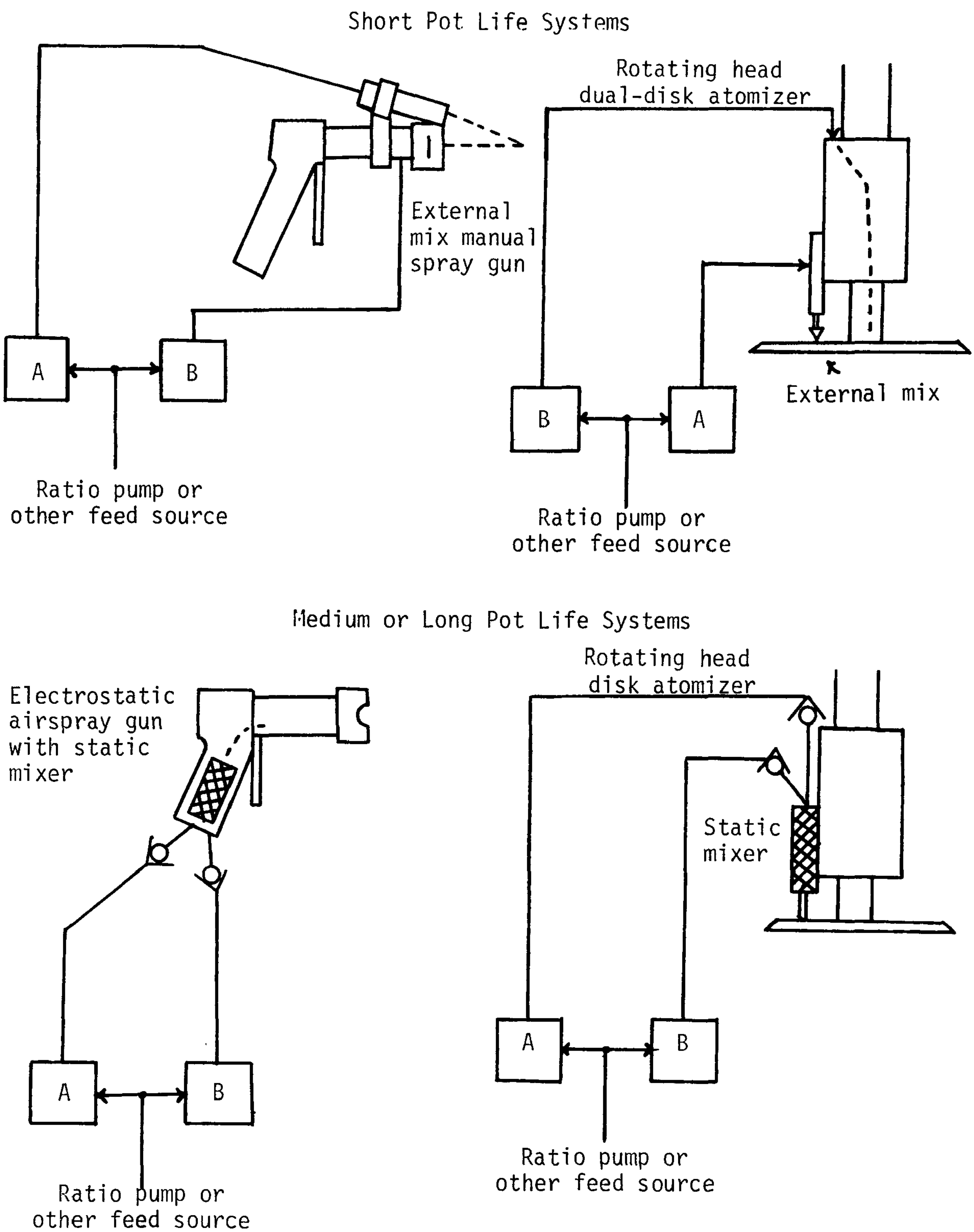


Figure 3-6. Static mixers.

emissions.[81,89,105] Most spray booth dimensions are based on the largest part to be coated.

For electrostatic systems, the spray booth is equipped with hand held and automatically operated guns, disks or bells. The number of electrostatic guns reported to be in use (mounted on vertical or horizontal reciprocators) range from one to twelve. For spray booths using a disk, the booths are designed in a circular shape. Also, coating lines equipped with disks or bells usually require two of each of these atomizing devices.

Due to the difficulty of controlling film thickness with high solids paints, automatic electrostatic spraying systems are usually employed; manual equipment is used for touch-up only.[69,94,112]

- Flash-Off Area

A flash-off area is required to allow a prescribed amount of solvent to evaporate before the coated part enters the bake oven. This prevents bubbling, uneven coating thickness, etc.[44]

Enclosed flash-off areas used with high solids coatings, when compared to conventional solvent based coatings, require less residence time for the coated part and allow reduced air flows.[89] However, most flash-off areas in the metal furniture industry are not enclosed.

- Baking Oven

Two-component systems require little or no baking to cure the resins. However, single-component coatings require baking at 425 to 450 K (300° to 350°F) which aids in the crosslinking of reactive groups, like hydroxyls or carboxyls, with amino compounds.

The process operating parameters are summarized in Table 3-12. This information is considered to be representative of a new coating line using high solids coatings.

Emissions of VOCs from high solids coating lines result from the application, flash-off and baking oven. For plants in which the flash-off area is not enclosed, VOC emissions that result from this area are considered to be fugitive. The other part of the plant that might be a source of fugitive VOCs is the coatings storage area. Section 3.3.2 discusses control efficiencies of high solids coating systems compared to conventional organic solvent-based coatings.

Table 3-12. PROCESS OPERATING PARAMETERS FOR HIGH SOLIDS COATING LINES

Parameter	Operating range
Conveyor speed	1.5-14 m/min (5-45 ft/min).[1-4,10,94]
Parts spacing	0.31-0.61 m (1-2 ft)[3]
Number of cleaning stages for parts	3-6[10,64,67,69]
Dry-off oven	370-530 K (200-500^{o}F) for 5-15 min.[1,10]
Application area	
Electrostatic gun systems	
Number of guns	1-12[64,67]
Touch-up guns	0-2[64,67]
High solids output	200-1500 l/min (0.05-0.4 gal/min)[113,114]
Compressed air	1420-7080 m^3/sec at 150-490 kg/m^3 (30-100 psig)[37,50,51]
Electrostatic disk systems	
Number of disks	2[108]
Rotation speed	1800-20,000 RPM[70]
High solids output	0-1000 l/min (0-0.3 gal/min)[115,116]
Disk diameters	200-500 mm (8-20 inches)[115,116]
Air requirements	0.009 m^3/sec (18 CFM) at 190 kg/m^3 (40 psig)[115,116]
Electrostatic bell systems	
Number of bells	2-6[94]
Rotation speed	900-30,000 RPM[70,94,117]
High solids output	0-400 l/min (0-0.1 gal/min)[117]
Air requirements	0.005 m^3/sec (10 CFM) at 290 kg/m^3 (60 psig)[117]
Coating thickness	(0.5-2.0 mil)[70,112]
Electrical output	0-140 KV[118]

(Continued)

Table 3-12. Concluded.

Parameter	Operating range
Bake oven	
High solids baking	
Single-component	410-470 K (275-400°F)[63,64,70,81,97,102]
Two-component	340-360 K (150-180°F) for 10 min.[19]

3.1.3 Waterborne Coatings

One of the control techniques presently employed in the metal furniture industry is the use of waterborne coatings. These coatings can be applied by conventional or electrostatic spray, conventional or electrophoretic dip, or flow coating lines to a wide variety of parts. Waterborne coatings are being successfully applied in the automobile, coil, appliance, metal can, and electronics industries as well as in the metal furniture industry.[119-124]

The term waterborne refers to any coating which uses water as the primary carrier combined with organic solvent and is differentiated from pure organic solvent-borne paints. There are basically three types of waterborne coatings: latex or emulsion paints, partially solubilized dispersions, and water-soluble coatings.[125] Table 3-13 lists the properties of these three types of paints. Most current interest is centered around the partially solubilized dispersions and emulsions. Emulsions are of particular interest because they can build relatively thick films without blistering and they contain no noxious amine solubilizers.[126,127]

Most of the solubilized waterborne paints are based on alkyd or polyester resins. Table 3-14 shows the solids and water content of several types of waterborne paints.

A common method of solubilizing is to incorporate carboxyl-containing materials such as maleic anhydride and acrylic acid into the polymer. The acids are then "solubilized" with low molecular weight amines such as triethylamine. After application, the coatings are baked and the water, solvent, and amine evaporate leaving a pigment film on the object.[128]

The use of waterborne coatings can reduce the explosion problem associated with organic solvent-based paints. Some organic solvents are used, but the amount used is greatly reduced. Waterborne coatings have the additional value of reducing the amount of air flow needed from the application areas and curing ovens and can reduce energy consumption.

In organic solvent-based paints, relatively few monomers can be used because of solubility and viscosity. Molecular weights are especially restricted. In waterborne coatings, the selection of useable monomers is much wider. In addition, waterborne paints can contain a higher solids

Table 3-13. PROPERTIES OF WATERBORNE COATINGS

Properties	Latex or emulsion paints	Partially solubilized dispersions	Water-soluble coatings
Molecular weight	Up to 1 million	50,000 to 200,000	20,000 to 50,000
Viscosity	Low - not dependent on molecular weight	Somewhat dependent on molecular weight	Very dependent on molecular weight
Viscosity control	Require thickness	Thickened by addition of co-solvent	Governed by molecular weight and solvent control
Solids content	High	Medium	Low
Gloss	Low	Medium	High
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	Good to excellent	Fair to good
Reducer	Water	Water	Water or solvent/water mix
Wash-up	Difficult	Moderately difficult	Easy

Table 3-14. SOLIDS AND SOLVENT CONTENT OF WATERBORNE PAINTS

Waterborne paint system	Solids content volume percent	Water to solvent ratio
High solids polyester	80	80/20
Coil-coating polyester	51	51/49
High solids alkyd	80	80/20
Short oil alkyd	34	34/66
Water reducible polyester	48	82/18
Water reducible alkyd	29	67/33
High solids water reducible conversion varnish	80	90/10

content than organic solvent-based coatings without an increase in viscosity.[42]

An additional advantage of waterborne systems is ease of cleanup. Waterborne paint systems can usually be cleaned with water whereas organic solvent-based systems require solvents for cleaning. Organic solvent may be needed for cleanup of waterborne systems if the paint has dried.

A problem associated with waterborne systems is the propensity to rust and corrode. Coating lines, including ovens, must therefore be protected by the use of stainless steel or some other appropriate material.

Another disadvantage is the requirement for more pretreatment. Most organic solvent-based systems can tolerate small amounts of grease or oil on the surface to be coated because they have the ability to "self clean" the part. This is not true for most waterborne systems in that the surface must be totally oil free or the paint will not adhere properly.[129] This can increase pretreatment costs. On the other hand, drying is not always needed prior to coating; therefore this step may be eliminated and pretreatment costs decreased.

Ambient humidity levels can cause problems for waterborne systems. On days of high humidity the drying process may be slowed, requiring proper air conditioning to overcome the problem. In addition, a longer flash-off time is usually needed for waterborne systems thereby increasing space requirements.

Color availability has been suggested as a problem with waterborne coatings. One furniture manufacturer reports, however, that any color can be obtained and that the quality of the finish is as good or better than that of organic solvent-based systems.[122]

Summaries of the advantages and disadvantages of waterborne paints are presented in Table 3-15 and 3-16. The use of these coatings in the metal furniture industry is limited at present; however, it is expected to increase.[130]

3.1.3.1 Waterborne Spray. Spraying of waterborne paints has been used little in the past although it is a growing technology. At present, waterborne paints are being applied electrostatically on commercial equipment,[131-133] farm machinery,[134,135] automobiles,[136] fabricated metal

Table 3-15. ADVANTAGES OF WATERBORNE COATINGS

1. Reduction of fire or explosion potential and toxicity in both the storage and application areas.
2. Greater variety of available monomers.
3. Higher solids content possible at same viscosity.
4. Lower raw material cost (e.g., water vs. solvent).
5. Ease of clean-up.
6. Good selection of colors.
7. Good quality finish.
8. Can be formulated for metallics.
9. Rapid color changes possible.

Table 3-16. DISADVANTAGES OF WATERBORNE COATINGS

1. Protection of equipment against rust needed.
2. More pretreatment may be required than for organic solvent-based paint.
3. Longer flash-off may be required.
4. Humidity control equipment may be necessary.
5. Possible emission of amines to the atmosphere.
6. "Faraday effect" is a problem for certain shapes.
7. Metallic finishes from organic solvent-based coatings have not been matched with other waterborne coatings.

products,[137-139] and appliances,[140] as well as on metal furniture.[122,141,142]

Since waterborne paints are readily atomized, they can be applied by air, airless, or by electrostatic spray using guns, disks, or bells.[140,143] These can be operated manually or automatically. Waterborne and organic solvent-borne paints are generally of similar viscosity; therefore, there are few if any differences between spray systems for the two coating types. Waterborne paints are more corrosive however, and require the use of stainless steel or plastic pipes and pumps, and stainless steel or aluminum spray nozzles.

The only significant problem associated with electrostatic spraying of waterborne paints is a safety hazard resulting from the high conductivity of the paint itself. As the paint is charged at the gun, the charge travels back through the supply line to the paint reservoir. The system, therefore, must be insulated or isolated. This presents no problem for small operations; however, for large facilities using separate paint supply rooms, it presents a significant problem. There is a possible method for overcoming this disadvantage. It involves the use of a small paint reservoir at the spray booth which, through the use of a level sensor, is automatically filled as needed from the main paint supply line. The supply line is equipped with a spray nozzle similar to that of a garden hose and the line is grounded. The small paint reservoir is charged to approximately 90 kV and is isolated. As the supply line fills the reservoir, the electrostatic charge atomizes the paint, thus producing an air gap between the reservoir and the nozzle. This gap isolates the supply line and paint supply room from the electrostatic charge at the booth. Color changes with this type of system can be accomplished through the use of multiple reservoirs at the spray booth. These buckets are small and could be changed within a matter of seconds.

The system appears to be technically feasible although it has not been applied to an actual coating line. The technology was developed by the Applied Technology Division of TRW, Inc., while designing a charged droplet scrubber. The system has been successfully tested for that operation.[144]

The basic spray painting process using waterborne paint differs very little from a process using organic solvent-borne coating.[122] Emissions come from the spray booth, flash-off area, and curing oven. The magnitude of the emissions is dependent upon the organic solvent content of the paint and the efficiency with which it is applied. Transfer efficiency for conventional spraying ranges from 30 to 60 percent depending upon a number of variables including part complexity.[56] Electrostatic spraying by guns, disks, and bells can increase to levels ranging from 60 to 95 percent.[56,108,140]

3.1.3.2 Waterborne Dip Coating. Dip coating is one of the most common techniques for the application of waterborne paints.[145] This method is presently being used in the automobile and bicycle industries as well as in the metal furniture industry.[146-150] The dip coating process is essentially the same for waterborne as with organic solvent-borne coatings. The dip tank must be constructed of stainless steel or some other corrosion resistant material and the flash-off period may have to be longer for the reasons previously explained. These are the only significant differences between the two systems.

The factors affecting emissions from a dip coating line are the same as for spray coating. The transfer efficiency for dip coating of waterborne paint is estimated at 90 percent which is the same as for organic solvent-borne paint.[56]

3.1.3.3 Electrodeposition of Waterbornes. Electrodeposition (EDP) of waterborne paint is one of the most promising emission control techniques available. It has proved successful when applied to automobiles, lawnmowers, metal furniture, and miscellaneous other metal parts and products.[151-155] Electrodeposition is capable of applying a 0.25 μm (1 mil) coating in a single application which makes it very attractive to the metal furniture industry. Autophoretic coating which is similar to EDP is not used in the metal furniture industry because this technique is presently limited to black paint only.[150]

Electrodeposition involves lowering parts to be coated into a tank of low solids waterborne coating solution. The tank or the periphery of the tank are negatively charged while the parts are grounded. The negatively charged polymer is attracted to the metal surface and is deposited uniformly. Systems of opposite polarity can also be used.[152] Figure 3-7 represents a typical EDP line using ultrafiltration.

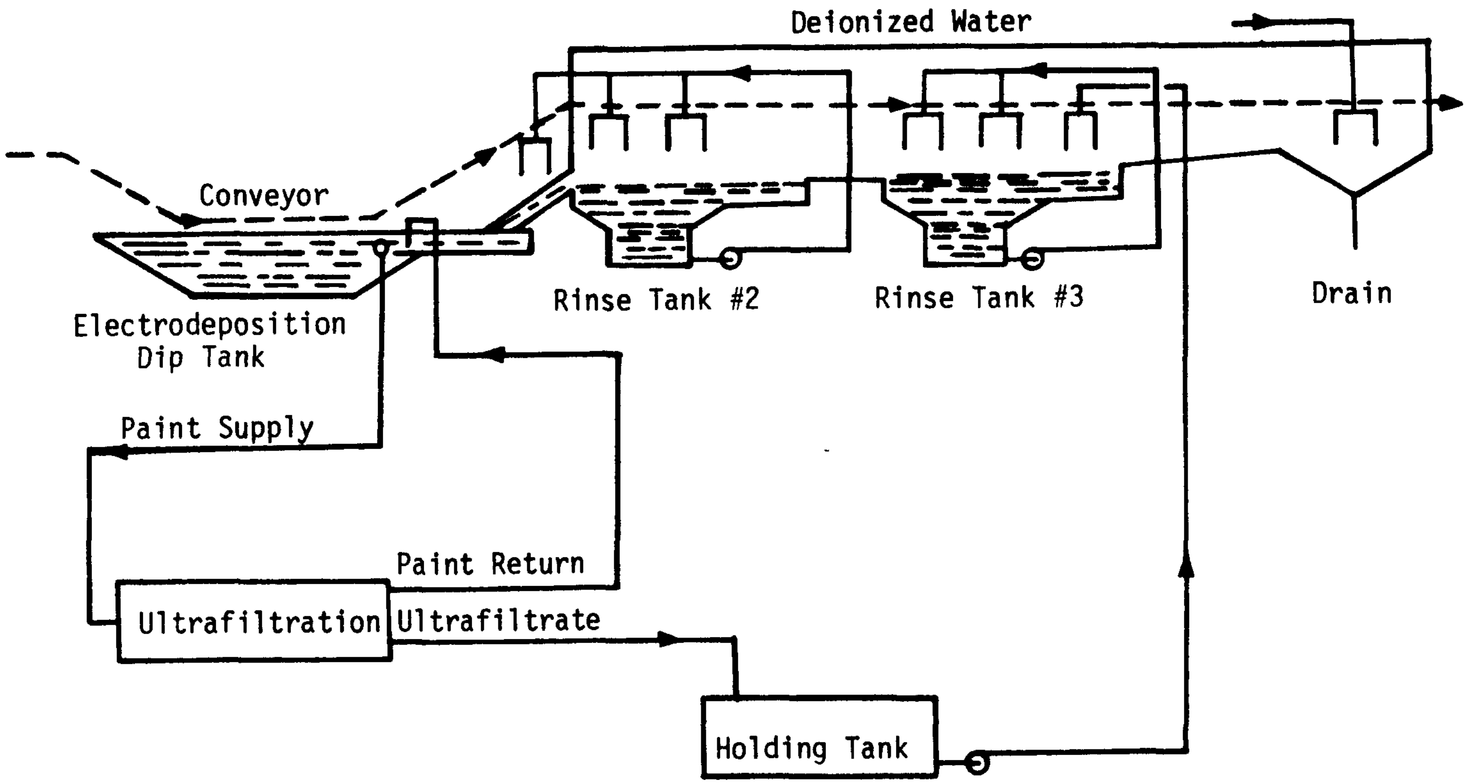


Figure 3-7. Typical EDP coating system.

Electrodeposition lines require a deionized water rinse stage at the end of the pretreatment cycle which is not found in other systems; however, a dry-off oven, though often used, is not required. The rinsed parts are lowered into the EDP tank containing waterborne paint consisting of a 7 to 10 percent dispersion of a colloidal polymer.[153] To avoid striping, the DC current is not applied until the parts are totally submerged. Dwell time in the tank is typically 1.5 to 2 minutes.[153,154] The thickness of the coating can be controlled by selecting the appropriate dwell time and electrical potential. The voltage ranges from 50 to 400 volts and the amperage ranges from 50 to 4,000 amps. Average conditions involve a voltage of 200 to 250 volts and an amperage of 300 to 450 amps.[125,152]

After the current is turned off, the parts are lifted from the bath, drained, rinsed in deionized water to remove "dragout," and then baked. Solids from the dragout are carried by the rinse water and collected by ultrafiltration. The rinse water is passed through an ultrafilter which allows no particles larger than 200 angstroms to pass. Only water, some electrolyte, and organic solvent permeate the filter and are reused in the rinse. Resin and pigment materials are returned directly to the EDP tank.[41] This process is reported to reduce paint consumption by up to 30 percent.[156,157]

The quality of the finish is affected by voltage, amperage, temperature, dwell time, pH, and paint solids content.[119] Excessively high voltage causes holes in the coating due to gassing. Too high a temperature is detrimental due to possible paint flocculation at temperatures approaching 305 K (90°F). At high pH levels, there is a reduction in deposition; if the pH drops below the isoelectric point, the entire tank of paint can coagulate.

As the paint solids are attracted to the grounded metal part, they tend to "wring" the water out of the coating leaving the coating which is approximately 90 percent solids with the remaining 10 percent consisting primarily of water. Approximately 2.5 percent of the coating on the substrate is volatile organic solvent.[125] If the solids content in the EDP tank is too high, the voltage cannot "wring" the moisture from the deposited film; if the paint is too low in solids, the film can be too thin.

Furniture parts painted with EDP are normally baked for 15 to 30 minutes at 410 to 480 K (275° to 400°F).

The EDP process has three potential sources of VOC emissions: solvent evaporation during curing, evaporation from the surface of the EDP tanks, and evaporation from the cascading rinse water. Emissions from the tank surface and the rinse water are very minor. This is due to a large extent to the ultrafiltration process. Emissions from the curing oven are low due to the small quantity of solvent on the wet substrate.

3.1.3.4 Waterborne Flow Coating. Waterborne flow coating is essentially no different from flow coating with organic solvent-based paint. This process has seen use in several industries including those producing major appliances, trailers, and metal furniture.[158,159] As with other types of waterborne applications, certain precautions have to be taken to prevent rusting of the flow coating chamber and nozzles.

Sources of emissions from this system are the flow coating chamber, flash-off area, and curing oven. Emissions from the flash-off and curing steps are similar to other waterborne processes. Emissions from the flow coating chamber are dependent upon the transfer efficiency which is achieved. This is estimated to be approximately 90 percent.[56]

3.2 EMISSIONS CONTROL WITH ADD-ON CONTROL EQUIPMENT

Each of the following sections describes add-on air pollution control equipment for VOC emissions as follows:

- Processes which employ add-on control equipment in the metal furniture industry
- Principle behind add-on control devices
- Variables of performance
- Process descriptions
- Advantages and disadvantages
- Process VOC controls
- Operating parameters for new add-on control devices.

3.2.1 Carbon Adsorption

Carbon adsorption as a control technique has been commercially used for several years. Although carbon adsorbers are not being employed in the metal furniture industry, nor any other metal coating industry to date, several other facilities within the surface coating industry have used carbon adsorption to control VOC emissions. These industries include those which surface coat paper, and rubber products.[160-163] It is felt that carbon adsorbers have the potential to be incorporated in the metal furniture industry.

In general terms, the principle behind adsorption as it applies to the metal furniture industry includes the following. The "activated" carbon constitutes the adsorbent, and the organic solvent that is removed from an airstream is referred to as the adsorbate. For the metal furniture industry, there is a mixture of organic solvents or adsorbates. These include a complex combination of aliphatics, aromatics, esters, ketones, alcohols, etc.[90,109,111] Adsorption of the adsorbates occurs at the surface of the adsorbent. The effectiveness of the adsorbent depends on its surface area, porosity and existence of capillaries. In the metal furniture industry, for each adsorbate removed, the type of adsorption is "physical." Physical adsorption means that the adsorbates are collected by and removed from the adsorbent without a chemical change. All adsorption processes are exothermic, and for surface coating operations, the temperature change in a carbon bed would be about 10 K.[34,164,165]

There are several variables which affect the performance of carbon adsorbers and most are related mathematically to the adsorptive capacity of the carbon. This term, adsorptive capacity, defines the weights of adsorbates that can be retained on a given weight of carbon and is expressed below:[166]

$$\text{Adsorptive Capacity} = \frac{Vm}{T \log (Co/Ci)}$$

where, adsorptive capacity = $\frac{\text{g of adsorbate}}{\text{g of adsorbent}}$

Vm = liquid molar volume of adsorbate at normal boiling point

T = absolute temperature

Co = concentration of adsorbate at saturation

Ci = initial adsorbate concentration into adsorber

The liquid molar volume of an individual adsorbate is related to the individual molecular weight and density of the solvent at its boiling point. The greater the Vm of the adsorbates, the higher the molecular weights and boiling points. In other words, carbon generally has a greater adsorptive capacity for higher boiling solvents. The removal of solvents by physical adsorption is practical for adsorbates with molecular weights over 45.[32] The actual quantity of adsorbates removed increases as their concentration increases and the adsorbent temperature decreases.

Generally, physical adsorption of a group of adsorbates in the metal furniture industry results in both low and high boilers at first being adsorbed across the bed uniformly. However, as more high boilers increase on the adsorbent, the more volatile portion of the adsorbates are vaporized. At this point, the bed has reached the breakthrough point. This process continues until the exit airstream contains the highest boiling component which means the adsorbent is saturated. In practice, it is best to operate the carbon bed until the breakthrough point has been reached and then the bed is regenerated.[32]

Figure 3-8 shows a typical carbon adsorption process and is representative of a unit that could be installed at a metal furniture facility. Usually, the equipment consists of a filter and cooler, blower, two carbon beds, condenser, and decanter. The blower maintains a constant flow of organic vapor-laden air to the unit. As the airstream travels through the carbon adsorber, it is first filtered to remove particulate matter and cooled to no greater than 311 K (100°F). The adsorbates in the airstream are adsorbed onto the activated carbon in one of the two carbon beds. Usually, two carbon beds are adequate for continuous operation; one unit adsorbs gaseous organics, while the other is desorbed with steam or hot air. However, three or more carbon beds may handle more effectively the heterogeneous mixture of adsorbates resulting from the surface coating of metal furniture. For the three bed case, two beds in series operate while the third is regenerated. This permits the activated carbon bed to remain in service after breakthrough since the second bed in series removes the low boiling solvents emitted from the first bed. When the first bed becomes saturated, it is removed from service and regenerated. The second bed then becomes the first bed and the newly regenerated bed is the new second bed in series.[34,164,166,167]

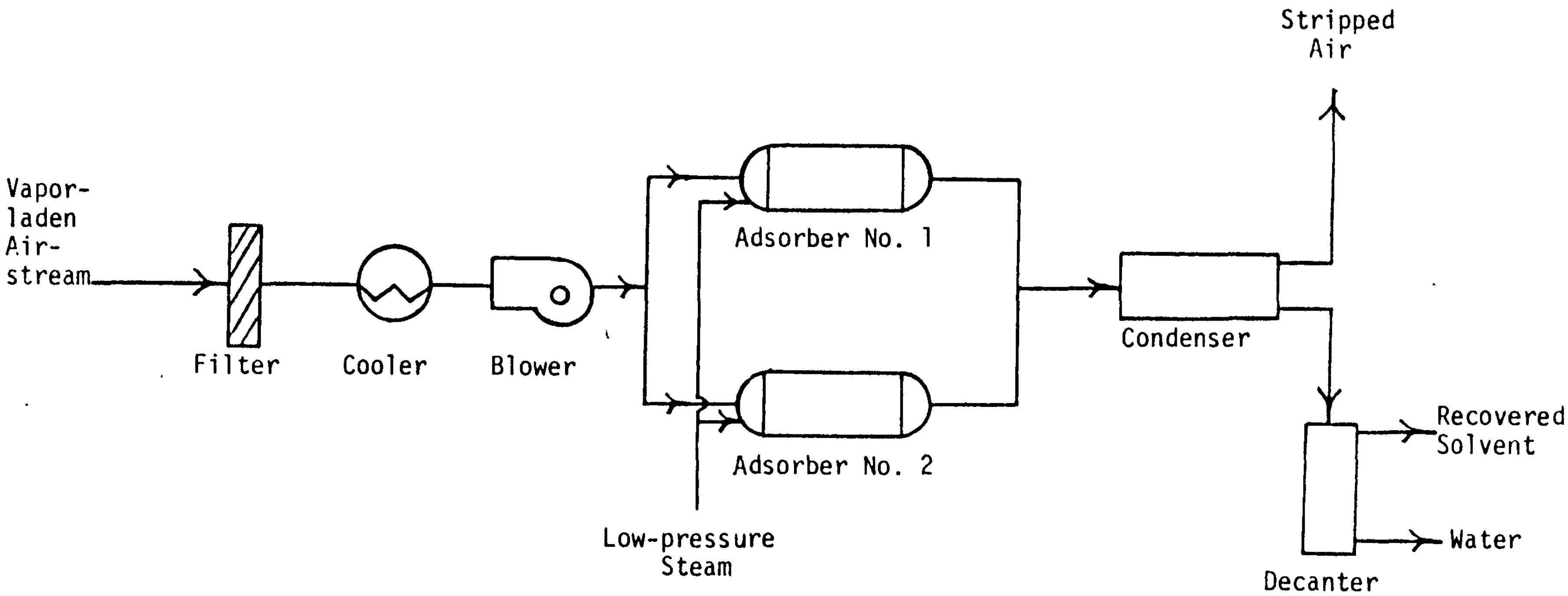


Figure 3-8. Carbon adsorption process.

During the desorption process, organics are removed from the carbon bed by blowing steam, hot air or inert gas across the bed. The removed organic vapors and steam (the preferred carrier gas) are liquified from the airstream in a condenser. The collected solvents and water are then separated in a decanter. To separate the recovered mixture into reusable solvents would require fractional distillation.[113,127] An alternative to this approach is to incinerate the organics in order to recover heat to produce steam for other processes at the plant.[32,111,164]

Tables 3-17 and 3-18 list advantages and disadvantages for employing carbon adsorbers on coating lines in the metal furniture industry. The advantages and disadvantages discussed relate only to carbon adsorbers that have the potential to be employed on coating lines that apply conventional solvent-based paints to metal parts. The remainder of this section concentrates upon the emissions from a coating line and determines what processes on the coating line can be controlled by carbon adsorbers.

Theoretically, carbon adsorbers could be employed to control VOC from the application, flash-off and bake oven areas. The applicability of doing this is discussed in detail for each process area that emits VOCs.

Carbon adsorbers could be used to control VOCs from all of the different types of application techniques (including touch-up) such as spray, flow, dip, and roller coating. The percent of VOC emitted from the application areas is shown in Table 3-19.[44] The table indicates that carbon adsorbers are best employed for coating methods using spray and flow. All of the coating methods could feasibly be controlled by this method if the flash-off area were enclosed and flash-off air were vented along with the air from the application area to the carbon adsorber. Generally, most of the emitted solvents from the application and flash-off areas used in the metal furniture industry fall into a molar volume range (80 to 190 cm^3/mole) that is generally acceptable for adsorption. Table 3-20 lists some of the solvents that present problems for carbon adsorbers. Of the solvents listed, nonane (a component of most grades of mineral spirits) is commonly used in the metal furniture industry. Mineral spirits are used in substantial proportions in many alkyd and acrylic enamels but might not be effectively desorbed with either super heated steam or hot

Table 3-17. ADVANTAGES FOR EMPLOYING CARBON ADSORBERS

Advantage	Reference
1. Proven technology for controlling solvent emissions in other non-related industries.	111, 168, 169
2. If treating a homogeneous phase, reduced costs because of solvent recovered.	111, 168

Table 3-18. DISADVANTAGES OF EMPLOYING CARBON ADSORBERS

Disadvantage	Reference
1. Carbon beds that treat exhaust concentrations of 100-200 ppm of solvent require large amounts of steam during regeneration (30 kg/kg of solvent).	44, 164, 168
2. Materials of construction must be corrosive resistant.	44, 164, 168
3. The Mass Transfer Zone (MTZ) will increase as air velocities increase.	44, 164
4. Increased non-production related operating costs of a facility.	168
5. Adsorbers have to handle a mixture of solvents.	44
6. Effluents from bake ovens must be cooled to less than 310 K (100°F).	44
7. Water vapor (spray booths) from the application area would compete for adsorptive sites.	44
8. High boiler solvents emitted from the bake oven would be difficult to desorb.	111, 170
9. Polymerized products and plasticizers from the bake oven could foul a carbon bed.	44
10. Carbon bed fires can occur.	111
11. Any particulate can coat a carbon bed and render it ineffective.	44

Table 3-19. PERCENT OF TOTAL VOC EMISSIONS FROM VARIOUS COATING STEPS[42]

	Coating Step		
Coating Method[a]	Application	Flash-Off	Bake Oven
Spray Coat	30-50	10-30	20-40
Flow Coat	30-50	20-40	10-30
Dip Coat	5-10	10-30	50-70
Roller Coat	0- 5	10-20	60-80

[a]Coating only with organic solvent-based coatings.

Table 3-20. PROBLEM SOLVENTS FOR CARBON ADSORPTION[169]

		Boiling Point	
Solvent	V_m cm^3/mol	K	(°F)
Dodecane	274	489	(421)
Undecane	251	468	(383)
2-ethylhexyl acetate	238	472	(390)
Decane	229	447	(345)
Butyl carbitol	213	504	(448)
Nonane	207	423	(302)
2,6-dimethyl 4-heptanone	207	446	(345)
Diethyl cyclohexane	207	---	---
Butyl cyclohexane	207	447	(345)
1-methyl pentyl acetate	194	---	---
Diethyl cyclopentane	192	425	(307)
Nitroethane	75	389	(239)
Propanone	74	329	(133)
Dichloromethane	65	313	(104)
Ethanol	61	351	(173)
Nitromethane	53	374	(214)
Methanol	42	339	(149)

air.[129] The major disadvantages that might prevent this control technique from being employed on this part of the coating line are 1, 3, 5, and 7 (Table 3-18).

Controlling VOCs from the flash-off area offers three alternatives all of which require enclosing the flash-off area: (a) control combined air flow from the flash-off and application areas (already discussed); (b) control individual air flow from flash-off; and (c) control combined air flow from the flash-off and baking oven areas. A fourth alternative, representative of the industry, is to allow this area to remain as a fugitive source of VOCs.[10] For carbon adsorbers, the handling of emissions from the flash-off area depends in part on a detailed analysis of Table 3-19.

The last area emitting VOCs that could be controlled by a carbon adsorber is the baking oven. However, Disadvantages 2, 5, 6, 8, and 9 shown in Table 3-18 may prevent utilization of this control technique for most metal furniture bake oven VOC emissions. Section 3.4.1 discusses the control efficiencies of using carbon adsorbers when employed to control VOC emissions from the various process areas. Table 3-21 contains information considered to be representative for new metal furniture coating lines employing carbon adsorbers.

3.2.2 Incineration

Incineration of gaseous organics has been widely used in several industrial surface coating industries including the metal furniture industry.[124] Other industries which have successfully employed incineration as a control technique for VOC emissions include automobile, paper, can fabric, and coil coating industries.[163,172-188] Data from these industries indicate that incineration could also be considered a possible control technique for the metal furniture industry.

There are two different types of incineration processes: thermal or direct flame, and catalytic. Before these two incineration methods are described, a brief explanation of the principle of this control technique for VOCs is provided here as it relates to the metal furniture industry.

In general terms, the gaseous solvents emitted from a coating line are combustible materials which can under proper conditions be converted to

Table 3-21. PROCESS OPERATING PARAMETERS FOR CARBON ADSORBERS EMPLOYED TO CONTROL VOC EMISSIONS

Parameter	Operating range
Application area	
Air flow through adsorber	4.7-21 SCMS (10,000-45,000 SCFM)[159,160,161]
Carbon in bed	5,000-12,000 kg (11,000-27,000 lb)[159,160,162]
Blower	1
Number of carbon beds	2-3[159,161]
Saturation point	60-90 min.[161]
Percent by volume of solvent in coating	50-78[159,160,161]
Steam usage	30 kg/kg of solvent (30 lb/lb of solvent)[163]
Carbon bed replacement	0.5-2 yr.[111,162,163]

carbon dioxide and water vapor. However, no combustion process is 100 percent efficient and some carbon monoxide is formed. During the incineration of these materials, proper control of time, temperature, and turbulence determines how efficient the incinerator is in controlling VOC emissions. The remainder of this section concentrates on the two types of incineration.[167]

3.2.2.1 Thermal or Direct Flame Incinerator. A thermal incinerator consists essentially of a fuel feed system and burners, a combustion zone, and a means of exhausting the products of combustion. The auxiliary fuel is usually natural gas, although propane and butane and some fuel oils are employed. The purpose of the burners is to combust the auxiliary fuel so that the temperature inside the combustion chamber is high enough to ensure incineration of the gaseous vapors emitted from the coating line. This zone of the thermal incinerator must also provide good mixing. There are four types of gas burners which are used to burn the auxiliary fuel; nozzle-mixing, premixing, multiport, and mixing plates. The gas burners are arranged either in distributive or discrete patterns. Nozzle-mixing and premixing burners are arranged in distributive patterns for which firing is done tangentially (Figure 3-9). Air for combustion of the gaseous fuel is taken from the waste stream or outside air. The contaminated air stream is introduced tangentially or along the major axis of the incinerator.[32,44]

Multiport burners are installed across a section of the incinerator and use only the air from the waste stream for combustion. This type of incineration cannot handle all of the VOC contaminated airstream. Thus the portion of the waste stream that is bypassed mixes with the burner flames in a restricted and baffled area.[32,44]

Mixing plate burners (discrete pattern) are placed across the inlet of the incinerator and the flames are mixed directly with the VOC contaminated exhaust stream. This mixing provides high velocities which improves turbulence of the waste stream. Figure 3-10 shows an example of a burner employing mixing plates.[32,44] Figure 3-11 shows a burner that employs fuel oil as the auxiliary fuel. This type of incinerator uses a discrete pattern.

To increase mixing in all of the above mentioned burning techniques, baffles or turning vanes are placed in front of the air inlet zone. Also,

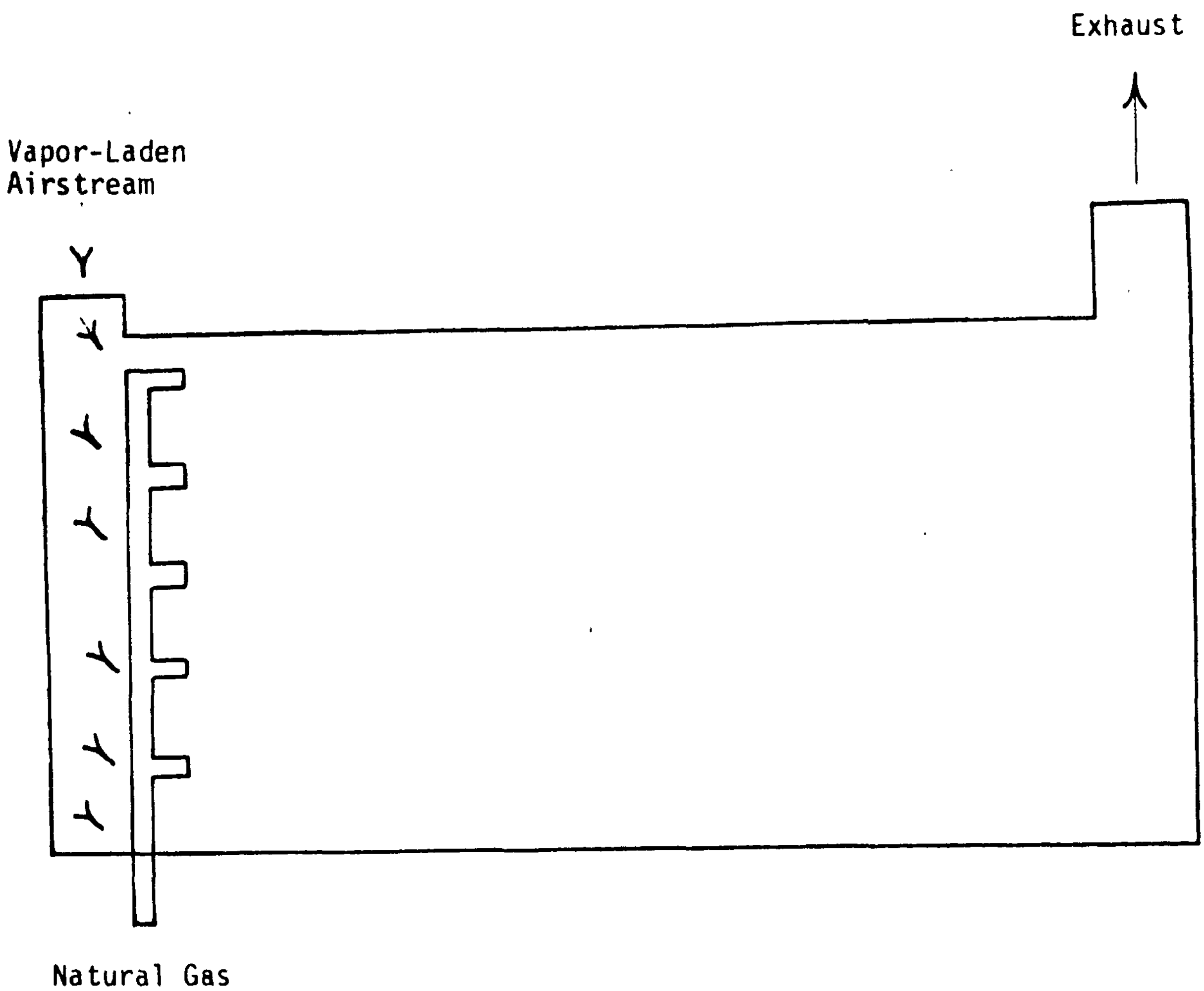


Figure 3-9. Incinerator with a distributed burner.

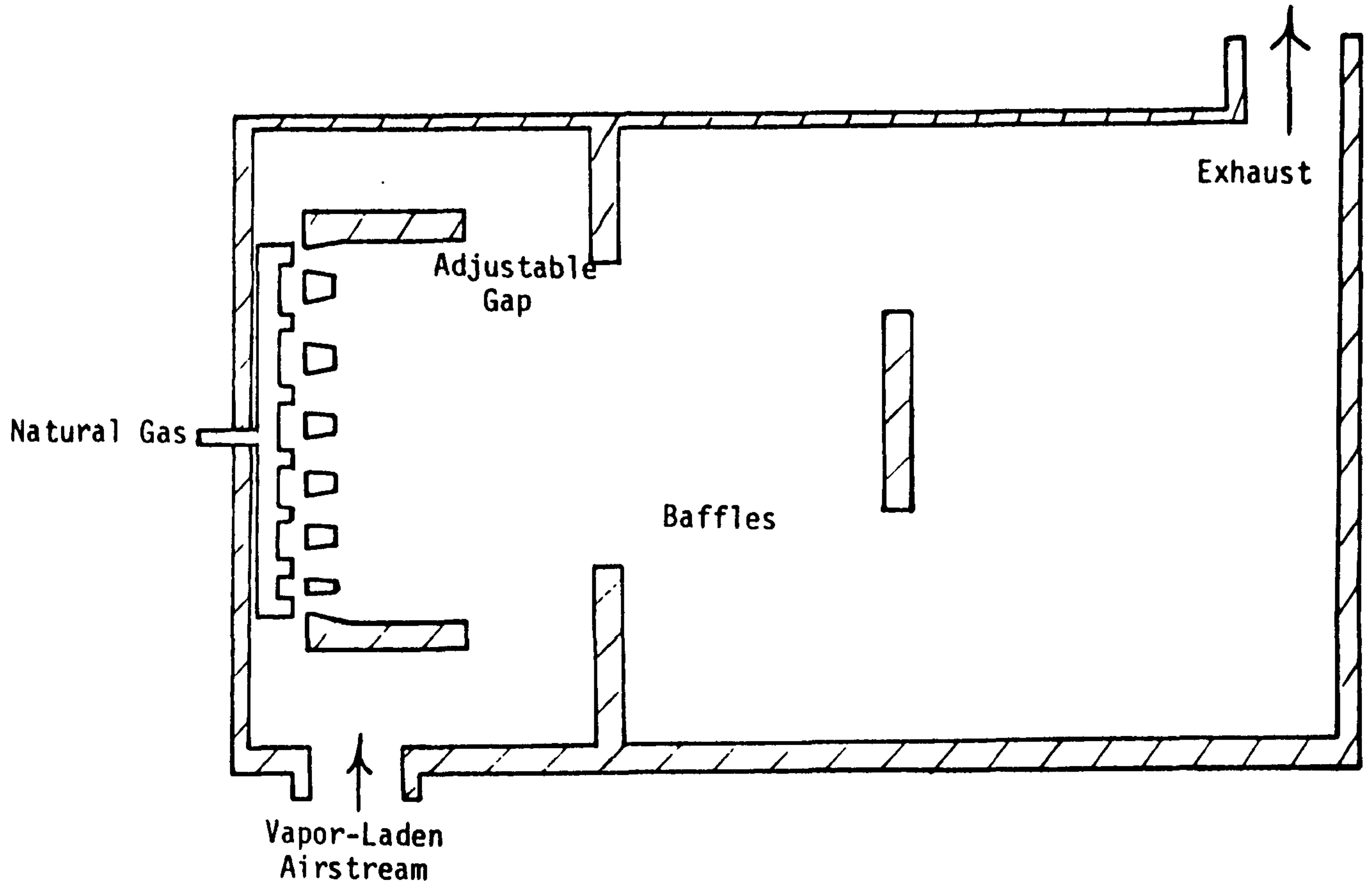


Figure 3-10. Incinerator employing mixing plates.

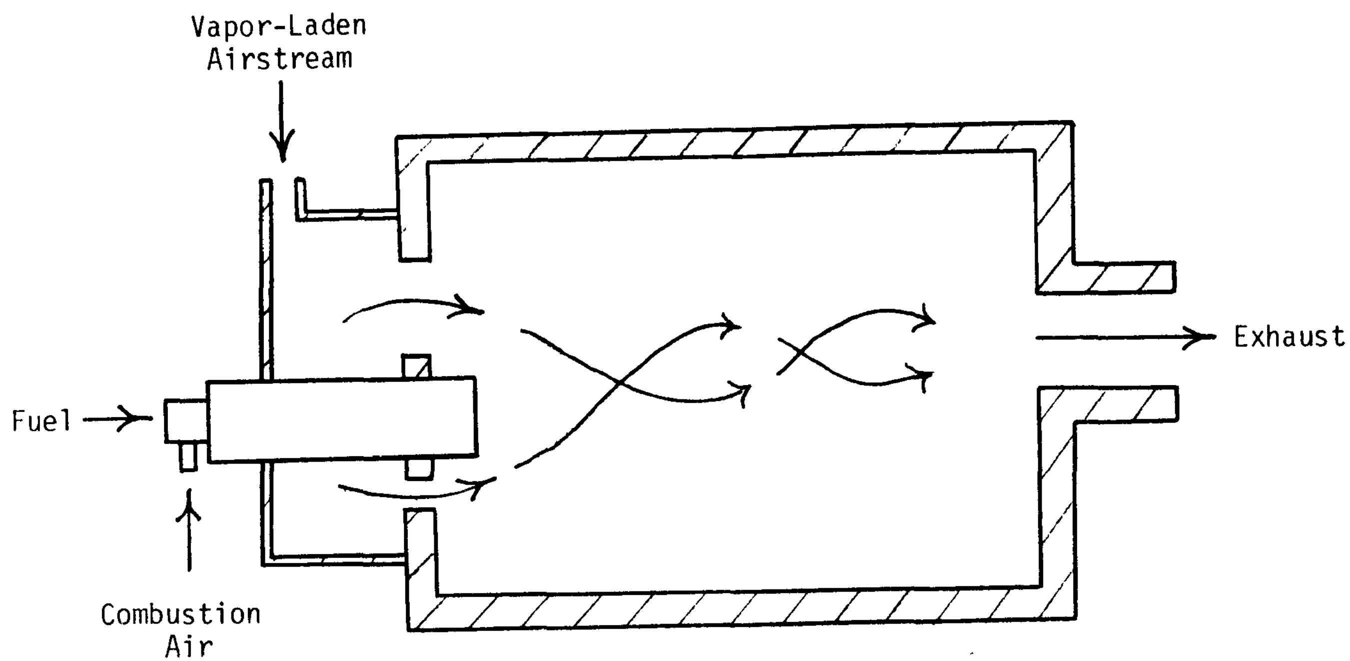


Figure 3-11. Incinerator using a discrete burner.

tangential air inlet is part of the design of the burner. The mixing in this part of the incinerator is very critical to efficient burning of the gaseous solvent.[44]

The next part of the incinerator is the combustion zone. After the temperature of the vapor-laden airstream is raised, the combustion zone must maintain this temperature and provide the required residence time for the organic solvents to be converted to carbon dioxide and water vapor. A range of 922 to 1,089 K (1,200° to 1,500°F) for 0.3 to 0.5 seconds is quite efficient in converting most gaseous solvents to carbon dioxide and water vapor. Insufficient combustion chamber volume has been the most significant design flaw in the failure of some incinerators. The size of the combustion chamber is determined by the volumetric flow rate of the vapor-laden gas stream, and combustion products at the design temperature and retention time.[44]

Additional equipment that can be installed along with thermal incinerators consists of heat recovery equipment. This equipment has been employed only with incinerators that control VOC emissions from bake oven areas. Heat recovery equipment reduces the amount of fuels required by the incinerator and, in some cases, by the bake ovens. The type of heat recovery equipment varies depending on the desired amount of fuel savings. The various heat recovery equipment and approximate thermal energy that can be recovered are shown in Table 3-22.

Figure 3-12 shows an incinerator equipped with a single pass fume preheater. Required equipment includes a preheat recuperator, piping, and a pump for the working fluid. Heat recovered by this system can be used in the metal dry-off ovens and makeup air for the oven.[44,177,189-191]

A second heat recovery system which is more efficient than the single pass is a multiple chamber preheat and recovery system. This type of heat recovery system has been installed on a coil coating line. The equipment includes an incinerator equipped with an odd number of preheat and recovery chambers which contain stoneware material. In operation, the bake oven exhaust is preheated in one chamber before passing through the incinerator, and heat is recovered from the incinerator exhaust stream. Each chamber can serve to preheat or recover heat in this system. All of the recovered

Table 3-22. HEAT RECOVERY EQUIPMENT AND THERMAL ENERGY RECOVERY

Heat recovery equipment	Percent of thermal energy recovered from incinerator	Reference
Single-pass fume preheater	40-69	44, 177, 189, 194
Multi-pass preheat and recovery	70-90	44, 177
Regenerative heat exchanger	75-90	44
Inert Gas drying system	90	191

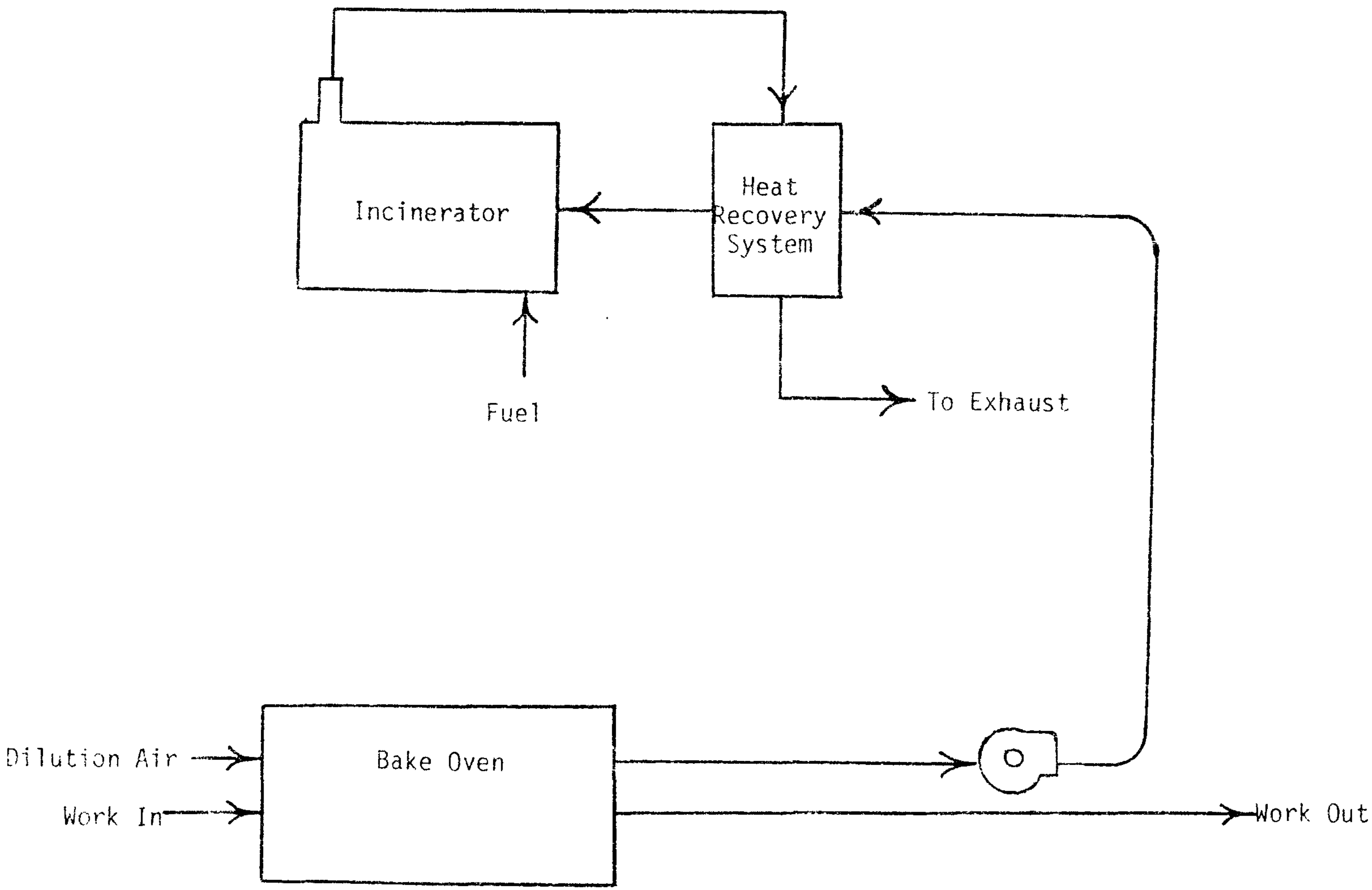


Figure 3-12. Bake oven equipped with incinerator and heat recovery.

energy is maintained with the process. Another example (regenerative heat exchange) of this type of heat recovery equipment uses both refractory and rotary plates instead of stoneware.[44,177]

A proposed inert gas drying system would reduce fuel consumption in the incinerator and bake oven. In this system, the incinerator handles only an inert gas with solvent vapors exhausted from a bake oven. The incinerator only required auxiliary fuel for a pilot burner and just enough combustion air (stoichiometrically balanced) to burn the solvents in the inert gas stream. This produces an exhaust gas from the incinerator which contains very little oxygen. Heat from the incinerator exhaust gas is recovered and heat demand in the bake oven is satisfied by recycling the cooled incinerator exhaust stream through the bake oven. Heat captured in the heat recovery system can be used in the metal preparation area. The inert gas drying system can reduce the size of the bake oven (reduced lower explosive limit [LEL] concerns) and the incinerator. The proposed system and incinerator are shown in Figure 3-13.[191]

Tables 3-23 and 3-24 provide advantages and disadvantages of employing incineration as a control technique for processes on a metal furniture coating line.

Thermal incinerators could be employed on all three process areas that emit VOCs on a coating line. However, as mentioned in Table 3-24, Disadvantage 3 would be a significant problem for controlling VOCs from a spray booth because of air flow requirements based on the threshold limit value (TLV) which by definition demands more air than lower explosive limit values used by ovens. For TLVs, about 60 times more air is necessary above the amount that is required for evaporation. Thus, it is not practical to recommend thermal incinerators for the spray booth or an enclosed flash-off area (which would require TLV design basis).[44,168]

Thermal incinerators have only been employed successfully on bake ovens. With heat recovery equipment to reduce fuel consumption, thermal incinerators have proven to be an acceptable control technique for this process area. Also, from Table 3-19, it appears for the dip and roller application methods that the majority of VOCs would be controlled by this method. Finally, if the flash-off area was enclosed and designed to

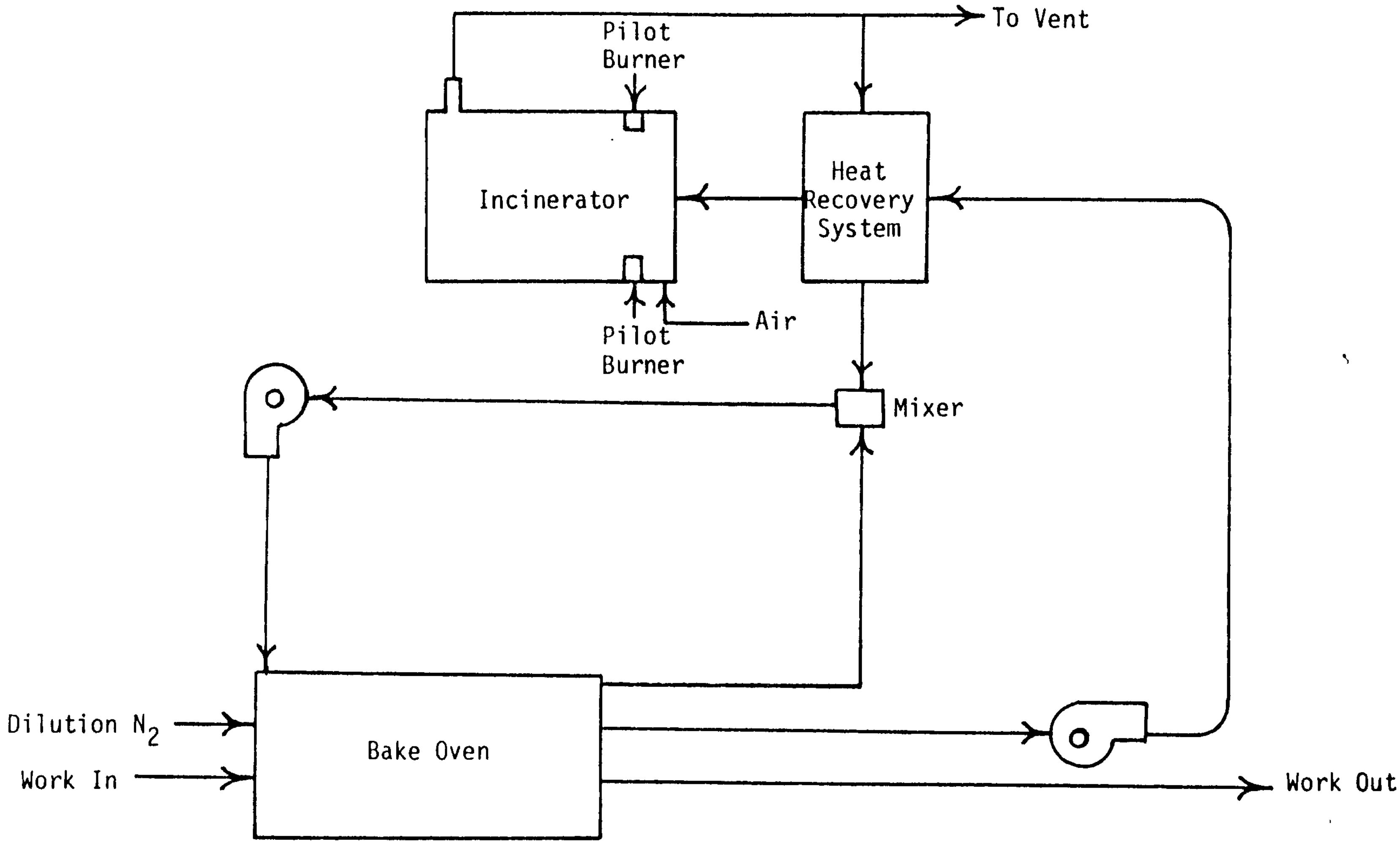


Figure 3-13. Inert gas drying system.

Table 3-23. ADVANTAGES OF EMPLOYING THERMAL INCINERATION AS A CONTROL TECHNIQUE

Advantage	Reference
1. Has small space requirement, low-maintenance operation.	167
2. Can provide waste boiler heat for other plant operations.	167
3. With heat recovery equipment, can provide energy to other process areas.	44, 177, 189-194

Table 3-24. DISADVANTAGES OF EMPLOYING THERMAL INCINERATION AS A CONTROL TECHNIQUE

Disadvantage	Reference
1. High operating costs in areas of large air requirements with low VOC concentrations (0.1 to 10 percent LEL).	167
2. Cannot be used on some types of halogenated solvents because of toxic combustible products.	167
3. Large air flows (e.g., from spray booth) reduce the efficiency of an incinerator.	44, 162
4. Problem of auto-ignition for single-pass heat recovery systems, because of condensation.	177
5. Warping of materials of construction for some incinerators.	174, 181

handle air flows in the 25 percent LEL range, it might be practical to combine this flow with bake oven exhaust to further reduce VOC emissions from the coating line.

Table 3-25 contains the process operating parameters for thermal incinerators that have been employed on surface coating lines other than the metal furniture industry. This information is considered to be representative of a metal furniture bake oven employing thermal incineration to control VOC emissions.

3.2.2.2 Catalytic Incineration. The catalytic incinerator differs from the direct-fired unit in that the catalyst enables combustion of the solvent at a lower temperature. The catalyst promotes combustion by increasing the rate of oxidation reactions without itself changing chemically. Oxidation of the solvents occurs at the surface of the catalyst (Figure 3-14).[34,44,168]

A catalytic incinerator contains a preheat section, a chamber which contains the catalyst, temperature indicator and controllers, safety equipment and optional heat recovery equipment. The preheat section is used to raise the temperature of the incoming gas stream to 590 to 750 K (600° to 900°F). The preheat section is basically a discrete burner followed by a mixing zone. The increase of gas temperature obtained in the preheat section is sufficient for the solvent vapors to be catalytically burned as the gas stream leaves the incinerator at an elevated temperature of 700 to 860 K (800° to 1,100°F). Heat recovery equipment at the exit of a catalytic incinerator is optional. This type of equipment has already been discussed in Section 3.2.2.1.

The catalyst itself is usually of the platinum family of metals supported on metal or matrix elements made of ceramic honeycombs or rods, or aluminum pellets. Criteria for catalyst supports are (a) high geometric surface area, (b) low pressure drop, (c) uniform gas flow across the surface of the catalyst, and (d) structural integrity and durability. The performance of the catalyst is dependent upon the temperature of the incoming gas and residence time between the solvent vapors and catalyst. In addition, the efficiency of the catalyst is also a function of organic compositions and concentration being oxidized.[32,44,195]

Table 3-25. PROCESS OPERATING PARAMETERS FOR A THERMAL INCINERATOR

Parameter	Range
Volumetric Flow Rate	2.4 to 24 SCMS (5000 to 50 000 SCFM)[172, 176, 180, 187, 190]
Oven Exhaust Temperature	330 to 420 K (140° to 300°F)[185, 187, 190, 191]
Oven Exhaust Residence Time Inside Incinerator	0.3 to 0.5 sec.[42]
Incinerator Operating Temperature	920 to 1250 K (1200° to 1800°F)[162, 170, 172-175, 181, 187, 189, 190]
Normal Operating Temperature	1030 K (1400°F)
Single Pass Fume Preheater Exhaust	620 to 730 K (650° to 850°F)[187, 190]

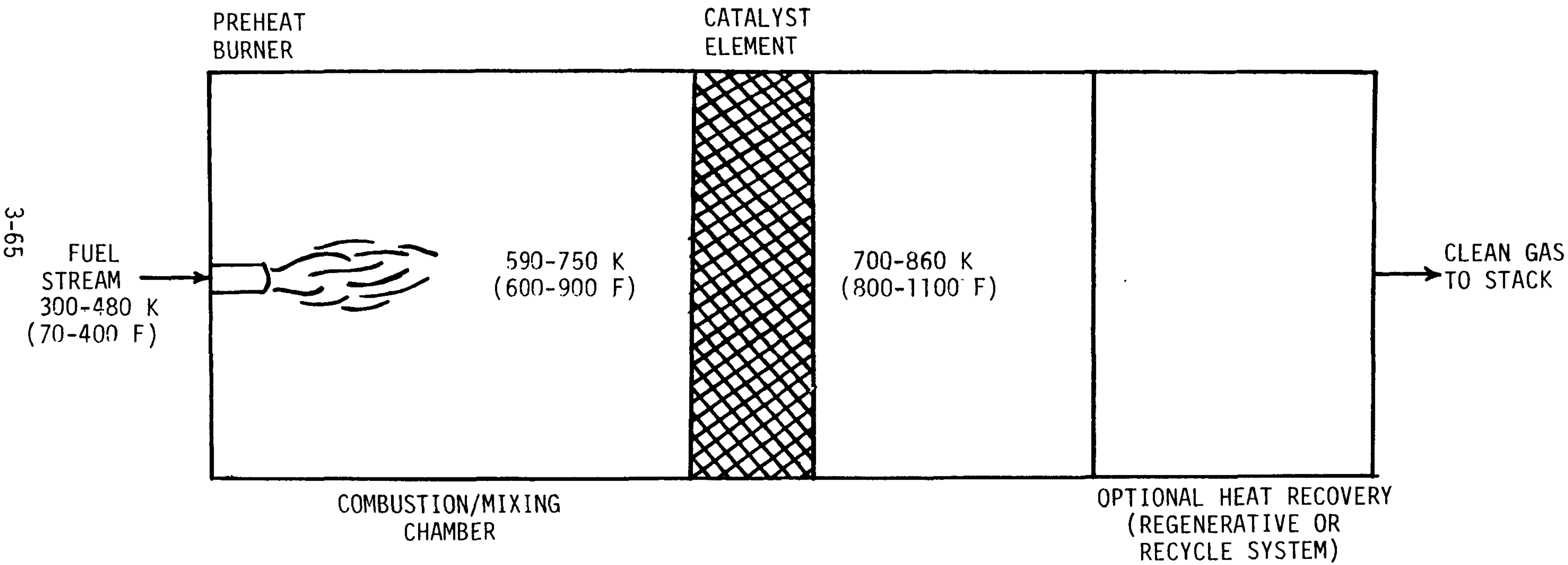


Figure 3-14. Schematic of catalytic afterburner system.

Tables 3-26 and 3-27 list advantages and disadvantages of employing catalytic incinerators on coating lines for the metal furniture industry. This information relates to coating lines that employ solvent based coatings (e.g., the model plants) in the application area.

Disadvantages 2 and 4 shown in Table 3-27 would present a problem for a catalytic incinerator employed in the application area of a coating line. Application areas (e.g., spray booths) would probably have to be equipped with water curtains and maybe even filtration pads to collect particulates emitted from applying the coating. The particulate contains pigments and additives. Inorganic pigments contain heavy metals that can poison the catalyst. The known heavy metal poisons contained in inorganic pigments are zinc, lead, arsenic, bismuth, tin, and cadmium. Organic pigments, additives (e.g., plasticizers, paint driers, etc.) and other metallic oxides coat and deactivate (disadvantage 3) certain catalyst sites. The catalyst poisoning and deactivating coupled with high air flow requirements and low vapor concentrations in the application oven exhaust reduces the effectiveness of this control technique. Therefore, catalytic incineration is not recommended to control VOC emissions from the application area, or combined application and flash-off areas.[32,44]

Catalytic incinerators could probably operate more effectively in controlling VOC emissions from the bake oven. This is the process in which the catalytic units have been employed to control VOCs in other surface coating industries[184-187] mainly due to the fact that the incinerator can handle lower air flows and, in turn, higher solvent vapor concentrations. Catalyst coating still might occur for certain solvent based coatings because of additives and plastic resins. Therefore, some gas conditioning may be required for bake oven gaseous exhaust.

It might also be applicable to combine the flash-off area exhaust air with the bake oven exhaust. This would require enclosing the flash-off area with design flow rates of 25 percent LEL or less. The disadvantages of such a recommendation are:

- The exhaust air from the flash-off area would lower the temperature of bake oven gaseous exhaust which, in turn, increases the fuel usage in the preheat section of the catalytic unit.

Table 3-26. ADVANTAGES OF EMPLOYING CATALYTIC INCINERATION AS A CONTROL TECHNIQUE

	Advantage	Reference
1.	Requires less auxiliary fuel to operate than a thermal incinerator.	42
2.	Smaller combustion chambers are employed than with a thermal incinerator.	42

Table 3-27. DISADVANTAGES OF EMPLOYING CATALYTIC INCINERATION AS A CONTROL TECHNIQUE

	Disadvantage	Reference
1.	Platinum family metals are very expensive.	32
2.	Catalysts can be poisoned by heavy metals present in the off-gas stream.	32, 42, 193
3.	Deactivation of the catalyst can result from coating of catalyst sites and excessive use at temperatures above 863 K (1100°F).	32, 42, 166, 193
4.	Gas conditioning, filtration of inlet gas stream to incinerator, might be necessary.	42

- Access to the flash-off area by plant personnel would require that protective respiratory devices be worn.

Table 3-28 contains process operating parameters for a catalytic incinerator employed to control VOCs from bake ovens. This information is based on data collected for catalytic units installed on bake ovens in other surface coating industries. However, these parameters are considered representative for the metal furniture industry.

3.2.3 Condensation

Vapor condensers have been employed principally in the refinery and petrochemical, and the chemical industries. They have found use in controlling odors from certain other industries (e.g., rendering cookers, coal-tar-dipping, etc.). Condensers have also been used as an integral part of other air pollution control systems (e.g., carbon adsorbers).[111,168] Condensers have not been used in the metal furniture nor any other surface coating industry to control VOC emissions. However, since the exhaust from metal furniture coating lines contains VOCs, this control technique may be employed under proper process conditions, alone or in conjunction with another control technique.

The principle behind condensation of vapors is operation of the condenser at an increased pressure or to extract heat from the vapor-laden exhaust stream. In practice, air pollution control condensers operate through removal of heat from the exhaust stream. With this type of unit, condensation occurs through two distinct physical mechanisms: (a) dropwise mechanism, and (b) filmwise mechanism. Only steam condenses in a truly dropwise manner. Dropwise condensation yields higher heat transfer coefficients than film condensation. Chemical promoters can be added to the condensing surface of certain metals to prevent the condensate from forming a film. It would be difficult to predict the physical mechanisms by which condensates would form from exhaust streams associated with the metal furniture or any other surface coating industry.

Two types of condensers that can be employed are contact and surface condensers. Contact condensers require that the coolant physically mix with the vapor-laden gas stream. For the most part, only surface condensers are recommended for this control technique.

Table 3-28. PROCESS OPERATING PARAMETERS FOR A CATALYTIC INCINERATOR

Parameter	Range
Volumetric Flow Rate	1.9 to 17 SCMS (4000 to 36 000 SCFM)[182, 184, 185]
Oven Exhaust Temperature	370 to 420 K (200° to 300°F)[184, 185]
Preheated Temperature	590 to 750 K (600°-900°F)[42]
Operating Temperature of Catalyst	700 to 860 K (800°-1100°F)[42, 183, 185]
Catalyst Replacement	0.2 - 3 years[182, 183]

Most surface condensers are the tube and shell type. Water or air flows inside the tubes and vapors condense on the shell side. Usually, if water is used as a coolant, chilling is required. Surface condensers recover 10 to 20 times less condensate than contact condensers. Other equipment that might be necessary is subcooling associated devices which prevent the condensate from vaporizing after it has been discharged from the condenser. This depends upon whether the surface contactor is a horizontal or vertical condenser.

Figure 3-15 depicts a tube and shell system which uses an inert or air gas stream and a precooler to lower the bake oven exhaust gas temperature. The inert or air stream contains the vaporized solvent from the bake oven which is removed in a two-stage condenser. After the inert or airstream leaves the second condenser, it is preheated by energy recovered by the precooler to satisfy the heating requirements of the bake oven. The inert gas stream can be liquid nitrogen or any inert gas at ambient temperature. An inert gas system would reduce the size of the bake oven and associated fuel requirements. If liquid nitrogen is used, it aids in removing the gaseous solvent by condensation. This type of system, therefore, would be a combined surface and contact condenser.[196,197]

Tables 3-29 and 3-30 contain advantages and disadvantages for employing condensation as a control technique. Because of the disadvantages 1 through 3 shown in Table 3-30, employing condensation to control VOC emissions from the application area is not recommended.

This control technique can only be considered for the flash-off or bake oven areas or both. Combining the flash-off exhaust with the bake oven exhaust stream would be beneficial since the oven's exhaust temperature would be lowered. This would reduce some of the cooling requirements of the condenser. However, this might require that the flash-off area be designed at flow rates of 25 percent LEL.

Table 3-31 contains process operating parameters for a condenser employed to control VOCs from the flash-off and bake oven areas. Very little actual data are available for controlling VOCs with the control technique for surface coating processes. Even though it is a proven technology, it has not been demonstrated successfully on any surface coating line in the metal furniture industry.

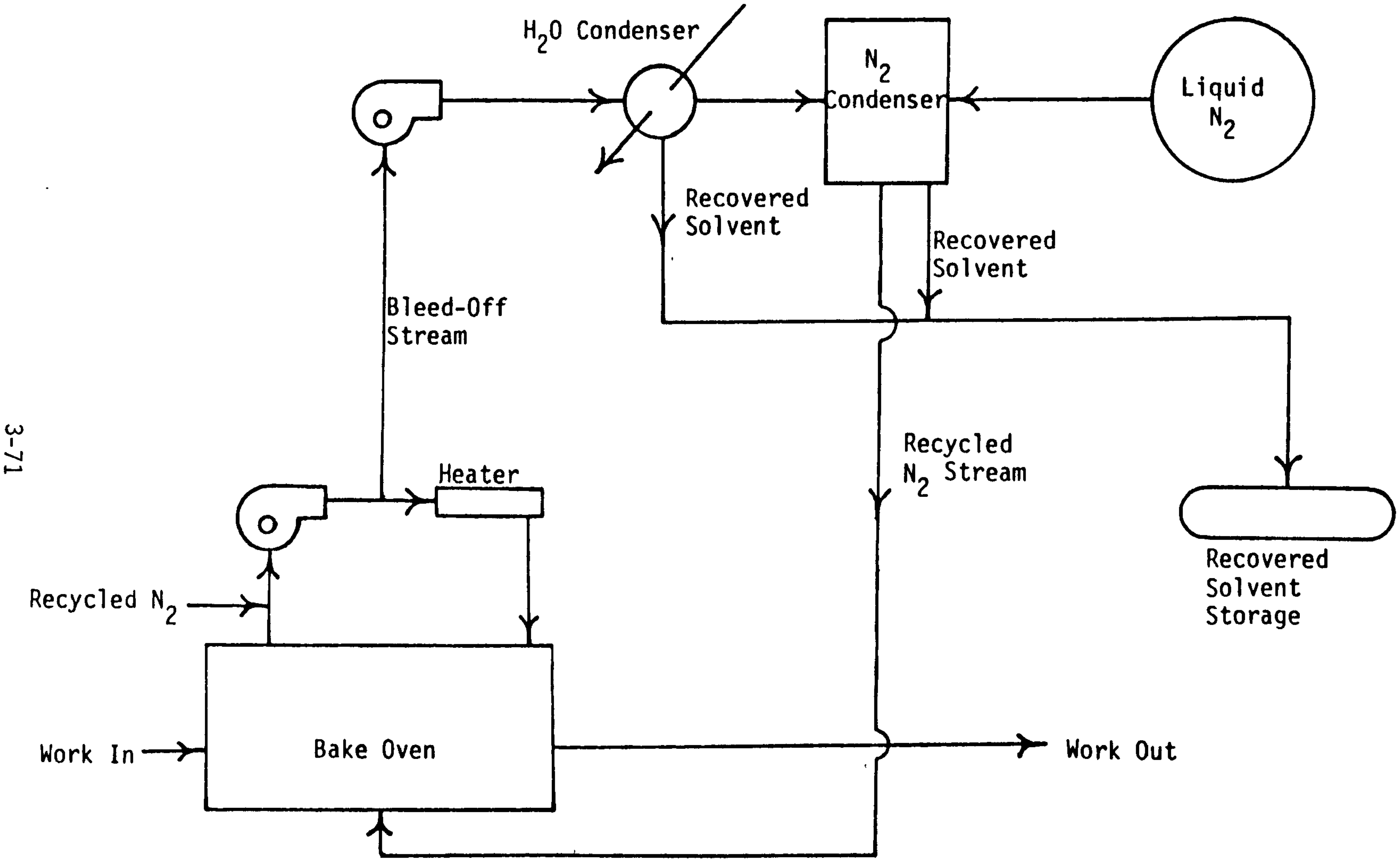


Figure 3-15. Bake oven equipped with N_2 condenser.

Table 3-29. ADVANTAGES OF EMPLOYING CONDENSATION AS A CONTROL TECHNIQUE

Advantage	Reference
1. Proven technology in other nonrelated industries.	109,166
2. Recovered heterogeneous mixtures of organic solvents could be burned in a process boiler.	42
3. Heat exchangers and low temperature cooling coils can reduce cooling requirements (sometimes up to 75%).	194
4. May perform best as an integral part of other air pollution control equipment.	109

Table 3-30. DISADVANTAGES OF EMPLOYING CONDENSATION AS A CONTROL TECHNIQUE

Disadvantage	Reference
1. At a solvent concentration in the 100 to 200 ppm range, refrigeration costs would be very expensive.	32
2. Since most application areas for conventional solvent based paints are equipped with water curtains, the condensation of water and solvent would occur. A decanter would be required to separate the collected water and solvents.	166
3. Large air volumes or particulate matter can reduce condensation efficiencies by as much as 50%.	109
4. Cooling requirements are more demanding for bake oven exhaust streams.	194, 195

Table 3-31. PROCESS OPERATING PARAMETERS FOR A SHELL TUBE CONDENSER

Parameters	Range
Volumetric flow rate	0.14 to 4.7 SCMS (300 to 10,000 SCFM)[196]
Oven exhaust temperature	370 to 420 K (200° to 300°F)[186,187]
Preheated temperatures of air or inert gas to bake oven	370 K (200°F)[196,197]
Solvent concentration	1500 ppm[a]
Pressure	1.0 (10^5)Pa (1 atm)[196]

[a]Model plant concentration.

3.2.4 Other Add-on Control Equipment and Process Modification

This section discusses other add-on equipment for controlling VOC emissions, and process modification of existing conventional solvent based coatings to reduce VOC emissions. Other add-on control devices evaluated were process boilers, and absorption systems. Both of these add-on control devices were rejected because of technical problems associated with each control system. Therefore, these control techniques will not be considered in Chapter 5 (Model Plants and Regulatory Alternatives).

Process modification, which would improve coating transfer efficiencies of existing lines applying conventional solvent based coatings, was also rejected as a control technique. It was rejected because there are no possible process modifications which would reduce emissions below the level specified by the existing State Implementation Plans (SIP).[103]

3.3 CONTROL EFFICIENCIES FOR COATING FORMULATION CHANGES

This section establishes control efficiencies of coating formulation changes such as powder, high solids, and waterborne formulations. The bases and assumptions for the control efficiencies are established in the following discussions. The control efficiencies presented in this section are utilized in Chapter 5 to determine emission reduction for the model plants in selecting regulatory alternatives.

It is assumed that all of the organic solvent in any paint is emitted and is proportional to a ratio of percent solvent per unit of dry solids applied. This is not a linear function but instead an exponential relationship. As solids content decreases in the coating, the organic solvent content increases exponentially. This ratio can be expressed mathematically as shown below:

Relative Solvent Emissions = RSE

$$RSE = \frac{\text{Percent Solvent}}{\text{Percent Solids}}$$

where percent solvent = 100 - percent solids

$$RSE = \frac{100 - \text{Percent Solids}}{\text{Percent Solids}} \qquad (3\text{-}2)$$

Equation 3-2 can also be employed to determine RSE values for waterborne by adjusting the equation for the amount of solvent presented in the volatile portion of the coating:

$$RSE = \frac{100 - \text{Percent Solids}}{\text{Percent Solids}} FV \qquad (3\text{-}3)$$

where FV = organic fraction of the volatile.

Finally, the calculated RSE for different coating formulations can be adjusted for different transfer efficiencies (TE) that result from application techniques and coating types.

$$RSE = \frac{100 - \text{Percent Solids}}{\text{Percent Solids}} \times \frac{FV}{TE} \qquad (3\text{-}4)$$

Equation 3-4 was employed to calculated RSE values for all coating formulations on a volume or weight basis.[44,77,82,86,93]

To obtain emission reduction by volume or weight basis when comparing two different coatings, the following example can be employed:

Example Calculation

Determine the emission reduction (volume and weight basis) when switching from a 35 percent by volume solids coating to a 70 percent by volume solids coating. Transfer efficiencies are 85 and 80 percent, respectively. Solvent density for both paints is 0.88 kg/liter.[103]

(a) Using Equation 3-4 to determine emission reduction by volume.

$$(RSE)_{35} = \frac{1 - .35}{.35} \frac{1}{0.85} = 2.18$$

$$(RSE)_{70} = \frac{1 - .7}{.7} \frac{1}{.80} = 0.56$$

$\therefore$, Emission reduction by volume is

$$\text{Percent Emission Reduction} = \frac{(RSE)_{35} - (RSE)_{70}}{(RSE)_{35}} (100) \qquad (3\text{-}5)$$

$$= 75 \text{ percent}$$

(b) Determine emission reduction by weight:

Equation 3-4 can be rewritten to consider percent solvent as shown below:

$$RSE = \frac{\text{Percent Solvent}}{1 - \text{Percent Solvent}} \times \frac{FV}{TE}$$

By multiplying both sides of the above equation by a solvent density (ρs), emission reduction by weight for two coatings can be obtained. The solvent density of 0.88 kg/liter is based on reference 106.

$$\rho_s \ (RSE)_{65} = \frac{\text{Percent Solvent}}{1 - \text{Percent Solvent}} \times \frac{FV}{TE}\rho_s = \frac{0.65}{1 - 0.65} \times \frac{1}{0.85} \ 0.88$$

$$\rho_s \ (RSE)_{65} = 1.92 \text{ kg/liter}$$

$$(\rho_s \ RSE)_{30} = \frac{0.30}{0.70}\frac{1}{.8} \ 0.88 = 0.47 \text{ kg/liter}$$

$\therefore$, Emission reduction by weight is:

$$\text{Percent Emission Reduction} = \frac{1.92 - 0.47}{1.92} = 76 \text{ percent}$$

The above calculations were verified by employing a material balance on each model. The material balance calculation presented below was used to verify Equation 3-4 calculations.

Example Calculation (Model Plant A, Chapter 5)

Total solids on coated parts = 101,600 liters

(35% by volume solids coating; 85% transfer efficiency; 0.88 solvent density)

$$\text{Total solids applied} = \frac{101{,}600}{0.85} = 119{,}500 \text{ liters}$$

$$\text{Total coating applied} = \frac{119{,}500}{\%\text{ solids}} = \frac{119{,}500}{0.35} = 341{,}000 \text{ liters}$$

$$\text{Total emitted solvent} = (341{,}000)(0.65)(0.88) = 195{,}000 \text{ kg}$$

(70% by volume solids coating; 80% transfer efficiency; 0.88 solvent density)

$$\text{Total solids applied} = \frac{101,600}{0.80} = 127,000 \text{ liters}$$

$$\text{Total coating applied} = \frac{127,000}{0.70} = 181,400 \text{ liters}$$

$$\text{Total emitted solvent} = (181,400)(0.30)(0.88) = 48,000 \text{ kg}$$

$$\therefore, \text{ Percent emission reduction by weight} = \frac{(195 - 48)(10^3)}{(195)(10^3)} = 75 \text{ percent}$$

3.3.1 Powder Coatings

After using Equations 3-4 and 3-5 for 100 percent solids coatings, the control efficiencies are 100 percent. This emission reduction can only be employed for the application and flash-off areas of a coating line, and for the spraying of thermoset powders. Therefore, transfer efficiencies for this type of coating were not considered because overspray in the metal furniture industry is not emitted through a bake oven. Other control efficiencies shown apply to thermoplastic powder not requiring a primer. The values are applicable when the thermoplastic is sprayed or applied via a fluidized bed. Control efficiency values shown in Table 3-32 are based upon percent by weight change in the applied solids coating. This change is a result of VOC emissions mainly from thermoset coatings. The VOC emissions are due to polymerization byproducts.[44,57]

Emission reduction from coating lines employing a thermoplastic that required a low solids primer will not be provided. This is because emissions from this type of coating would be comparable to model plants applying 35 percent by volume solids coating by the dip methods. Therefore, control efficiencies for these lines would be above the level established by the State Implementation Plans (SIPs).[10]

3.3.2 High Solids Coatings

The control efficiencies (by volume and weight) shown in Table 3-33 are based on the approach shown in the example calculation provided in Section 3.3. The emission reductions represent a comparison with the 35 percent by volume solids coating associated with the model plants presented in Chapter 5. All three electrostatic spraying techniques were evaluated: gun, disk, and bell.[85,86] The following assumptions were employed in determining the control efficiencies:

Table 3-32. EMISSION REDUCTION VIA POWDER COATINGS

Coating	Emission reduction (%)	References
Thermosetting powders[a]		
Epoxy	97-99	48, 57
Acrylics	99	48, 57
Polyester (urethane)	96-98	48, 57
Thermoplastic powders[b]		
Polyester (others)	99	48, 57
Acrylics	99	48, 57
PVC and cellulose acetate Butyrate	90-95	48, 57

[a]VOC emissions from bake oven only.

[b]VOC emissions from application and cool down areas.

Table 3-33. CONTROL EFFICIENCIES FOR HIGH SOLIDS COATINGS

High solids coatings	Emission reduction[a,b] by weight or volume (%)
60% by Volume solids	
Flat surface	62
Complex surface	61
65% by Volume coatings	
Flat surface	69
Complex surface	69
70% by Volume coatings	
Flat surface	75
Complex surface	75
80% by Volume coatings	
Flat surface	85
Complex surface	85

[a]Approach the same as reported in References 44, 85, 86 and 90.

[b]Some round-off error (approximately 2 percent) may exist for the calculations (e.g., 60% solids).

A. In converting from a volume to weight basis, the solvent density employed was 0.88 kg per liter (7.3 lb per gal). This value is consistent with the density employed in reference 106 which is the basis for the 0.36 kg of VOC per liter of coating (minus water) limitation that has been adopted by most states in their State Implementation Plans. The emission limitation of 0.36 kg of VOC per liter of coating (minus water) is the regulation being employed for new coating lines in the absence of a New Source Performance Standard.

B. The transfer efficiencies employed in the calculations for flat and complex surfaces are 80 and 60 percent, respectively. These values are considered to be conservative, but data presented in references 89 and 106 are inconsistent. The transfer efficiencies employed, however, are considered to be representative at high solids (greater than 60 percent by volume) coatings because mechanical energies associated in applying the coatings are higher.

C. The control efficiencies presented in Table 3-33 are considered to be applicable for both single and dual component high solids coatings.

D. Only electrostatic spraying techniques are considered to be applicable.

3.3.3 Waterborne Coatings

Control efficiencies (by volume and weight) shown in Table 3-34 for the spray, dip, flow, and electrodeposition coating of waterborne paints are also based on the example calculations shown in Section 3.3. These control efficiencies are also based on a comparison with solvent emissions from systems applying solvent based paint containing 35 percent by volume solids. The water-to-solvent ratio of the volatile portion of the paint considered ranged from 67/33 to 82/18.[44] Assumptions employed in determining the control efficiencies are presented below:

(a) All waterborne spraying was assumed to be accomplished by electrostatic techniques.

(b) Transfer efficiencies for electrostatic spraying used in the calculations are based on data reported in reference 106.

(c) Transfer efficiency used for dip and flow coating is 90 percent.[56]

Table 3-34. CONTROL EFFICIENCIES FOR WATER-BASED COATINGS

Application technique	Control efficiency % by weight or volume	Ref.
82/18 Waterborne - Electrostatic spraying[a,b]		
Flat surface	80-82	42, 54, 118
Complex surface	80-82	123, 143
67/33 Waterborne - Electrostatic spraying[b,c]		
Flat surface	67	42, 54, 123, 143
Complex surface	67	
82/18 Waterborne - Dip and flow coating[a]	82	42, 118, 123, 143
67/33 Waterborne - Dip and flow coating[c]	67	42, 118, 123, 143
82/18 Waterborne - Electrodeposition[d]	95	123, 152, 154, 155

[a]For a 35 percent by volume solids with 82 to 18 H_2O solvent ratio.

[b]Control efficiencies for any electrostatic spraying technique.

[c]For a 35 percent by volume solids with 67 to 33 H_2O to solvent ratio.

[d]Regardless of chemical composition of coating - 20 percent solids.

3.4 CONTROL EFFICIENCIES FOR ADD-ON CONTROL EQUIPMENT

Control efficiencies of VOCs for add-on air pollution control equipment are presented in Table 3-35, and these data will be used in Chapter 5 to select regulatory alternatives. Add-on control equipment evaluated for emission reduction were carbon adsorbers, thermal and catalytic incinerators, and condensers. The bases and assumptions for the control efficiencies are presented in the following sections.

3.4.1 Carbon Adsorption

The control efficiencies (weight basis) presented in Table 3-35 are based on data collected by Springborn Laboratories. This information includes control efficiencies received from plant trips.[159-162,166] None of the control efficiency data for VOCs are for coating lines in the metal furniture industry. The control efficiencies are for spray booths equipped with carbon adsorbers in such industries as surface coating of paper and asbestos fibers. The only source test data were for a can coating line equipped with a carbon adsorber.[161] All process emissions of VOCs on the coating line were vented to this control device. The following assumptions were employed in utilizing the above data:

A. The control efficiencies reported in Table 3-35 were considered to be representative of metal furniture coating lines since surface coating lines in other industries are comparable or exactly the same.

B. Control efficiencies would only be applicable for coating lines spraying conventional solvent based coatings.

3.4.2 Incinerators

The control efficiencies for incinerators are based on stack test data reported in references 42, 185 and 196, and data obtained during plant trips taken by Springborn Laboratories.[13,171-175,181,182,184,185] Only one plant trip, taken by Springborn Laboratories was to a metal furniture facility using an incinerator.[13] Also, control efficiency data are only applicable for incinerators controlling VOC emissions from bake ovens. Figures 3-16 and 3-17 show effects of temperature on percent VOC destruction for a thermal and catalytic incinerator, respectively. Assumptions employed in selecting control efficiencies for incineration are presented below:

Table 3-35. CONTROL EFFICIENCIES FOR ADD-ON AIR POLLUTION CONTROL EQUIPMENT

Add-on control device	Process being controlled	Control efficiency for control device (% by wt)	Ref.
Carbon adsorber	Spray booth	90	111,160,163
Carbon adsorber	Entire coating line	80	162
Thermal incinerator	Bake oven	96	44,183,187 198
Catalytic incinerator	Bake oven	90	44,183,187
Shell-tube condenser	Bake oven and flash-off	--[a]	----------

[a]See Section 3.4.3 for explanation of control efficiency.

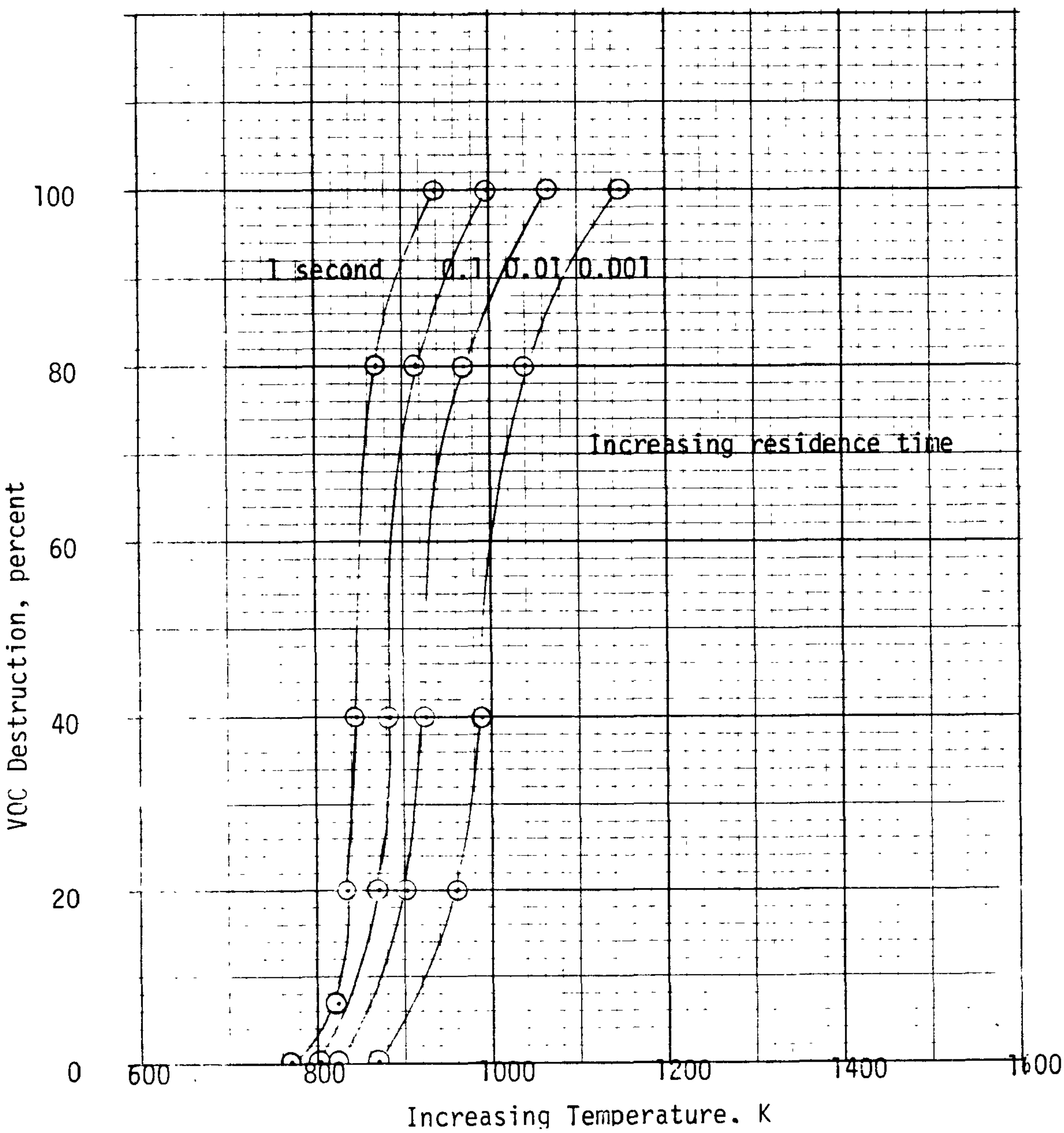


Figure 3-16. Effects of temperature and time.
(Redrawn from Reference 42)

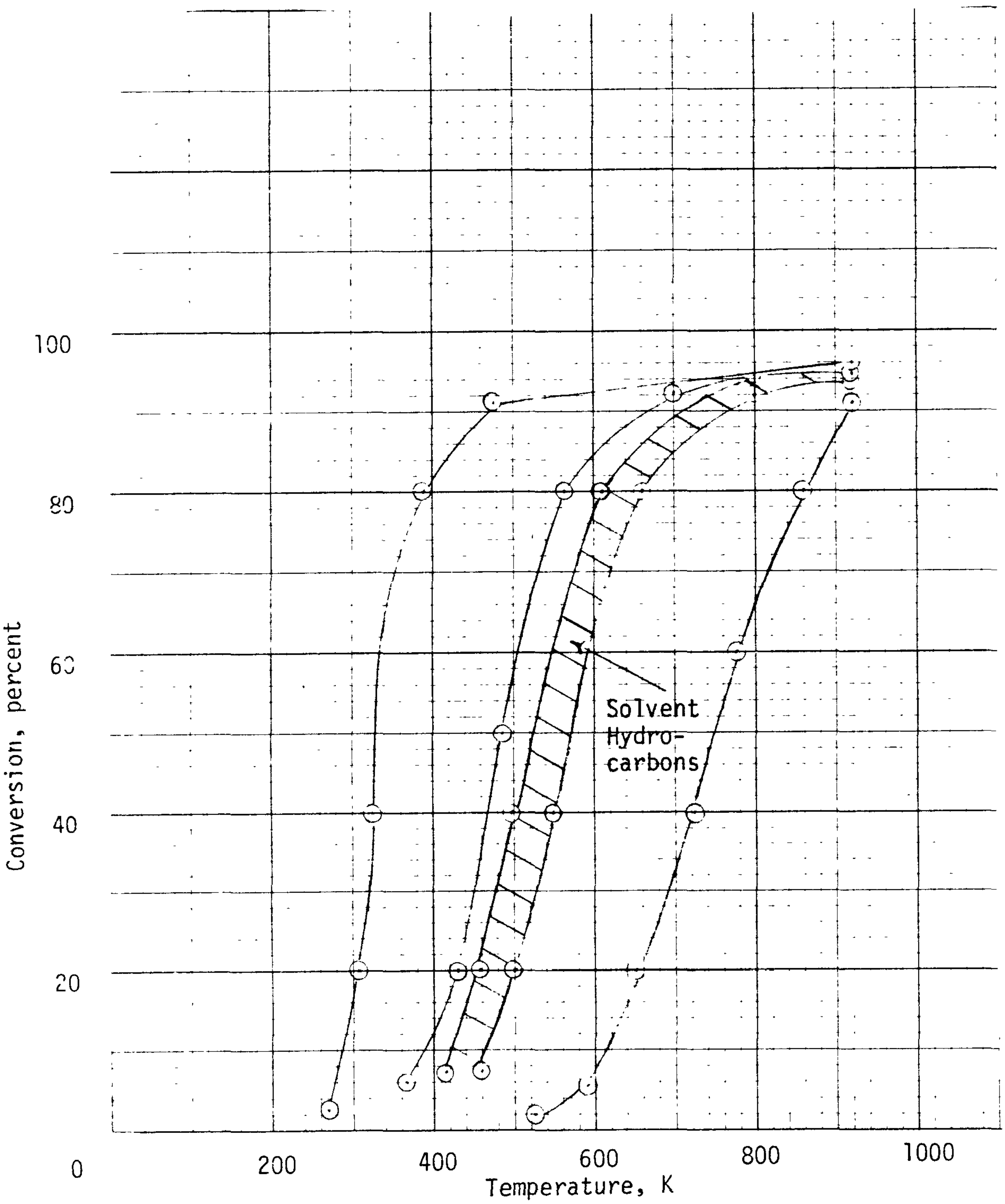


Figure 3-17. Typical temperature - performance curve for various molecular species being oxidized over Pt/Al_2O_3 catalyst. (Redrawn from Reference 42).

A. The control efficiencies for both the thermal and catalytic incinerator are mainly based on operating temperatures of 1,033 K (1,400°F) and 703 K (800°F), respectively. These operating temperatures are consistent with temperature data presented in trip reports written by Springborn Laboratories and information obtained from a literature search.[13,44,171-175,181-189]

B. Reported control efficiencies and operating temperatures reported for incinerators being employed on bake ovens in other surface coating industries are considered to be applicable.

3.4.3 Condensers

No control efficiency for condensers is shown in Table 3-35 because no stack test data are available for this control technique. Vendor and literature information indicate the control efficiencies range from about 90 to 95 percent by weight.[167,195,196] A more conservative 90 percent by weight control efficiency is used to control VOC emissions from flash-off areas or bake oven areas or both.

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4. MODIFICATION AND RECONSTRUCTION

After the new source performance standards have been promulgated in accordance with Section 111 of the Clean Air Act, as amended, all "affected facilities" will include those constructed, modified, or reconstructed after the date of proposal. These new source performance standards are also to apply to an "existing facility" as defined in 40 CFR 60.2. An existing facility would become an affected facility if determined to be modified or reconstructed. This chapter provides potential examples of modified and reconstructed affected facilities and details the required conditions under which an existing facility becomes subject to the standards of performance. However, the enforcement division of the appropriate EPA regional office will make the final determination as to whether a source is modified or reconstructed and, as a result, becomes an affected facility. The remainder of the sections in this chapter defines and provides potential examples of modification and reconstruction.

4.1 40 CFR 60 PROVISIONS FOR MODIFICATION AND RECONSTRUCTION

4.1.1 Definition of Modification

It is important that these provisions be understood before considering potential examples of modifications.

Section 60.14 defines modification as follows:

> except as provided under paragraphs (e) and (f) of this section, any physical or operational changes to an existing facility which result in an increase in emission rate to the atmosphere of any pollutant or precursor to pollutant to which a standard applies shall be a modification. Upon modification, an existing facility shall become an affected facility for each pollutant to which a standard applies and for which there is an increase in the emission rate.

Paragraph (e) lists certain physical or operational changes which are not considered as modifications, regardless of any changes in the emission rate. These changes are shown below:

(1) Routine maintenance, repair, and replacement.

(2) An increase in the production rate not requiring a capital expenditure as defined in Section 60.2.

(3) An increase in the hours of operation.

(4) Use of an alternative fuel or raw material if, prior to the standard, the existing facility was designed to accommodate that alternate fuel or raw material.

(5) The addition or use of any system or device whose primary function is the reduction of air pollutants, except when an emission control system is removed or replaced by a system considered to be less efficient.

(6) The relocation or change in ownership of an existing facility.

Paragraph (b) specifies that an increase in emissions is defined in kilograms per hour and delineates the methods for determining the increase, including the use of emission factors, material balances, continuous monitoring systems, and manual emission tests. Paragraph (c) affirms that the addition of an affected facility to a stationary source does not make any other facility within that source subject to standards of performance. Paragraph (f) simply provides for superseding any conflicting provisions.

4.1.2 Definition of Reconstruction

Section 60.15 regarding reconstruction states:

> If an owner or operator of an existing facility proposes to replace components, and the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost which would be required to construct a comparable, entirely new facility, he shall notify the Administrator of the proposed replacements. The notice must be postmarked 60 days (or as soon as practicable) before construction of the replacements is commenced.

The purpose of the reconstruction portion of the regulation is to prevent an owner or operator from continuously replacing an operating process except for support structures, frames, housing, etc., in an attempt to avoid falling under new source performance standards.

4.2 APPLICABILITY TO SURFACE COATING OF METAL FURNITURE

The purpose of this section is to outline some of the most probable types of "modifications" to existing plants and to describe the applicability of "reconstruction" to this industry. The modification and reconstruction samples provided in this section are only to be examples of changes that would require an existing facility to comply with the standard. The final determination will be made by the appropriate EPA regional office on a case-by-case basis.

The examples apply to process areas of a metal furniture coating line that emit volatile organic compounds (VOCs) which are precursors to air pollution. This would include the coating application, flash-off and bake oven areas, and exempts metal part precleaning and preheating areas. The amount of VOCs emitted from the application, flash-off, and bake oven areas varies depending on the method of coating application. Paint can be applied by spray, dip, flow, and roller coating methods. The following two sections define modification and reconstruction examples for the metal furniture coating lines.

4.2.1 Modification Examples

Examples of increasing VOC emissions as a result of raw material, coating application, and process changes are provided. Each change is discussed and the ones that are considered to be potential modifications are identified. The examples to be evaluated are shown in Table 4-1 along with a determination as to whether or not the example is a modification. Each is discussed in the following paragraphs.

The modification examples 1 through 3, as shown in Table 4-1, would cause an increase in VOC emissions. Despite the fact that VOC emissions would increase, examples 1 and 2 are not considered to be a modification because of 40 CFR Part 60.14(e)(4). This is because a change in raw materials, regardless of emission rate, does not constitute a process modification if the existing process was designed to handle the new raw materials. The only exception to this might be operators or owners of coating lines who switch from applying powder to organic solvent-based coatings. Such a switch might result in a redesign of the application, flash-off and bake oven areas for some affected facilities. Even though this type of switch is highly unlikely, it could occur as a result of changing the color of the coating applied to a particular part at the request of the customer. This would happen if the required color was not commercially available in the powder coating. However, because of

Table 4-1. POTENTIAL MODIFICATION EXAMPLES

Potential modification example	Determination of modification
(1) Switching from a higher to a lower solids coating.	Is not a modification based on the above definition in accordance with 40 CFR Part 60.14(e)(4).
(2) Adding solvent thinners to coatings.	Same as (1) above.
(3) Increasing coating thickness.	A potential modification.
(4) Changing part size or complexity.	Is not a modification based on the above definition in accordance with 40 CFR Part 60.14(e)(1) and 40 CFR Part 60.14(e)(4).
(5) Addition of extra application equipment.	A potential modification.
(6) Temporary substitution of process equipment.	Is not a modification based on the above definition in accordance with 40 CFR Part 60.14(e)(1).
(7) Relocation of a coating line from another plant site.	Is not a modification based on the above definition in accordance with 40 CFR Part 60.14 (e)(6).

the cost of such a switch, the change might be termed a reconstruction instead of a modification.

Increased coating thicknesses, other factors being constant, would result in increased VOC emissions. Such a change could occur from a desire to increase durability and resistance for outdoor exposure. This is a potential modification if the spray booth is enlarged or extra spray guns are added or both on the coating line. However, operating changes such as higher air flow rate to a spray gun, decreased conveyor speed, etc., are not modifications because the existing coating line would be designed to handle these operational changes.

Changing part size or complexity could feasibly increase VOC emissions from the existing facility. An increase in part size, maintaining a constant conveyor speed, would be a source of increased solvent emissions. Changing the design of a metal part on a production line is common engineering practice. If the design change resulted in a more difficult metal part to coat, VOC emissions would increase. The increased emission rate of VOCs would be due to higher paint consumption, poorer paint transfer efficiency or both. Each of the above part changes would not, however, be considered a modification because of 40 CFR Part 60.14(e)(1) and 40 CFR 60 (e)(4).

The addition of extra application equipment (increased VOC emissions) to an existing coating line in order to increase production and the improvement of product quality by the application of coating for touch-up purposes, are examples of process modifications, provided the same coating is employed. This could also involve reconstruction which is discussed in the next sections.

Substitution of application equipment on a temporary basis at existing sources for specific coating jobs might increase VOC emissions. For example, existing line components such as spray booths and flow chambers may be interchanged to handle certain customer demands. These changes would not be considered a modification if such changes are made routinely with existing equipment prior to the development of a new source performance standard. This complies with 40 CFR Part 60.14(e)(1).

The last potential modification example to be discussed is the relocation of any VOC-emitting part of a coating line from one state to another state. Emissions of VOC would increase at the new location but in accordance with 40 CFR Part 60.14(e)(6), this would not be a modification.

4.2.2 Examples of Reconstruction

This provision of the regulation is relatively straightforward in that, regardless oт the VOC emission rate, an existing facility may become an affected facility because of the "50 percent of the fixed capital cost" in the above definition. Potential examples on a coating line that would be affected are shown below:

(1) Replacing or enlarging of the coating application area. This would include the part touch-up area.

(2) Replacing or enlarging of the bake oven.

(3) Replacing or enlarging of the area (flash-off) between the application and bake oven where the coated parts travel on a conveyor line.

The examples shown above are not restricted by any type of time schedule under present regulations. In other words, once an existing facility starts to replace or enlarge an existing line and exceeds 50 percent fixed capital costs requirement of a new comparable line, the existing line may become an affected facility depending upon the Administrator's decision.

5. MODEL PLANTS AND CONTROL OPTIONS

This chapter defines model plants which represent the metal furniture surface coating industry and the alternative means by which volatile organic compound (VOC) emissions can be regulated.

5.1 MODEL PLANTS

Model surface coating plants were developed which represent the various processes used in the industry and the various sizes of plants found in existence. The models were developed on the basis of plant operation and economic data collected from a variety of sources including trip reports, industry surveys, computer listings, and published literature.[1-15]

Based on the industry size fragmentation described in Chapter 2, it was tentatively decided that three model plants would be needed for each of the three coating techniques. Annual paint consumption was selected as the basis for determining the size categories, due to the fact that this type of data was much more readily available than was information pertaining to the total surface area coated per year. The three size categories which were selected are as follows:

Size Category	Annual Paint Consumption liters	(gallons)
Large	400,000	(106,000)
Medium	75,000	(20,000)
Small	4,000	(1,050)

The medium size plant is approximately equal to the average plant size found in the industry.

5.1.1 Spray Coating

Spray coating is the most common application technique used in the metal furniture industry. Transfer efficiency for electrostatic spraying ranges from 50 to 95 percent depending upon the type of application equipment and the configuration of the item being painted.[16-19] Transfer efficiency for flat surfaces is generally 85 percent and for complex shaped objects, it is 65 percent. This difference in efficiency has a substantial affect on emission rates; therefore, two model plants were developed for each size category. Emission estimates were calculated by material balance based upon a dry coating thickness of 2.54×10^{3} cm (1 mil), a solvent based alkyd paint with 35 percent by volume solids, and the indicated application efficiency. The amount of organic solvent emitted in the application, flash-off, and curing areas was estimated at 40 percent (including overspray), 30 percent, and 30 percent, respectively.[20] The operating schedule for all plants is assumed to be 8 hours per day, 5 days per week, 50 weeks per year. Other operating data such as conveyor speed, number of daily color changes, and energy consumption were estimated on the basis of survey data. Application exhaust flow rates were calculated on the assumption that a 100 ppm organic solvent concentration would be maintained in the spray booths. Oven exhaust flow rates were calculated on the basis of maintaining an organic solvent concentration of 15 percent of the lower explosive limit (LEL) in the curing ovens. In addition a flow rate of approximately 15 meters per minute (50 ft/min) was assumed across all oven openings.

Figures 5-1, 5-2, and 5-3 depict the model spray coating lines. Tables 5-1 through 5-6 show material and energy balances and operational descriptions of the spray coating model plants.

5.1.2 Dip Coating

Dip coating is the second most commonly used method of paint application in the metal furniture industry. Transfer efficiency for this method is approximately 90 percent and there is no appreciable difference resulting from differing object configurations. Diagrams of the dip coating models are shown in Figures 5-4 and 5-5.

Emissions for the model plants were calculated by material balance assuming a dry coating thickness of 2.54×10^{3} cm (1 mil), a 90 percent transfer efficiency,[16,17] and the use of an alkyd paint containing 35 volume percent solids. Energy consumption and other operating data were

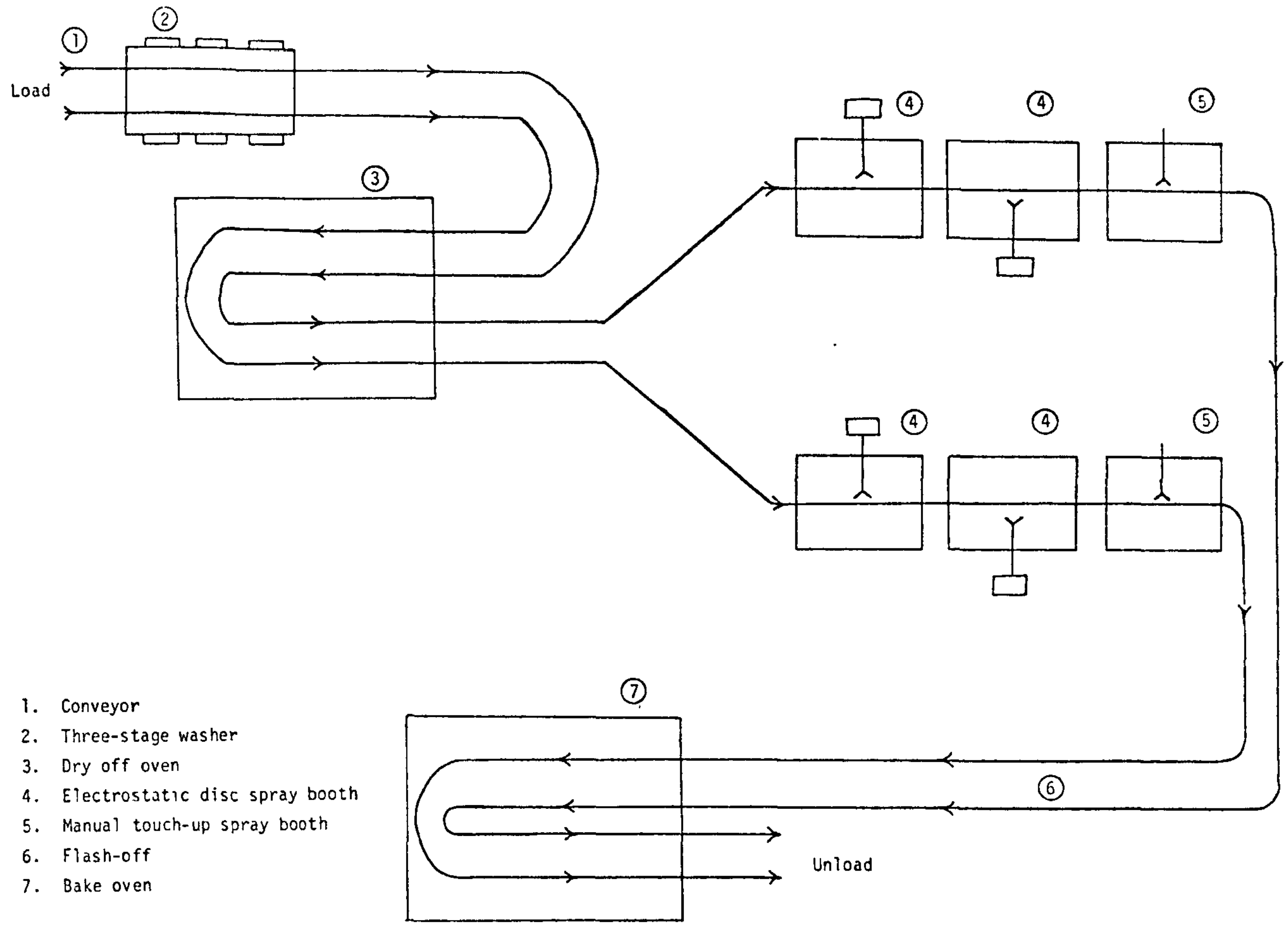

Figure 5-1. Example automated spray coating lines with manual touch-up for flat metal furniture surfaces (Models A and C).

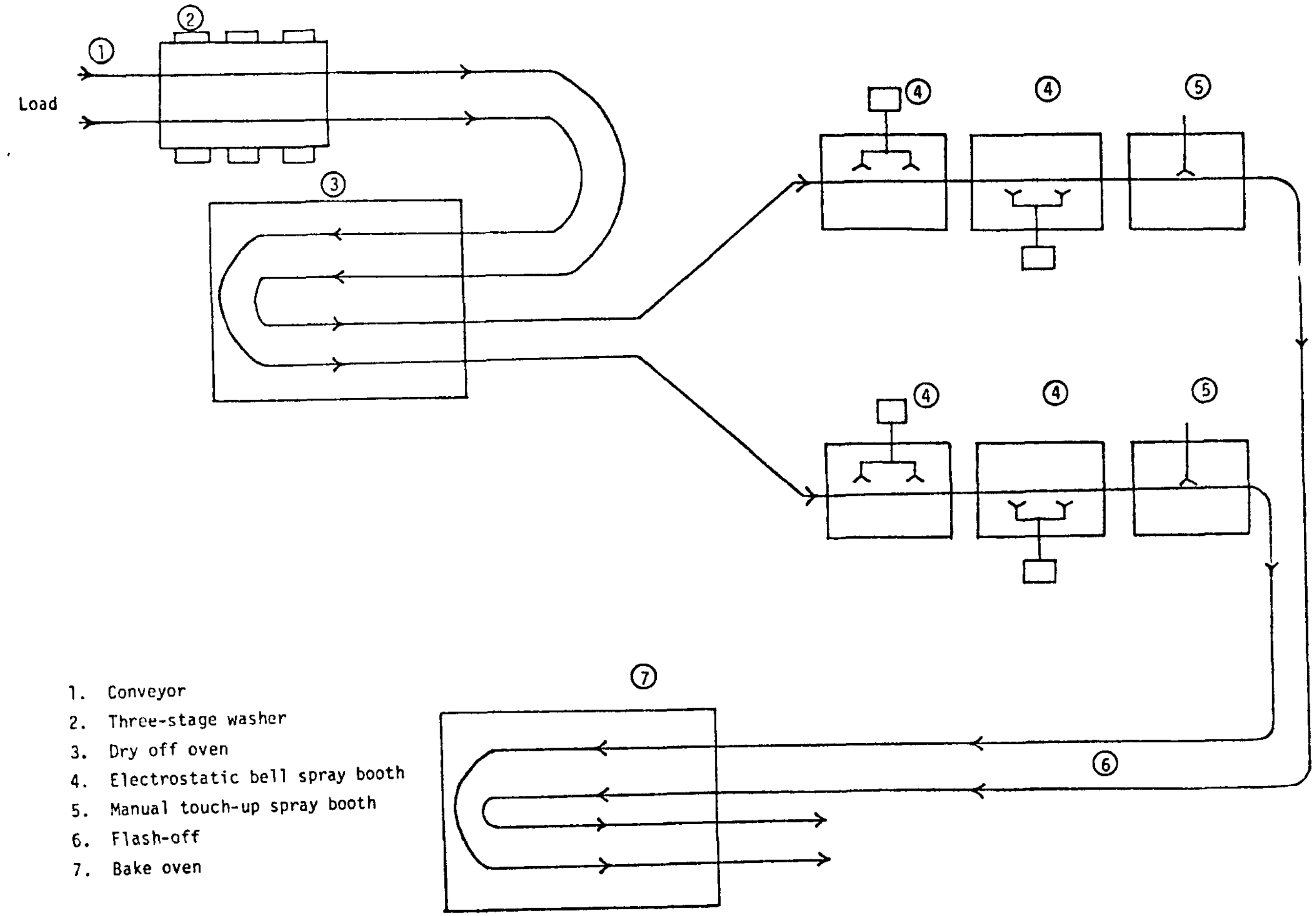

Figure 5-2. Example automated spray coating lines with manual touch-up for complex metal furniture surfaces (Models B and D).

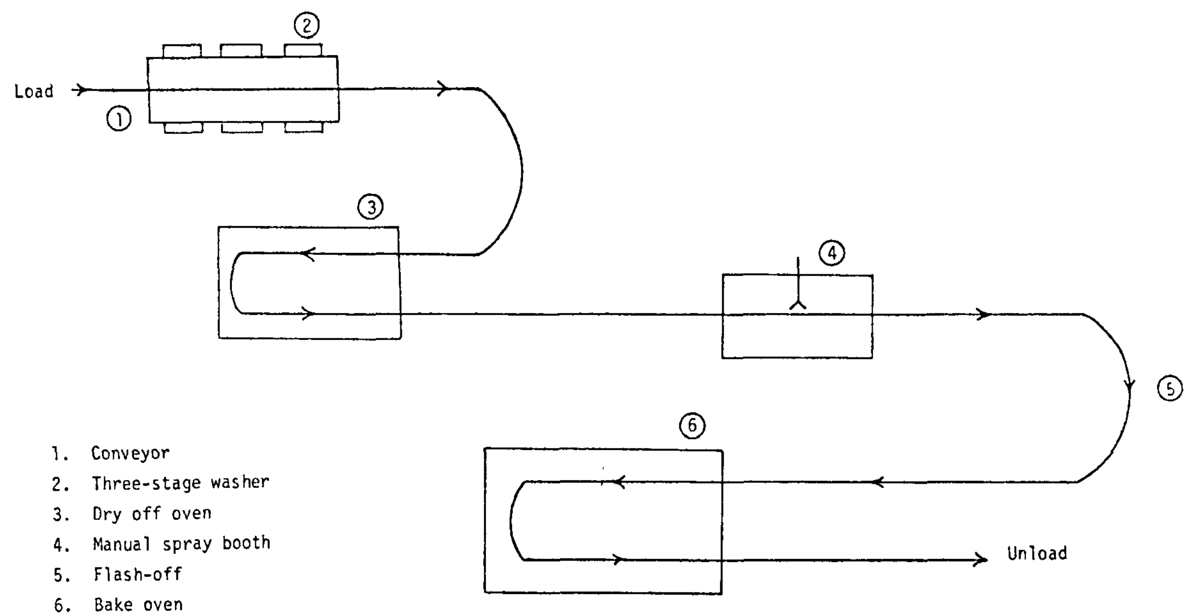

Figure 5-3. Example small metal furniture manual spray coating line (Models E and F).

Table 5-1. MODEL PLANT A

Application method/efficiency: Electrostatic spray/85 percent
Surface type: Flat
Approximate surface area per item: 1.0 m^2
Total area coated per year: 4,000,000 m^2
Operating schedule: 8 hours/day 5 days/week 50 weeks/year

Conveyor speed: 4.2 meters/min.
Number of lines: 6 (3 spray booths per line)
Number of color changes per day: 5
Number of plant employees: 620
Number of coating line employees: 45

MATERIAL BALANCE:	Per Line	Total
Items coated:	666,667	4,000,000
Coating used (liters):[a]	56,924	341,543
Material loss during application and flash off		
Solids (liters):	2,989	17,931
Solvents (liters):[b]	25,900	155,402
Total coating applied to items (liters):	48,386	290,312
Net dry solids on items (liters):	16,934	101,600
Solvent emissions during curing (kilograms):	9,768	58,608
Total emissions (kilograms):	32,560	195,362
Application exhaust flow rate (meters^3/sec):	19	114
Application exhaust concentration (ppm):	100	100
Oven exhaust flow rate (meters^3/sec):	0.95	5.7
Oven exhaust concentration (ppm):	1,500	1,500
ENERGY CONSUMPTION:		
Application - Electric (joules):	150×10^{10}	900×10^{10}
- Gas (joules):	0	0
Cure - Electric (joules):	3×10^{10}	18×10^{10}
- Gas (joules):	590×10^{10}	3538×10^{10}

[a] 35 percent solids

[b] Overspray is also included in this estimate.

Table 5-2. MODEL PLANT B

Application method/efficiency: Electrostatic spray/65 percent	Conveyor speed: 4.6 meters/min
Surface type: Complex	Number of lines: 10 (3 spray booths per line)
Approximate surface area per item: 0.33 m^2	Number of color changes per day: 12
Total area coated per year: 4,000,000 m^2	Number of plant employees: 620
Operating schedule: 8 hours/day 5 days/week 50 weeks/year	Number of coating line employees: 75

MATERIAL BALANCE:	Per Line	Total
Items coated:	1,200,000	12,000,000
Coating used (liters):[a]	44,660	446,593
Material loss during application and flash off		
Solids (liters):	5,471	54,708
Solvents (liters):[b]	20,320	203,200
Total coating applied to items (liters):	29,029	290,285
Net dry solids on items (liters):	10,160	101,600
Solvent emissions during curing (kilograms):	7,664	76,636
Total emissions (kilograms):	25,545	255,452
Application exhaust flow rate ($meters^3$/sec):	19	190
Application exhaust concentration (ppm):	100	100
Oven exhaust flow rate ($meters^3$/sec):	0.95	9.5
Oven exhaust concentration (ppm):	1,500	1,500
ENERGY CONSUMPTION:		
Application - Electric (joules):	150×10^{10}	1500×10^{10}
- Gas (joules):	0	0
Cure - Electric (joules):	3×10^{10}	30×10^{10}
- Gas (joules):	590×10^{10}	5896×10^{10}

[a]35 percent solids

[b]Overspray is also included in this estimate.

Table 5-3. MODEL PLANT C

Application method/efficiency: Electrostatic spray 85 percent	Conveyor speed: 2.5 meters/min.
Surface type: Flat	Number of lines: 2 (3 spray booths per line)
Approximate surface area per item: 1.0 m^2	Number of color changes per day: 5
Total area coated per year: 780,000 $meters^2$	Number of plant employees: 140
Operating schedule: 8 hours/day 5 days/week 50 weeks/year	Number of coating line employees: 11

MATERIAL BALANCE:	Per Line	Total
Items coated:	390,000	780,000
Coating used (liters)[a]	33,298	66,596
Material loss during application and flash off		
Solids (liters):	1,748	3,496
Solvents (liters):	15,150	30,300
Total coating applied to items (liters):	28,303	56,606
Net dry solids on items (liters):[b]	9,906	19,812
Solvent emissions during curing (kilograms):	5,714	11,428
Total emissions (kilograms):	19,046	38,092
Application exhaust flow rate ($meters^3$/sec):	19	38
Application exhaust concentration (ppm):	100	100
Oven exhaust flow rate ($meters^3$/sec):	0.95	1.9
Oven exhaust concentration (ppm):	1,500	1,500
ENERGY CONSUMPTION:		
Application - Electric (joules):	55×10^{10}	110×10^{10}
- Gas (joules):	0	0
Cure - Electric (joules):	3×10^{10}	6×10^{10}
- Gas (joules):	435×10^{10}	870×10^{10}

[a] 35 percent solids

[b] Overspray is also included in this estimate.

Table 5-4. MODEL PLANT D

Application method/efficiency: Electrostatic spray/65 percent	Conveyor speed: 2.4 meters/min.
Surface type: Complex	Number of lines: 2 (3 spray booths per line)
Approximate surface area per item: 0.33 meters	Number of color changes per day: 5
Total area coated per year: 780,000 meters^2	Number of plant employees: 140
Operating schedule: 8 hours/day 5 days/week 50 weeks/year	Number of coating line employees: 11

MATERIAL BALANCE:	Per Line	Total
Items coated	1,181,800	2,363,636
Coating used (liters):[a]	43,543	87,086
Material loss during application and flash off		
Solids (liters):	5,334	10,668
Solvents (liters):[b]	19,812	39,624
Total coating applied to items (liters):	28,303	56,606
Net dry solids on items (liters):	9,906	19,812
Solvent emissions during curing (kilograms):	7,472	14,944
Total emissions (kilograms):	24,907	49,814
Application exhaust flow rate (meters^3/sec):	19	38
Application exhaust concentration (ppm):	100	100
Oven exhaust flow rate (meters^3/sec):	0.95	1.9
Oven exhaust concentration (ppm):	1,500	1,500
ENERGY CONSUMPTION:		
Application - Electric (joules):	55×10^{10}	110×10^{10}
- Gas (joules):	0	0
Cure - Electric (joules):	3×10^{10}	6×10^{10}
- Gas (joules):	435×10^{10}	870×10^{10}

[a]35 percent solids

[b]Overspray is also included in this estimate.

Table 5-5. MODEL PLANT E

Application method/efficiency: Electrostatic spray/85 percent
Surface type: Flat
Approximate surface area per item: 1.0 m^2
Total area coated per year: 45,000 $meters^2$
Operating schedule: 8 hours/day 5 days/week 50 weeks/year

Conveyor speed: 2.5 meters/min.
Number of lines: 1 (1 spray booth)
Number of color changes per day: 5
Number of plant employees: 18
Number of coating line employees: 3

	Total
MATERIAL BALANCE:	
Items coated:	45,000
Coating used (liters):[a]	3,842
Material loss during application and flash off	
Solids (liters):	202
Solvents (liters):[b]	1,748
Total coating applied to items (liters):	3,266
Net dry solids on items (liters):	1,143
Solvent emissions during curing (kilograms):	659
Total emissions (kilograms):	2,197
Application exhaust flow rate ($meters^3$/sec):	19
Application exhaust concentration (ppm):	100
Oven exhaust flow rate ($meters^3$/sec):	0.95
Oven exhaust concentration (ppm):	1,500
ENERGY CONSUMPTION:	
Application - Electric (joules):	45×10^{10}
- Gas (joules):	0
Cure - Electric (joules):	2×10^{10}
- Gas (joules):	366×10^{10}

[a]35 percent solids

[b]Overspray is also included in this estimate.

Table 5-6. MODEL PLANT F

Application method/efficiency: Electrostatic spray/65 percent
Surface type: Complex
Approximate surface area per item: 0.33 $meters^2$
Total area coated per year: 45,000 $meters^2$
Operating schedule: 8 hours/day 5 days/week 50 weeks/year

Conveyor speed: 2.5 meters/min.
Number of lines: 1 (1 spray booth)
Number of color changes per day: 5
Number of plant employees: 18
Number of coating line employees: 3

	Total
<u>MATERIAL BALANCE</u>:	
Items coated:	136,360
Coating used (liters):[a]	5,024
Material loss during application and flash off	
Solids (liters):	615
Solvents (liters):[b]	2,286
Total coating applied to items (liters):	3,266
Net dry solids on items (liters):	1,143
Solvent emissions during curing (kilograms):	862
Total emissions (kilograms):	2,874
Application exhaust flow rate ($meters^3$/sec):	19
Application exhaust concentration (ppm):	100
Oven exhaust flow rate ($meters^3$/sec):	0.95
Oven exhaust concentration (ppm):	1,500
<u>ENERGY CONSUMPTION</u>:	
Application - Electric (joules):	45×10^{10}
- Gas (joules):	0
Cure - Electric (joules):	2×10^{10}
- Gas (joules):	366×10^{10}

[a]35 percent solids

[b]Overspray is also included in this estimate.

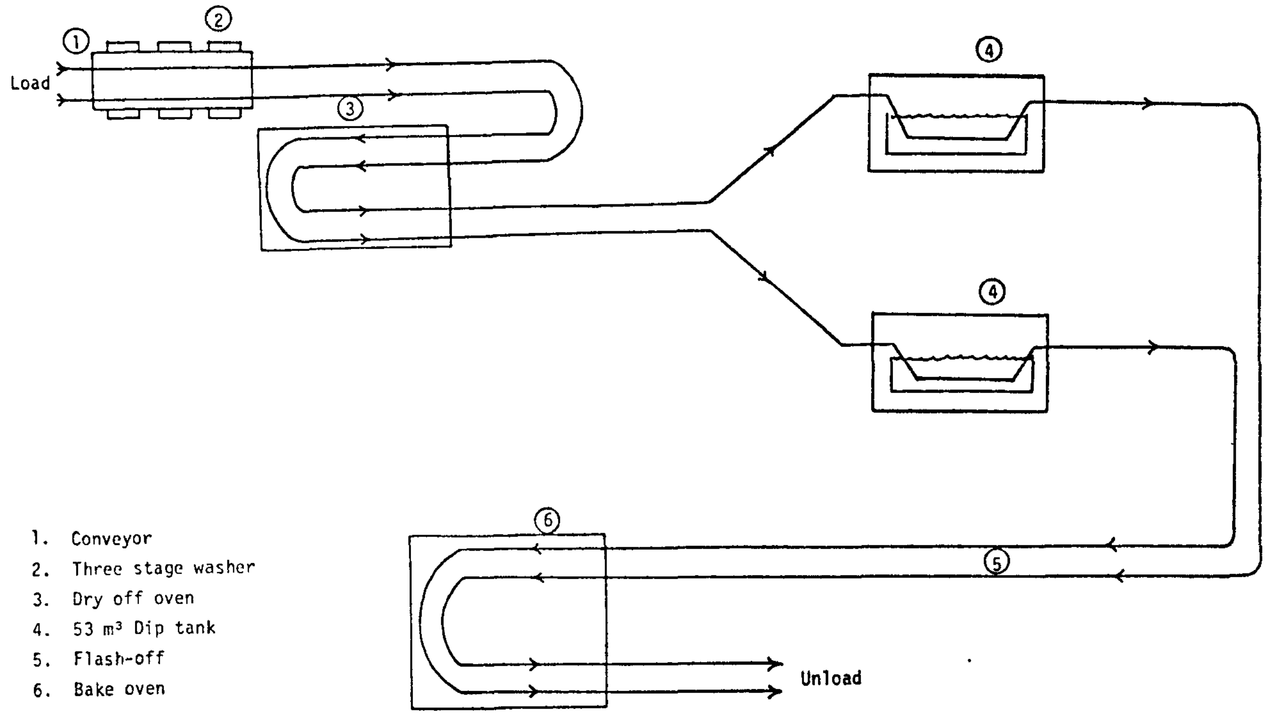

Figure 5-4. Example metal furniture dip coating lines for medium and large plants (Models G and H).

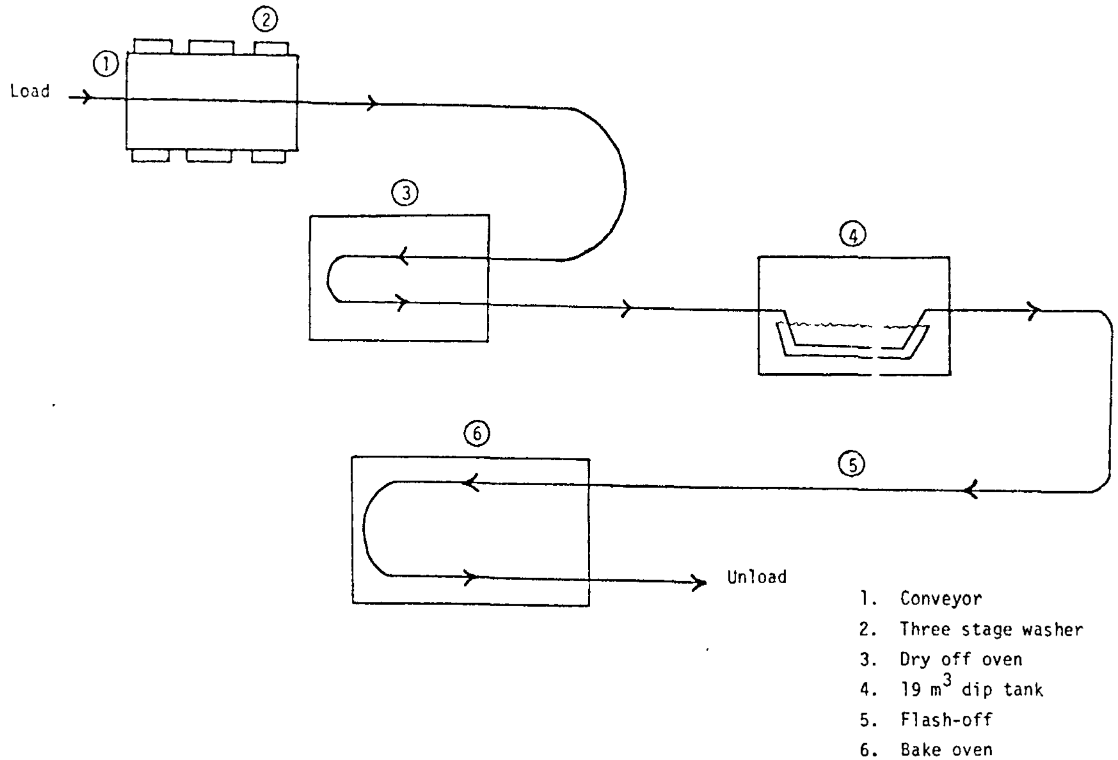

Figure 5-5. Example small metal furniture dip coating line (Model I).

estimated from the survey data. Application area and oven exhaust flow rates were calculated in the same manner described in the previous section.

Material and energy balances and operational data are listed in Tables 5-7, 5-8, and 5-9 for the three dip coating model plants.

5.1.3 Flow Coating

Flow coating is the least used application method in the metal furniture industry. This method is used primarily by small plants; therefore, only one model plant was developed.

Transfer efficiency for flow coating is estimated at 90 percent with no difference for varying part complexity.[16,17] Emissions for the model plant were calculated by material balance using the same assumption discussed for dip coating. Energy consumption and other operating data were estimated from the survey information. Application area and exhaust flow rates were calculated by the methods previously delineated.

Figure 5-6 depicts the model flow coating plant. Material and energy balances and operational data are listed in Table 5-10 for this model.

5.2 REGULATORY ALTERNATIVES

The purpose of this section is to define different regulatory alternatives based upon their effectiveness for reducing VOC emissions. The regulatory alternatives are established from the control technologies described in Chapter 3. Four regulatory alternatives are considered in developing the control options:

I. No additional emission reduction above the baseline case.

II. 30 percent VOC emission reduction above the baseline case.

III. 50 percent VOC emission reduction above the baseline case.

IV. 85 percent VOC emission reduction above the baseline case.

The baseline case is the emission limitation required by existing regulations in the absence of an NSPS. This emission limitation is recommended in the Control Techniques Guideline (CTG) document for this industry. Many states have already adopted or are in the process of adopting this emission limitation into their State Implementation Plans (SIPs). For the purpose of this study it is assumed that the SIPs are based on the emission limitation of 0.36 kg of VOC per liter of coating (minus water).

Table 5-7. MODEL PLANT G

Application method/efficiency: Dip coating/90 percent
Surface type: Complex
Approximate surface area per item: 0.33 $meters^2$
Total area coated per year: 4,000,000 $meters^2$
Operating schedule: 8 hours/day 5 days/week 50 weeks/year

Conveyor speed: 4.6 meters/min.
Number of lines: 10 (1-53 m^3 tank per line)
Number of color changes per day: 0[a]
Number of plant employees: 620
Number of coating line employees: 60

	Per line	Total
MATERIAL BALANCE		
Items coated:	1,200,000	12,000,000
Coating used (liters)[b]:	32,254	322,540
Material loss during application and flash off		
Solids (liters):	1,129	11,289
Solvents (liters):	8,386	83,860
Total coating applied to items (liters):	29,029	290,290
Net dry solids on items (liters):	10,160	101,600
Solvent emissions during curing (kilograms):	11,070	110,700
Total emissions (kilograms):	18,449	184,490
Application exhaust flow rate ($meters^3$/sec):	2.5	25
Application exhaust concentration (ppm):	100	100
Oven exhaust flow rate ($meters^3$/sec):	0.95	9.5
Oven exhaust concentration (ppm):	1,500	1,500
ENERGY CONSUMPTION		
Application - Electric (joules):	7×10^{10}	70×10^{10}
- Gas (joules):	0	0
Cure - Electric (joules):	3×10^{10}	30×10^{10}
- Gas (joules):	590×10^{10}	$5,900 \times 10^{10}$

[a]Different color paints in the different tanks.
[b]35 percent solids.

Table 5-8. MODEL PLANT H

Application method/efficiency: Dip coating/90 percent
Surface type: Complex
Approximate surface area per item: 0.33 meters^2
Total area coated per year: 780,000 meters^2
Operating schedule: 8 hours/day 5 days/week 50 weeks/year

Conveyor speed: 2.5 meters/min.
Number of lines: 2 (1-53 m^3 tank per line)
Number of color changes per day: 0[a]
Number of plant employees: 140
Number of coating line employees: 11

	Per line	Total
MATERIAL BALANCE		
Items coated:	1,181,818	2,363,636
Coated used (liters)[b]:	31,448	62,896
Material loss during application and flash off		
Solids (liters):	1,100	2,200
Solvents (liters):	8,177	16,354
Total coating applied to items (liters):	28,303	56,606
Net dry solids on items (liters):	9,906	19,812
Solvent emissions during curing (kilograms):	10,793	21,586
Total emissions (kilograms):	17,988	35,976
Application exhaust flow rate (meters^3/sec):	2.5	5
Application exhaust concentration (ppm):	100	100
Oven exhaust flow rate (meters^3/sec):	0.95	1.9
Oven exhaust concentration (ppm):	1,500	1,500
ENERGY CONSUMPTION		
Application - Electric (joules):	7×10^{10}	14×10^{10}
- Gas (joules):	0	0
Cure - Electric (joules):	3×10^{10}	3×10^{10}
- Gas (joules):	435×10^{10}	870×10^{10}

[a]Different color in each tank.

[b]35 percent solids.

Table 5-9. MODEL PLANT I

Application method/efficiency: Dip coating/90 percent
Surface type: Complex
Approximate surface area per item: 0.33 $meters^2$
Total area coated per year: 45,000 $meters^2$
Operating schedule: 8 hours/day 5 days/week 50 weeks/year

Conveyor speed: 2.5 meters/min.
Number of lines: 1 (1-19 m^3 tank)
Number of color changes per day: 0
Number of plant employees: 18
Number of coating line employees: 3

	Total
MATERIAL BALANCE	
Items coated:	136,360
Coating used (liters):[a]	3,629
Material loss during application and flash off	
Solids (liters):	127
Solvents (liters):	944
Total coating applied to items (liters):	3,266
Net dry solids on items (liters):	1,143
Solvent emissions during curing (kilograms):	1,245
Total emissions (kilograms):	2,076
Application exhaust flow rate ($meters^3$/sec):	0.3
Application exhaust concentration (ppm):	100
Oven exhaust flow rate ($meters^3$/sec):	0.95
Oven exhaust concentration (ppm):	1,500
ENERGY CONSUMPTION	
Application - Electric (joules):	2×10^{10}
- Gas (joules):	0
Cure - Electric (joules):	2×10^{10}
- Gas (joules):	366×10^{10}

[a]35 percent solids.

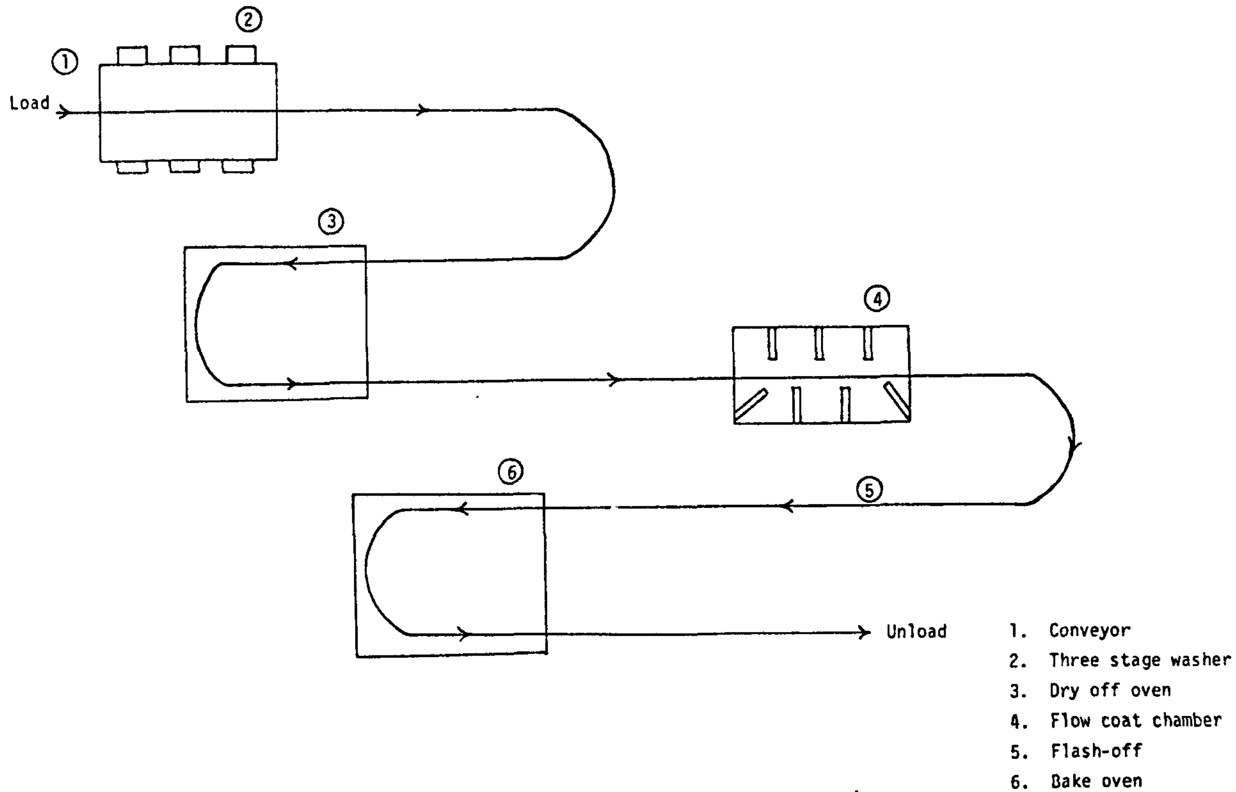

Figure 5-6. Example metal furniture flow coating line (Model J).

Table 5-10. MODEL PLANT J

Application method/efficiency: Flow coating/90 percent
Surface type: Complex
Approximate surface area per item: 0.33 meters^2
Total area coated per year: 45,000 meters^2
Operating schedule: 8 hours/day 5 days/week 50 weeks/year

Conveyor speed: 2.5 meters/min.
Number of lines: 1 (1 flow-coat booth)
Number of color changes per day: 0
Number of plant employees: 18
Number of coating line employees: 3

MATERIAL BALANCE	Total
Items coated:	136,360
Coating used (liters)[a]:	3,629
Material loss during application and flash off	
Solids (liters):	127
Solvents (liters):	1,877
Total coating applied to items (liters):	3,266
Net dry solids on items (liters);	1,413
Solvent emissions during curing (kilograms):	415
Total emissions (kilograms):	2,076
Application exhaust flow rate (meters^3/sec):	0.4
Application exhaust concentration (ppm):	100
Oven exhaust flow rate (meters^3/sec):	0.95
Oven exhaust concentration (ppm):	1,500
ENERGY CONSUMPTION	
Application - Electric (joules):	3×10^{10}
- Gas (joules):	0
Cure - Electric (joules):	2×10^{10}
- Gas (joules):	366×10^{10}

[a]35 percent solids.

Listed below are the selected control options (from control techniques in Chapter 3) for each emission reduction level:

- No NSPS above recommended baseline case.
- 30 percent VOC emission reduction
    1. Electrostatic spraying of powder coatings.
    2. Applying powder coatings by a fluidized bed.
    3. Electrostatic spraying of high solids coatings (60-80 percent).
    4. Electrostatic spraying of waterborne coatings (82/18 and 67/33).
    5. Thermal incinerator on bake oven plus electrostatic spraying of high solids coatings (60-80 percent).
    6. Dip coating with waterborne coatings (82/18 and 67/33).
    7. Flow coating with a waterborne coating (82/18).
    8. Thermal incinerator on bake oven plus dip coating with waterborne coating (82/18 and 67/33).
    9. Electrodeposition with a 82/18 waterborne coating.
- 50 percent VOC emission reduction.
    1. Electrostatic spraying of powder coatings.
    2. Applying powder coatings by a fluidized bed.
    3. Electrostatic spraying with a waterborne coating (82/18).
    4. Dip coating with a waterborne coating (82/18).
    5. Thermal incinerator on bake oven plus dip coating with a waterborne coating (82/18).
    6. Electrodeposition with a 82/18 waterborne coating.
    7. Flow coating with a 82/18 waterborne coating.
- 85 percent VOC emission reduction.
    1. Electrostatic spray of powder coatings.
    2. Applying powder coatings by a fluidized bed.
    3. Electrodeposition with a 82/18 waterborne coating.

Some possible control techniques are not presented (e.g., carbon adsorption) and the reasons for this are discussed later in Section 5.2.1. The above list of control options is large and was reduced to a more manageable size through consideration of a cost effectiveness screening study. The analyses indicated the number of control options required for spray, dip, and flow coating lines varies as follows:

Coating line	Control alternative	Use frequency of control techniques to meet control options
Spray	30 percent	4
Spray	50 percent	2
Spray	85 percent	1
Dip	30 percent	4
Dip	50 percent	4
Dip	85 percent	2
Flow	30-85 percent	1

The main parameter was cost changes to comply with any proposed NSPS above the baseline case associated with the control options. As a result, the above number of required control techniques are representative of all of the possible control options from a cost change standpoint. This is also true regardless of the three regulatory alternatives selected at VOC emission reduction levels.

The selected control options are shown in Table 5-11. Two general types of control options are presented in Table 5-11: (a) add-on control equipment, and (b) coating formulation changes. Emission reductions of VOC are shown in Tables 5-12 through 5-21 for each model plant. Each control option is discussed in Sections 5.2.1 and 5.2.2. For reasons which will be discussed later, not all control techniques evaluated in Chapter 3 can be applied to each model plant.

5.2.1 Add-on Control Equipment

Add-on control equipment which can be used for metal furniture coating operations are thermal and catalytic incinerators, carbon adsorbers, and condensers. A combination of the above can also be used, but this was not considered in developing control options. The reason for not considering combinations is presented in the following sections.

5.2.1.1 Incineration. Incineration can be used to control emissions for curing only and has been used to a limited extent in the metal furniture industry. Based on information provided in Chapter 3, incineration of emissions from the application area is not considered technologically feasible due to the high flow rate and low solvent concentration of the exhaust gas.

Table 5-11. CONTROL OPTION SUMMARY FOR EACH MODEL PLANT

Control option	Model plants									
	A	B	C	D	E	F	G	H	I	J
Powder coating	X	X	X	X	X	X	X	X	X	
Electrodeposition							X	X	X	
Waterborne	X	X	X	X	X	X	X	X	X	X
70 percent high solids	X	X	X	X	X	X				
Incineration	X	X	X	X			X	X		
65 percent high solids	X	X	X	X	X	X				

Table 5-12. EMISSION REDUCTION FOR MODEL PLANT A - LARGE SPRAY COATING FACILITY FOR FLAT METAL FURNITURE SURFACES

Plant	Regulatory alternative	Control technique	Emission reduction[a] by weight (%)	Process being controlled on coating line	Emission estimate[b] for coating line (kg/yr)	Emission reduction by weight[c] over the base case (%)	Emission reduction by weight over the[d] uncontrolled plant (%)
A	IV	Powder	98	Entire line[e]	3,680	95	98
A	III	Waterborne (35% by volume solids 82/18 H_2O to solvent)	80	Entire line	38,000	50	80
A	II	70% by volume high solids	75	Entire line	48,300	35	75
A	II	Thermal incinerator	96	Bake oven	52,600	30	72
A	I	65% by volume high solids	69	Entire line	60,700	19	69
A	I	Base case	61	Entire line	75,100	--	61

[a]Emission reduction for the individual control technique, but not the entire coating line.

[b]Overall emission estimate for the entire coating line.

[c]Base case = 0.35 kg VOC/liter of coating applied.

[d]Uncontrolled = 35 percent solids paint.

[e]"Entire line" only refers to the processes on the coating line that might emit VOCs. Therefore, this includes application, flash-off and curing oven areas.

Table 5-13. EMISSION REDUCTION FOR MODEL PLANT B - LARGE SPRAY COATING FACILITY FOR COMPLEX METAL FURNITURE SURFACES

Plant	Regulatory alternative	Control technique	Emission reduction[a] by weight (%)	Process being controlled on coating line	Emission estimate[b] for coating line (kg/yr)	Emission reduction by weight over the base case[c] (%)	Emission reduction by weight over the uncontrolled plant[d] (%)
B	IV	Powder	99	Entire line[e]	3,680	96	99
B	III	Waterborne (35% volume solids, 82/18 H_2O to solvent)	80	Entire line	51,000	50	80
B	II	70% by volume high solids	75	Entire line	64,200	36	75
B	II	Thermal incinerator	96	Bake oven	69,800	50	72
B	I	65% by volume high solids	68	Entire line	80,600	19	68
B	I	Base case	61	Entire line	99,700	--	61

[a]Emission reduction for the individual control technique, but not the entire coating line.

[b]Overall emission estimate for the entire coating line.

[c]Base case = 0.36 kg VOC/liter of coating applied.

[d]Uncontrolled = 35 percent solids paint.

[e]"Entire line" only refers to the processes on the coating line that might emit VOCs. Therefore, this includes application, flash-off and curing oven areas.

Table 5-14. EMISSION REDUCTION FOR MODEL PLANT C - MEDIUM SIZE SPRAY COATING FACILITY FOR FLAT METAL FURNITURE SURFACES

Plant	Regulatory alternative	Control technique	Emission reduction[a] by weight (%)	Process being controlled on coating line	Emission estimate[b] for coating line (kg/yr)	Emission reduction by weight over the[c] base case (%)	Emission reduction by weight over the[d] uncontrolled plant (%)
C	IV	Powder	98	Entire line[e]	715	95	98
C	III	Waterborne (35% by volume solids, 82/18 H_2O to solvent)	80	Entire line	7,300	50	80
C	II	70% by volume high solids	75	Entire line	9,350	36	75
C	II	Thermal incinerator	96	Bake oven	10,200	30	72
C	I	65% by volume high solids	69	Entire line	11,800	19	69
C	I	Base case	62	Entire line	14,500	--	62

[a]Emission reduction for the individual control technique, but not the entire coating line.

[b]Overall emission estimate for the entire coating line.

[c]Base case = 0.35 kg VOC/liter of coating applied.

[d]Uncontrolled = 35 percent solids paint.

[e]"Entire line" only refers to the processes on the coating line that might emit VOCs. Therefore, this includes application, flash-off and curing oven areas.

Table 5-15. EMISSION REDUCTION FOR MODEL PLANT D - MEDIUM SIZE SPRAY COATING FACILITY FOR COMPLEX METAL FURNITURE SURFACES

Plant	Regulatory alternative	Control technique	Emission reduction[a] by weight (%)	Process being controlled on coating line	Emission estimate[b] for coating line (kg/yr)	Emission reduction by weight over the[c] base case (%)	Emission reduction by weight over the[d] uncontrolled plant (%)
D	IV	Powder	99	Entire line[e]	715	96	99
D	III	Waterborne (35% by volume solids, 82/18 H_2O to solvent)	80	Entire line	9,700	50	80
D	II	70% by volume high solids	75	Entire line	12,400	36	75
D	II	Thermal incinerator	96	Bake oven	13,600	30	72
D	I	65% by volume high solids	69	Entire line	15,600	20	69
D	I	Base case	61	Entire line	19,400	--	61

[a]Emission reduction for the individual control technique, but not the entire coating line.

[b]Overall emission estimate for the entire coating line.

[c]Base case = 0.36 kg VOC/liter of coating applied.

[d]Uncontrolled = 35 percent solids paint.

[e]"Entire line" only refers to the processes on the coating line that might emit VOCs. Therefore, this includes application, flash-off and curing oven areas.

Table 5-16. EMISSION REDUCTION FOR MODEL PLANT E - SMALL SPRAY COATING FACILITY FOR FLAT METAL FURNITURE SURFACES

Plant	Regulatory alternative	Control technique	Emission reduction[a] by weight (%)	Process being controlled on coating line	Emission estimate[b] for coating line (kg/yr)	Emission reduction by weight over the[c] base case (%)	Emission reduction by weight over the[d] uncontrolled plant (%)
E	IV	Powder	98	Entire line[e]	41	95	98
E	III	Waterborne	80	Entire line	420	50	80
E	II	70% by volume high solids	76	Entire line	539	36	76
E	I	65% by volume high solids	69	Entire line	678	19	69
E	I	Base case	62	Entire line	838	--	62

[a]Emission reduction for the individual control technique, but not the entire coating line.

[b]Overall emission estimate for the entire coating line.

[c]Base case = 0.36 kg VOC/liter of coating applied.

[d]Uncontrolled = 35 percent solids paint.

[e]"Entire line" only refers to the processes on the coating line that might emit VOCs. Therefore, this includes application, flash-off and curing oven areas.

Table 5-17. EMISSION REDUCTION FOR MODEL PLANT F - SMALL SPRAY COATING FACILITY FOR COMPLEX METAL FURNITURE SURFACES

Plant	Regulatory alternative	Control technique	Emission reduction[a] by weight (%)	Process being controlled on coating line	Emission estimate[b] for coating line (kg/yr)	Emission reduction by weight over the base case[c] (%)	Emission reduction by weight over the uncontrolled plant[d] (%)
F	IV	Powder	99	Entire line[e]	39	97	99
F	III	Waterborne	80	Entire line	560	50	80
F	II	70% by volume high solids	75	Entire line	780	36	75
F	I	65% by volume high solids	69	Entire line	905	19	69
F	I	Base case	61	Entire line	1,120	--	61

[a]Emission reduction for the individual control technique, but not the entire coating line.

[b]Overall emission estimate for the entire coating line.

[c]Base case = 0.36 kg VOC/liter of coating applied.

[d]Uncontrolled = 35 percent solids paint.

[e]"Entire line" only refers to the processes on the coating line that might emit VOCs. Therefore, this includes application, flash-off and curing oven areas.

Table 5-18. EMISSION REDUCTION FOR MODEL PLANT G - LARGE DIP COATING FACILITY FOR METAL FURNITURE

Plant	Regulatory alternative	Control technique	Emission reduction[a] by weight (%)	Process being controlled on coating line	Emission estimate[b] for coating line (kg/yr)	Emission reduction by weight over the[c] base case (%)	Emission reduction by weight over the[d] uncontrolled plant (%)
G	IV	Powder-fluidized bed	96	Entire line[e,f]	8,370	89	96
G	IV	Electrodeposition of waterborne	95	Entire line	9,300	88	95
G	III	Thermal incinerator	96	Bake oven	31,700	58	83
G	III	Waterborne	82	Entire line	34,100	54	82
G	II[g]	Base case	60	Entire line	74,800	--	60

[a]Emission reduction for the individual control technique, but not the entire coating line.

[b]Overall emission estimate for the entire coating line.

[c]Base case = 0.36 kg VOC/liter of coating applied.

[d]Uncontrolled = 35 percent solids paint.

[e]"Entire line" refers to the processes on the coating line that might emit VOCs. Therefore, this includes application, flash-off and curing oven areas.

[f]Assuming a thermosetting powder or thermoplastic powder that does not require a primer.

[g]Base case - regulatory alternative II because of increased transfer efficiency.

Table 5-19. EMISSION REDUCTION FOR MODEL PLANT H - MEDIUM SIZE DIP COATING FACILITY FOR METAL FURNITURE

Plant	Regulatory alternative	Control technique	Emission reduction[a] by weight (%)	Process being controlled on coating line	Emission estimate[b] for coating line (kg/yr)	Emission reduction by weight over the[c] base case (%)	Emission reduction by weight over the[d] uncontrolled plant (%)
H	IV	Powder-fluidized bed	96	Entire line[e,f]	1,550	89	96
H	IV	Electrodeposition waterborne	95	Entire line	1,800	87	95
H	III	Thermal incinerator	96	Bake oven	6,120	58	83
H	III	Waterborne	82	Entire line	6,640	54	82
H	II	Base case	60	Entire line	14,500	--	60

[a]Emission reduction for the individual control technique, but not the entire coating line.

[b]Overall emission estimate for the entire coating line.

[c]Base case = 0.36 kg VOC/liter of coating applied.

[d]Uncontrolled = 35 percent solids paint.

[e]"Entire line" only refers to the processes on the coating line that might emit VOCs. Therefore, this includes application, flash-off and curing oven areas.

[f]Assuming a thermosetting or a thermoplastic powder that does not require a primer.

[g]Base case - regulatory alternative II because of increased transfer efficiency.

Table 5-20. EMISSION REDUCTION FOR MODEL PLANT I - SMALL DIP COATING FACILITY FOR METAL FURNITURE

Plant	Regulatory alternative	Control technique	Emission reduction[a] by weight (%)	Process being controlled on coating line	Emission estimate[b] for coating line (kg/yr)	Emission reduction by weight over the[c] base case (%)	Emission reduction by weight over the[d] uncontrolled plant (%)
I	IV	Powder-fluidized bed	96	Entire line[e,f]	89	89	96
I	IV	Electrodeposition waterborne	95	Entire line	104	88	95
I	III	Waterborne	82	Entire line	383	54	82
I	II	Base case	60	Entire line	838	--	60

[a]Emission reduction for the individual control technique, but not the entire coating line.

[b]Overall emission estimate for the entire coating line.

[c]Base case = 0.36 kg VOC/liter of coating applied.

[d]Uncontrolled = 35 percent solids paint.

[e]"Entire line" only refers to the processes on the coating line that might emit VOCs. Therefore, this includes application, flash-off and curing oven areas.

[f]Assuming a thermosetting powder or a thermoplastic powder that does not require a primer.

[g]Base case - regulatory alternative II because of increased transfer efficiency.

Table 5-21. EMISSION REDUCTION FOR MODEL PLANT J - SMALL FLOW COATING FACILITY FOR METAL FURNITURE

Plant	Regulatory alternative	Control technique	Emission reduction[a] by weight (%)	Process being controlled on coating line	Emission estimate[b] for coating line (kg/yr)	Emission reduction by weight over the base case[c] (%)	Emission reduction by weight over the uncontrolled plant[d] (%)
J	III	Waterborne	82	Entire line[e]	383	54	82
J	II[f]	Base case	60	Entire line	838	--	60

[a]Emission reduction for the individual control technique, but not the entire coating line.

[b]Overall emission estimate for the entire coating line.

[c]Base case = 0.36 kg VOC/liter of coating applied.

[d]Uncontrolled = 35 percent solids paint.

[e]"Entire line" only refers to the processes on the coating line that might emit VOCs. Therefore, this includes application, flash-off and curing oven areas.

[f]Base case - regulatory alternative II because of increased transfer efficiency.

Thermal incineration is applied only to model plants A, B, C, D, G, and H. The emission estimates are based on the addition of the incinerator to the curing oven of a coating line using a CTG level coating material (60 percent by volume solids or waterborne). Catalytic incineration was not considered for two reasons; (a) it has lower control efficiencies than thermal incineration, and (b) precleaning equipment might be necessary to protect the catalyst. The smaller plants (models E, F, I, and J) are not considered due to their low emission rates and the high cost of this control technique. Incineration is most effective for dip coating lines due to the fact that more solvent (50 to 70 percent) is evaporated in the baking oven with this process. Spray and flow coating operations emit less during curing. Figure 5-7 shows a block diagram of a process controlled by incineration.

5.2.1.2 Carbon Adsorption. Carbon adsorption can be applied only to the application and flash-off areas of a coating line. Carbon adsorption is not presently used in the metal furniture industry; however, it is conceivable that some companies may choose to use it. The emission reduction achievable is similar to that of incineration; however, the costs are extremely high. Because of the expense and the technological problems discussed in Chapter 3, this control technique was not employed as a control option .

5.2.1.3 Condenser. Condensers can possibly be applied to control VOC's from the flash-off and bake oven gaseous exhausts. However, this control technique was not employed as a control option since it is not a proven technology.

5.2.2 Coating Formulation Change

Coating formulation changes evaluated for control options are powder, high solids, and waterborne coatings.

5.2.2.1 Powder Coating. Control of VOC emissions by coating with powder is evaluated for two application techniques: (a) electrostatic spray and (b) fluidized bed. Electrostatic spray application of thermoset powders is evaluated for all spray coating model plants. This option offers the greatest emission reduction potential when compared with other control techniques. Changes that would occur in model plants A through F as a

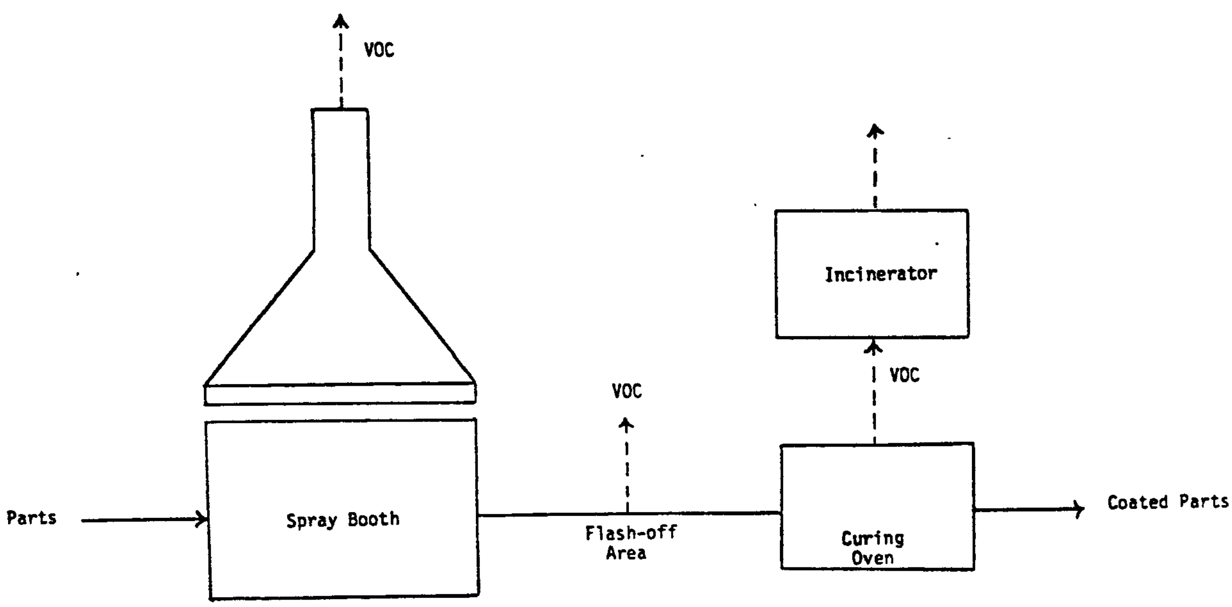

Figure 5-7. VOC control by incineration.

result of switching from conventional organic solvent to powder coatings are shown in Table 5-22.

Also, application of thermoplastic or thermoset powder with a fluidized bed is evaluated for all dip coating model plants. It is assumed that no primer is added to the parts before they are coated with a thermoplastic powder. Changes that would occur on the dip coating lines are also shown in Table 5-22.

Powder coating is not considered as a control alternative for flow coating because no appropriate application method is known to be available.

5.2.2.2 High Solids Coatings. Control of VOC emissions by the use of high solids coatings is considered for electrostatic spray model plants only. Problems with dip and flow coating are encountered due to the viscosity of high solids paints.

Two different levels of high solids coatings are considered (65 and 70 percent). Coating formulations in this range are used to a limited extent in the metal furniture industry, however, it is a proven technology.

Transfer efficiencies for high solids paints were assumed to be slightly less than those for conventional solvent-borne paints. The transfer efficiencies used in calculating emission reduction potential are 80 percent for flat surfaces and 60 percent for complex surfaces. Table 5-23 shows coating line changes that result in switching from organic solvent-borne coatings to high solids coatings.

5.2.2.3 Waterborne Coatings. Waterborne coatings can be used as control options for all types of application techniques. A volatile formulation of 82 percent water and 18 percent solvent is used to calculate emissions from this alternative. For electrostatic spray operations, application efficiencies of 80 percent for flat surfaces and 60 percent for complex surfaces are used.

Two control options are developed for waterborne dip coating. Standard dip coating of waterborne paint involves an application efficiency of 90 percent and an emission reduction of 82 percent. Electrodeposition of waterbornes, however, yields a much higher application efficiency and an overall emission reduction of 95 percent.

Table 5-22. PROCESS PARAMETERS FOR MODEL PLANTS APPLYING POWDER COATINGS

Model plant	Coating[a] used, 10^3 liters	(10^3 gallons)	Application[b] exhaust flow rate m^3/sec	(ft^3/min)	Oven[c] exhaust flow rate m^3/sec	(ft^3/min)	Operating energy consumption[d]: total electric, 10^{10} Joules	(10^6 kwh)	Operating energy consumption[d]: total gas, 10^{10} Joules	(10^6 BTU/hr)
Spraying[e]										
A	283	(75)	1.7	(3600)	2.85	(6 000)	872	(2.42)	1 770	(16 800)
B	283	(75)	2.3	(4900)	4.75	(10 000)	1 450	(4.03)	2 950	(28 000)
C	55	(15)	0.3	(640)	0.95	(2 000)	110	(0.31)	435	(4 120)
D	55	(15)	0.45	(950)	0.60	(1 260)	110	(0.31)	435	(4 120)
E	3.2	(0.85)	0.02	(42)	0.48	(1 000)	4	(0.09)	183	(1 730)
F	3.2	(0.85)	0.03	(59)	0.48	(1 000)	4	(0.09)	183	(1 730)
Dipping[f]										
G	644	(170)	----	--	----	--	130	(0.36)	2 950	(28 000)
H	119	(31)	----	--	----	--	22	(0.06)	435	(4 120)
I	6.9	(1.8)	----	--	----	--	5	(0.01)	183	(1 730)

[a] Assuming coating thicknesses for spraying and dipping to be 6.35 and 15.24 (10^{-3}) cm, respectively.

[b] Air flow rates (entire line) based upon a LEL of 30 g/m^3 (0.03 oz/ft^3).[21]

[c] Assumed about half the flow rate (entire line) required for model plants.[22]

[d] Energy consumption data based on Table 7-20.

[e] For model plants A through D the assumed powder utilization was 90 percent due to the required color change. For model plants E and F powder utilization was 95 percent.

[f] Powder utilizations for model plants G, H, and I are 95 percent and 97.5 percent, respectively.

Table 5-23. PROCESS PARAMETERS FOR MODEL PLANTS APPLYING HIGH SOLIDS COATINGS

Model plant	% by volume solids	Coating[a] used, 10^3 liters	(10^3 gallons)	Application[b] exhaust flow rate m^3/sec	(ft^3/min)	Oven[b] exhaust flow rate m^3/sec	(ft^3/min)	Operating energy consumption[c] total electric 10^{10} Joules	(10^6kwh)	Operating energy consumption[c] total gas, 10^{10} Joules	(10^6 BTU/hr)
A	65	197	(52)	35	(74,200)	1.9	(4,020)	872	(2.42)	2,370	(22,500)
A	70	183	(48)	23.5	(60,400)	1.3	(2,750)	872	(2.42)	2,370	(22,500)
B	65	262	(69)	59	(125,000)	3.2	(6,780)	1,450	(4.03)	3,950	(37,400)
B	70	243	(64)	47.5	(100,700)	2.1	(4,450)	1,450	(4.03)	3,950	(37,400)
C	65	38.2	(10.1)	12	(25,440)	0.6	(1,270)	10	(0.31)	583	(5,530)
C	70	35.4	(9.35)	9.5	(20,140)	0.4	(850)	110	(0.31)	583	(5,530)
D	65	50.8	(13.4)	12	(25,440)	0.4	(850)	110	(0.31)	583	(5,530)
D	70	47.1	(12.4)	9.5	(20,140)	0.3	(640)	110	(0.31)	583	(5,530)
E	65	2.2	(0.58)	5.9	(12,500)	0.3	(640)	34	(0.09)	245	(2,320)
E	70	2.0	(0.53)	4.75	(10,230)	0.2	(420)	34	(0.09)	245	(2,320)
F	65	2.9	(0.77)	5.9	(12,500)	0.3	(640)	34	(0.09)	245	(2,320)
F	70	2.7	(0.71)	4.75	(10,070)	0.2	(420)	34	(0.09)	245	(2,320)

[a] A coating thickness of 2.54 (10^{-3}) cm was employed.

[b] Flow rates through spray booths and ovens were reduced based on percent solvent savings from the model plant parameters.[3] Some regulations, however, may require minimum flow rates for all spray booths.

[c] Energy consumption data based upon Table 7-20.

Waterborne paint can be applied by flow coaters with an application efficiency of 90 percent. This yields an emission reduction of 82 percent. Table 5-24 shows coating line changes that result in switching from organic solvent-borne coatings to waterborne coatings.

Table 5-24. PROCESS PARAMETERS FOR MODEL PLANTS APPLYING WATERBORNE COATINGS

Model plant	Coating[a] used, 10^3 liters	(10^3 gallons)	Application[b] exhaust flow rate m^3/sec	(ft^3/min)	Oven exhaust flow rate m^3/sec	(ft^3/min)	Operating energy consumption[c] total electric 10^{10} Joules	(10^6kwh)	total gas, 10^{10} Joules	(10^6 BTU/hr)
Spraying										
A	172	(45)	22.8	(48,300)	1.1	(2,330)	1,060	(2.94)	2,370	(22,500)
B	229	(61)	38.0	(80,500)	1.9	(4,020)	1,760	(4.89)	3,950	(37,400)
C	33.3	(8.8)	7.6	(16,100)	0.4	(850)	133	(0.369)	583	(5,530)
D	44.3	(12)	7.6	(16,100)	0.2	(420)	133	(0.369)	583	(5,530)
E	1.92	(0.51)	3.8	(8,050)	0.2	(420)	54	(0.15)	245	(2,320)
F	2.57	(0.68)	3.8	(8,050)	0.2	(420)	54	(0.15)	245	(2,320)
Dipping										
G[d]	110	(29)	2.0	(4,240)	0.2	(420)	500	(1.39)	3,950	(37,400)
G	152	(40)	7.2	(15,200)	1.9	(4,020)	115	(0.319)	3,950	(37,400)
H[d]	21.6	(5.7)	0.40	(847)	0.04	(85)	85	(0.236)	583	(5,530)
H	29.6	(7.8)	1.4	(2,970)	0.4	(850)	20	(0.056)	583	(5,530)
I[d]	1.32	(0.35)	0.02	(42)	0.02	(40)	20	(0.056)	245	(2,320)
I	1.71	(0.45)	0.07	(152)	0.2	(420)	5	(0.014)	245	(2,320)
Flow										
J	1.71	(0.45)	0.07	(152)	0.2	(420)	6	(0.017)	245	(2,320)

[a] A 2.54 (10^{-3}) cm coating thickness was employed and coating applied in this column excludes water.

[b] Flow rates through spray booths and ovens were reduced based on percent solvent savings from the model plant parameters[3]. Some regulations, however, may require minimum flow rates for all spray booths.

[c] Electrodeposition-type processes.

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6. ENVIRONMENTAL IMPACT

This chapter discusses the environmental impacts associated with each control option developed in Chapter 5. The environmental analyses include impacts from air and water pollution, solid waste, and energy consumption. Each is addressed in separate sections of this chapter.

For each specific analysis, both primary and secondary impacts are identified and discussed. Primary impacts are those directly associated with the application of a control option. Examples of primarv impacts caused by employing one of the control options (such as a thermal incinerator) are decreased air emissions and increased energy utilization. An example of a secondary impact is the carbon dioxide generated while burning the volatile organic compounds (VOC) emitted from a bake oven.

6.1 AIR POLLUTION IMPACT

The air pollution impact is evaluated for coating lines applying paints by spray, dip, and flow coating methods. Emission reduction of VOC industry-wide for each application technique were determined and are shown in Tables 6-1, 6-2, and 6-3. The methodology for developing the emission estimates shown in the tables is presented in the following paragraphs.

Uncontrolled emission estimates are based on paint consumption of about 113.6 x 10^6 liters (30.0 x 10^6 gallons) in 1975. Of this consumption, 65 percent by volume is solvent. This represents about 68 percent of the total solvent used in this industry during 1975. Therefore, the total uncontrolled emission estimate for the metal furniture industry is calculated in the following manner.[1,2]

Amount of solvent in paint = 113.6 x 10^6 (.65) = 73.8 (10^6) liters
using a solvent density of 0.88 kg/l (Reference 3)

Table 6-1. EMISSION ESTIMATES FOR SPRAY COATING EMPLOYING CONTROL OPTIONS

VOC Emissions, Metric Tons per Year[a]

Year	Uncontrolled emissions	SIP regulations	High solids (65%)	Thermal incinerator[b]	High solids (70%)	Waterborne	Powder
1975	81,300	81,300	81,300	81,300	81,300	81,300	81,300
1976	84,200	84,200	84,200	84,200	84,200	84,200	84,200
1977	87,100	87,100	87,100	87,100	87,100	87,100	87,100
1978	90,200	90,200	90,200	90,200	90,200	90,200	90,200
1979	93,400	93,400	93,400	93,400	93,400	93,400	93,400
1980[c]	96,700	90,900	90,100	89,800	89,500	89,100	87,300
1981	100,000	88,300	86,800	86,200	85,700	84,700	81,300
1982	104,000	86,100	83,700	82,800	82,000	80,500	75,200
1983	108,000	83,800	80,600	79,500	78,300	76,300	69,200
1984	112,000	81,600	77,600	76,100	74,600	72,100	63,100
1985	116,000	79,300	74,500	72,700	70,900	67,900	57,000
1986	120,000	77,000	71,400	69,300	67,200	63,700	51,000

[a]Columns 3 through 9 are emission estimates for the control options presented in Chapter 5.

[b]On curing oven only.

[c]Emission controls begin in 1980.

Table 6-2. EMISSION ESTIMATES FOR DIP COATING EMPLOYING CONTROL OPTIONS
VOC Emissions, Metric Tons per Year[a]

Year	Uncontrolled emissions	SIP regulations[b]	Waterborne	Thermal incinerator[c]	Electrodeposition	Powder
1975	8,600	8,600	8,600	8,600	8,600	8,600
1976	8,900	8,900	8,900	8,900	8,900	8,900
1977	9,220	9,220	9,220	9,220	9,220	9,220
1978	9,540	9,540	9,540	9,540	9,540	9,540
1979	9,880	9,880	9,880	9,880	9,880	9,880
1980[d]	10,200	9,600	9,400	9,390	9,270	9,260
1981	10,600	9,350	8,920	8,900	8,660	8,620
1982	11,000	9,110	8,450	8,420	8,050	7,990
1983	11,400	8,860	7,980	7,940	7,440	7,360
1984	11,900	8,650	7,530	7,480	6,840	6,730
1985	12,300	8,400	7,060	7,000	6,230	6,100
1986	12,700	8,160	6,590	6,520	5,620	5,470

[a]Columns 3 through 8 are emission estimates for the control options presented in Chapter 5.

[b]Must be a waterborne coating that would at least provide a 61 percent by weight emission reduction.

[c]On curing oven only.

[d]Emission controls begin in 1980.

Table 6-3. EMISSION ESTIMATES FOR FLOW COATING EMPLOYING CONTROL OPTIONS
VOC Emissions, Metric Tons per Year[a]

Year	Uncontrolled emissions	SIP regulations	Waterborne
1975	5,640	5,640	5,640
1976	5,840	5,840	5,840
1977	6,050	6,050	6,050
1978	6,260	6,260	6,260
1979	6,480	6,480	6,480
1980	6,710	6,310	6,170
1981	6,970	6,160	5,860
1982	7,230	6,000	5,550
1983	7,500	5,850	5,240
1984	7,780	5,700	4,930
1985	8,080	5,560	4,630
1986	8,390	5,420	4,330

[a]Columns 3 and 4 are emission estimates for the control options presented in Chapter 5.
[b]Emission controls begin in 1980.

$$\text{Amount of solvent consumed in kg} = \frac{73.8\ (10^6)\ (0.88)}{0.68}$$

Amount of solvent consumed in metric tons (MT) = 95,500 (for 1975)

The uncontrolled emission estimates developed in 1975 are proportioned into the three different application techniques (spray, dip, and flow) based on survey data.[4] The uncontrolled emissions shown in the tables are projected from Equation 6-1.

$$UE = E_{1975}\ (1 + G)^{Yr}\ F \qquad (6\text{-}1)$$

where, UE = uncontrolled emissions, MT.

E_{1975} = 95 500, MT.

G = New coating line growth rate, per year 0.0353 (1975-1980) and 0.0379 (1981-1985).

F = Fraction of industry employing a certain application technique.

Yr = Years since 1975.

The growth rate in Equation 6-1 is based on economic data presented in Chapter 7 and is weighted based on emission estimates per Standard Industrial Classification (SIC) code obtained from emission inventory data.[5]

The controlled emission estimates are based on three separate projections that considered State Implementation Plans (SIP) and New Source Performance Standards (NSPS) based on the control options. The first projection, $(\Delta E)_{new}$, represents emission estimates after air pollution controls are required on new coating lines because of SIP or NSPS regulations. The next projection, $(\Delta E)_{m\&r}$, is for affected, modified, and reconstructed coating lines which have been assumed to have a 15-year life. The last projections, $(\Delta E)_{yr}$, is for facilities remaining uncontrolled after SIP and NSPS regulations. These terms are combined into Equation 6-2.

$$E = (\Delta E)_{new} + (\Delta E)_{m\&r} + (\Delta E)_{yr} \qquad (6\text{-}2)$$

where, E = controlled emissions, MT.

$(\Delta E)_{new} = (UE - E_{1979})\ (1\text{-}CE)$

E_{1979} = emissions for which the SIP and NSPS regulations go into effect, MT.

CE = control efficiency of selected control techniques from Chapter 5, or SIP requirement.

$(\Delta E)_{m\&r} = (n)\ MR\ E_{1979}\ (1-CE)$

$n = 1+$ years after 1979.

MR = rate per year of modified and reconstructed coating lines, 0.067 (see Chapter 7)

$(\Delta E)_{yr} = UE - (\Delta E)_{m\&r}$

For the above calculations it was assumed that emission controls would take effect in 1980.

The primary impacts of the control options from Chapter 5 are summarized below.

- All of the control options will reduce VOC emissions below 1975 levels before the last projected year of 1986 (see Tables 6-1 to 6-3). This assumes that NSPS regulations will be required by 1980.

Secondary impacts associated with each control option is discussed below.

- Carbon dioxide is produced as a combustion product from coating lines employing thermal incineration as a control technique. Even though carbon dioxide is not considered a pollutant, it is being studied to determine if increased emissions of carbon dioxide from combusting fossil fuels, forest fires, etc., could cause a "green house" effect. Thermal incineration is a source of increased emissions of carbon dioxide because of the organic solvents and fossil fuels burned by the incinerators. No emission estimate is presented for carbon dioxide because chemical composition of the solvent used in the metal furniture industry varies from plant to plant.

- The utilization of waterborne coatings has been identified as a potential source of N-nitrosamines.[6] N-nitrosamines are considered to be among the most potent and versatile of all chemical carcinogenic agents. The amines released from waterborne coatings may contribute to the formation of N-nitrosamines in the atmosphere. No data are available on emission rates of these compounds, however, based on ambient data reported in Reference 7, the health hazard associated with the amine emissions is minimal. Therefore, until other data can be obtained it is assumed in this report that emission of amines from waterborne coatings does not appear to be a significant health hazard.

6.2 WATER POLLUTION IMPACT

This section addresses water quantities and qualities impacted by the control option for a coating line.

Processes on the coating line that use water are listed below:

Process	Coating type
Pretreatment	All coating types
Spray booth	Conventional organic solvent-borne, some high solids, some waterborne.
Dip tank	Waterborne, conventional solvent-borne.
Electrodeposition tank	Waterborne

Only water pollution associated with the above processes is considered in this section.

Table 6-4 shows "typical" waste effluents from coating lines (not necessarily the metal furniture) in metal finishing facilities that have been studied.[8] It is assumed for this evaluation that the metal furniture facilities using conventional organic solvent-borne coatings fall within the effluent ranges shown in the table. The effluent concentration and chemical composition is due to process water from the metal pretreatment and application areas. In this industry process water reuse seems to be the general rule of operation. Water usage from the pretreatment area increases or remains the same for all of the control options. For high solids and waterborne coatings, water usage associated with pretreatment may actually increase due to the need for more pretreatment.[9]

Spray booths are usually equipped with water curtains which aid in particulate capture and removal of overspray. The utilization of water curtains for existing lines that are modified or reconstructed will probably continue unless the metal parts are coated with powder. This is a problem for waterborne spray coatings containing water-miscible solvents which require removal by ultrafiltration. For new coating lines employing coating formulation changes such as high solids, waterborne or powder, spray booths will be designed without water curtains. Some high solids and waterborne spray booths are equipped with filter pads while all powder

Table 6-4. QUALITY OF WATER DISCHARGE

Subcategory 7 - Material Coating (variations among plants)

Parameter[a,b]	Minimum	Maximum	Mean
pH	1.5	11.3	----
Turbidity (JTU)[c]	0.300	3800	395.6
Temperature	282K	336K	296.3K
Dissolved oxygen	1.0	12.0	7.0
Sulfide	0.010	24	1.3
Cyanide	0.010	1.6	1.03
Total solids	35	63,090	2917.9
Total suspended solids	0.200	28,390	917.8
Settleable solids	0.200	40	10.5
Cadmium	0.002	60.9	2.1
Chromium, total	0.005	400	20.1
Chromium, hexavalent	0.005	36.4	1.5
Copper	0.011	1060	21.1
Fluoride	0.130	110	6.8
Iron, total	0.130	422.2	21.6
Iron, dissolved	0.003	367.7	17.9
Lead	0.006	102.8	1.7
Oil, grease	0.500	13,510	545.2
COD	3.7	40,000	1837
Total phosphates	0.200	62.4	9.5
Zinc	0.020	86.5	4.6
Boron	0.050	21.3	2.5
Mercury	0.002	0.055	0.012
Nickel	0.007	0.950	0.207
Silver	0.002	0.100	0.007

Flow (for a production floor area of 107,000 ft^2) - 108,000 GPD

[a]All parameters measured in mg/liter except pH, turbidity, and temperature.

[b]Many of these pollutants are under consideration.

[c]Jackson Turbidity Units.

spray booths utilize an exhaust gas filtration system. This reduction in water usage should benefit facilities having to comply with water pollution control regulations.

Coating lines employing dip or electrodeposition tanks have a water pollution problem because of dragout. Dragout is defined as the volume of solution carried over the edge of a process tank by an emerging piece of work. The solution usually ends up in water used to clean the application area, or in process drains. Switching to a control option such as powder (fluidized-bed) will reduce or eliminate this problem.

The use of electrodeposition, however, presents a somewhat different problem due to the difference in paint formulation. Because of this, ultrafiltration is usually an integral part of an electrodeposition process. This is quite effective in removing paint solids from the waste streams.

Table 6-5 qualitatively summarizes water usage for Model Plant A concerning each control option. Projections are not presented for water usage for this industry because it is difficult to differentiate water flow data into recycled or fresh water. Also, Table 6-6 provides a qualitative evaluation of some of the pollutant flows from Table 6-4 versus control options.

Water pollution regulations for this and other industries are governed by the Federal Water Pollution Control Act. This Act specifies several levels of control that are applicable to industries including the metal furniture coating industry. These levels of control are:

1. For existing plants, best practicable control technology currently available (BPCTCA/BPT) by 1977.

2. For existing plants, best available technology economically achievable (BATEA/BAT) by 1983.

3. For new sources, New Source Performance Standards considering costs and any non-water quality environmental impact and energy requirements.

4. The Act allows States to establish more stringent than Federal standards if desired.

Methods that facilities can employ to reduce or eliminate water pollution include in-plant controls and wastewater treatment. In-plant controls reduce water pollution treatment costs by minimizing pollutants to be

Table 6-5. QUALITATIVE ANALYSIS FOR WATER USAGE AT MODEL PLANT A

Control option	Pretreatment area	Application area	Overall water usage
Powder	Unchanged	Reduced or eliminated	Reduced
Waterborne	Increased or unchanged	Unchanged or reduced	Unknown
High solids	Increased or unchanged	Unchanged or reduced	Unknown
Thermal incinerator plus high solids	Increased or unchanged	Unchanged or reduced	Unknown

Table 6-6. QUALITATIVE ANALYSIS FOR POLLUTANT DISCHARGE RATES IN WATER EFFLUENTS VERSUS COATING FORMULATION CHANGES

Pollutant	Powder[a] spray	Powder[a] fluidized bed	Waterborne[a] spray	Waterborne[a] dip	High solids[a] spray
Sulfide	Reduced	Reduced	Unknown	Unknown	Unknown
Cyanide	Reduced	Reduced	Unknown	Unknown	Unknown
Total solids	Reduced	Reduced	-----[b]	-----[b]	-----[b]
Total suspended solids	Reduced	Reduced	-----[b]	-----[b]	-----[b]
Cadmium	Reduced	Reduced	Unknown	Unknown	Unknown
Chromium, total	Reduced	Reduced	Increased or unchanged	Increased or unchanged	Increased or unchanged
Iron, total	Unchanged	Unchanged	Increased or unchanged	Increased or unchanged	Increased or unchanged
Lead	Reduced	Reduced	Unknown	Unknown	Unknown
COD	Reduced	Reduced	Increased	Increased	Increased

[a]Control options presented in Chapter 5.

[b]May depend on whether the coating line is new or existing.

treated. In-plant controls include reducing process flow, improving housekeeping, separating nonprocess and process water, employing counter current concept, equalizing water flow, and reusing and recycling water. After in-plant controls have been applied to the practical limit, wastewater treatment may be necessary to satisfy permits or municipal requirements. These treatment technologies have been divided into categories of primary treatment, physical/chemical treatment, biological treatment, membrane technologies, and sludge treatment. Primary treatment is the method chosen by those plants that merely separate solids from wastewater without chemical conditioning, and it is often a first treatment step for those that treat the wastes further. Physical/chemical treatment involving chemical addition to enhance precipitation, separation, etc., is the most widely practiced of the treatment options. Biological treatment in aerated lagoons is applicable to waterborne wastes and has been practiced. It is particular relevance for direct dischargers when BOD and COD would not otherwise be sufficiently reduced. Membrane treatment technologies of ultrafiltration and reverse osmosis are described as potentially effective methods for the treatment of painting wastewater. Sludge treatment describes the methods used to thicken, dewater, and chemically treat the sludge solids generated by the solids separation treatment technology used.[10]

6.3 SOLID WASTE IMPACT

Table 6-7 shows quantities of solid waste that are produced from the model plants for each control option. These data are based on a material balance performed on each model plant. The following assumptions were employed during development of the solid waste estimates.

1. Transfer efficiencies and paint consumption data reported in Chapter 5 were utilized in the calculations.

2. Solid waste estimates are limited to those for the application area of the coating line.

3. Solid waste generated from pretreatment areas on a coating line is considered to be negligible.

Other solid waste produced in the application area but not estimated include filter pads and dry filter media. Filter pads are used instead of water curtains on spray booths for coating formulations such as high solids

Table 6-7. SOLIDS WASTE ESTIMATES FOR MODEL PLANTS

Kg per Year

Model Plant	Solvent-borne[a]	High solids[b]			Waterborne[b] spray & dip	Waterborne[b] electrodeposition	Powder[b]	Thermal[b] incinerator
		60%	65%	70%				
A	23,300	33,200	33,300	33,300	33,300	------	36,800	33,200
B	71,100	88,300	88,600	88,500	88,500	------	36,800	88,300
C	4,550	6,450	6,460	6,450	6,440	------	7,150	6,450
D	13,900	17,200	17,200	17,100	17,200	------	7,150	17,200
E	263	371	372	371	372	------	413	a
F	800	992	994	994	994	------	196	------
G	14,700	------	------	------	14,700	1,420	41,900	14,700
H	2,860	------	------	------	2,860	278	7,740	2,860
I	165	------	------	------	165	17	223	------
J	165	------	------	------	165	------	------	------

[a]Estimates for uncontrolled plant.

[b]Estimates for control options presented in Chapter 5.

See Appendix E for additional comments considering solid waste generation.

and waterborne. Dry filter media are installed on spray booths and fluidized beds applying powder coatings to metal parts. This waste is removed to a landfill. The amount of waste from these sources cannot be quantified since these data have not been reported in the literature.

The chemical composition of the solid waste presented in Table 6-7 depends upon the type of film formers, pigments, and additives contained in the applied paint. The film formers contain the synthetic organic resins (e.g., alkyd, vinyl, acrylic, etc.) that produce the protective covering of the metal part. The pigments are inorganic or organic compounds which give the formed film color. Inorganic pigments are sources of elements such as zinc, lead, arsenic, bismuth, tin, and cadmium. Additives contain organic and inorganic compounds which provide surface agents, driers, thickeners, flame retardants, etc., and are very important for coatings such as waterborne and high solids. Solid wastes produced from coating lines are disposed of in three ways: (1) incineration, (2) landfill, and (3) stockpiling. While combustible waste recovered from a coating line can be incinerated, trace elements may be emitted as air pollutants. Also, incineration of some powder coatings may be impractical.[9] Most industries use the second method of disposal, landfill. However, many landfill operators are beginning to reject solid waste from industry because of some of the elements present in the waste. The last method of solid waste disposal is stockpiling or dumping of material on property owned by the facility which produced the solid wastes. Solid waste stored in this manner could be concentrated in rain water runoff, however, and therefore presents an adverse impact.

Projections of solid waste over a five year period were not done since the estimates would show the same impacts as displayed in Table 6-7. Those primary impacts are summarized as:

1. Sprayed high solids and waterborne coatings produce more solid waste because of lower transfer efficiencies.

2. Solid waste generated from powder coatings sprayed on parts is a function of the number of color changes and total amount of powder utilized.

3. For dip coating operations powder applied by the fluidized bed technique is the biggest producer of solid waste. The lowest amount of solid waste produced for this coating technique is from electrodeposition applying waterborne paints.

4. Solid wastes generated from 60, 65, and 70 percent-by-volume high solids coatings are comparable.

6.4 ENERGY IMPACT

Table 6-8 shows energy consumption estimates for the model plants by control options. These data are based on References 1-15 of Chapter 5. For each control option total energy consumption is less than for the uncontrolled case (solvent-borne). The only exception consists of waterborne coatings applied by the electrodeposition process. Though it might not be expected that thermal incineration would consume less energy than the uncontrolled case, it does because the incinerator is utilized on a coating line applying high solids (60 percent by volume) rather than a conventional solvent-borne coating.

Explanations for the lower energy consumption for powder, high solids, and waterborne coatings when compared with organic solvent-borne coatings are shown quantitatively in Table 6-9.

Energy consumption projections for 1979 and 1983 are shown in Table 6-10. The projections are for a five year period covering SIP and NSPS regulations. Equation 6-3 is employed for projecting energy consumption for spray coating lines.

$$(\text{Energy})_{yr} = \frac{(\text{EE})_{RA}}{(\text{EE})^{B}_{RA}} (\text{energy})_{RA} + \frac{(\text{EE})_{SIPs}}{(\text{EE})^{B}_{RA}} (\text{energy})_{SIPs} + \frac{\text{UE}}{(\text{UE})^{B}} (\text{energy})_{UE} \qquad (6\text{-}3)$$

Where, $(\text{Energy})_{yr}$ = energy consumed in any one year (1979-1983), joules.

$(\text{EE})_{RA}$ and $(\text{EE})_{SIPs}$ = emission estimates from equation 6-1 for each control option and SIP regulation, respectively.

$(\text{EE})^{B}_{RA}$ and $(\text{EE})^{B}_{SIPs}$ = emission estimates from Table 5-2 (Model Plant B) for each control option and SIP regulation, respectively.

$(\text{energy})_{RA}$, $(\text{energy})_{SIPs}$ and $(\text{energy})_{UE}$ = energy consumption estimates from Table 6-8 for each control option, SIP regulation, and solvent-borne, respectively.

UE and $(\text{UE})^{B}$ = uncontrolled emission estimates from Table 6-1 and Table 5-2, respectively.

Table 6-8. ENERGY CONSUMPTION ESTIMATES FOR MODEL PLANTS

10^{10} Joules per year[a]

Model plants	Solvent-borne[b]		High solids[c] (60, 65, 70%)		Water-borne[c]		Powder[c]		Thermal incinerator[c,d]	
A	918	(3,540)	872	(2,370)	1,060	(2,370)	872	(1,770)	872	(2,590)
B	1,530	(5,896)	1,450	(3,950)	1,760	(3,950)	1,450	(2,950)	1,450	(4,130)
C	116	(870)	110	(583)	133	(583)	110	(435)	110	(635)
D	116	(870)	110	(583)	54	(245)	34	(183)	-----	-----
E	47	(366)	34	(245)	54	(245)	34	(183)	-----	-----
F	47	(366)	34	(245)	54	(254)	34	(183)	-----	-----
G	100	(5,900)	-----	-----	115 & 500	(3,950)[e]	130	(2,950)	100	(4,020)
H	17	(870)	-----	-----	20 & 85	(583)[e]	22	(435)	17	(688)
I	4	(366)	-----	-----	5 & 20	(245)[e]	5	(183)	-----	-----
J	5	(366)	-----	-----	6	(245)	-----	-----	-----	-----

[a] First set of numbers are for total electric usage and numbers inside parentheses are total additional natural gas usage.

[b] Estimates for uncontrolled plant.

[c] Estimates for control options presented in Chapter 5.

[d] For thermal incinerators utilizing 50 percent energy recovery.

[e] The range of electric usage rates for dip and electrodeposition, respectively.

Table 6-9. QUALITATIVE ANALYSIS OF ENERGY CONSUMPTION ON A COATING LINE

Coating type[a]	Pretreatment area	Dry-off oven	Application area	Flash-off area	Bake oven
Powder	Same as organic solvent-borne.	Same as organic solvent-borne.	Energy reduction because of less make-up air.	Energy reduction because there is no flash-off area.	Energy reduction because of elimination of heat-up zone.
High solids	A possible increase in energy consumption, or remain the same.	Same as organic solvent-borne.	Energy reduction because of less make-up air.	Energy reduction because of less solvent applied.	Energy reduction because of possible lower curing temperature.
Waterborne	A possible increase in energy consumption, or remain the same.	Energy reduction because this step is not always necessary.	Energy reduction because of less make-up air.	Same as organic solvent-borne.	Increase of energy consumption because of water.

[a]Coating formulation changes that are some of the control options presented in Chapter 5.

Table 6-10. PROJECTIONS OF ENERGY CONSUMPTION FOR EACH CONTROL OPTION

Joules (10^{14}) per Year

Year	Conventional solvent-borne[a]	High solids[b] (60, 65, and 70%)	Waterborne[b]	Powder[b]	Thermal incinerator[b,c]
1979	272	251	251	251	251
1980	281	240	241	232	241
1981	291	229	232	212	232
1982	302	219	223	193	223
1983	314	225	227	171	229

[a]Estimates industrywide for uncontrolled plants.

[b]Estimates obtained after each control option (see Chapter 5) has been applied industrywide.

[c]This control option should vary more than any control option when considering energy consumption.

The primary impact of the control options according to Equation 6-3 seems to occur after year 1982. For all regulatory alternatives except powder, energy consumption will begin to increase during 1983. However, the amount of energy consumed is still less in each case than for conventional solvent-borne coatings.

Although discussion in this section has been limited to energy consumption associated with the coating line, energy consumption related to producing and shipping each control option must also be addressed. Energy consumption associated with producing different coating formulations has not been compiled. However, it is known that powder and high solids coatings require less energy to ship than any other alternative since fewer drums have to be shipped to perform a coating job. In addition, waterborne coatings require less shipment energy due to the reduced need for additional solvent.

6.5 OTHER ENVIRONMENTAL IMPACTS

Some electrodeposition coatings that contain amines may cause visible emissions from a bake oven. Some automobile coating plants have, as a result, utilized incinerators on bake exhaust streams to eliminate visible emissions and odors associated with these amines.[11] Such a problem has not been witnessed at a metal furniture coating facility.

The only other possible environmental impact is associated with visible emissions resulting from powder coatings. During one plant trip, visible emissions were observed from a fluidized bed process in which metal parts were coated with powder. This particular case occurred because the baghouse attached to the fluidized bed was not operating.[9]

6.6 OTHER ENVIRONMENTAL CONCERNS

6.6.1 Irreversible and Irretrievable Commitment of Resources

Regardless of which alternative emission control system is selected, additional equipment will be required. Thus, additional steel and other raw materials will be consumed. This commitment of resources is small compared to the national usage of each resource. However, a good quantity of these resources will ultimately be salvaged and recycled. Also, the commitment of land on which to locate additional control devices or application equipment or both is expected to be minor.

Without heat recovery, significant energy would be lost. Thus, the use of primary and secondary heat recovery would enhance the value of incineration.

6.6.2 Environmental Impact of Delayed Standards

Increased emissions of VOC based on growth projections for the metal furniture industry are discussed in Section 6.1 of this chapter. If a new source performance standard is delayed, VOC emissions would continue to increase even though SIP regulations now exist. Also, the amount of energy consumed on a coating line will continue to increase after 1982.

The only possible negative environmental impacts associated with the control options are for water and solid waste. The use of some waterborne coatings may require ultrafiltration to remove dissolved solids. All of the coating formulation changes, except powder, could cause an increase in the amount of solid waste generated by the industry. However, both impacts are considered to be minor compared to the environmental gains achievable by reduction of VOC emissions into the air.

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7. ECONOMIC IMPACT

7.1 INDUSTRY PROFILE

This section profiles the metal furniture manufacturing industry. The information contained herein is intended as an input to the analysis of economic impact that results from the control of volatile organic compound (VOC) emissions from metal furniture coating operations. The manufacturing industry is of concern because the amount of metal furniture coating and painting performed is highly correlated with industry output. Because manufacturers perform most of the coating themselves, the main burden of control costs falls on them. A small percentage of furniture is sent to independent jobbers who coat items that they do not manufacture. This type of operation is largely undocumented; for instance, although jobbers are covered by Standard Industrial Classification (SIC) 3479 (metal coating, engraving, and allied services), published data do not separate them specifically from sandblasters, galvanizers, and other operations. It is believed that the volume of metal furniture painted by jobbers is small and that these operations are relatively few in number.

The metal furniture industry is covered by four SIC codes:

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).

A finer breakdown of the four categories can be found in section 2.1.

7.1.1 Industry Structure

In 1976, the metal furniture industry included approximately 1400 establishments, employed about 100,000 people and made shipments valued at $3,657 million (see Table 7-1). Figures on the four segments of the industry show that three of them have a similar small business orientation.

Table 7-1. METAL FURNITURE MANUFACTURING INDUSTRY, 1976-1977

	Number of establishments			Value of industry shipments (millions of dollars)			Number of employees (thousands)			Average shipments per establishment (millions of dollars)	
	1976[a]	%	1977[b]	1976[c]	%	1977[b]	1976[d]	%	1977[b]	1976	1977
Metal household furniture (SIC 2514)	391	28	441	991.6	27	1256.7	30.5	31	32.2	2.5	2.8
Metal office furniture (SIC 2522)	177	13	185	1073.1	29	1375.5	25.7	36	28.4	6.1	7.4
Public building and related furniture (SIC 2531)	377	27	415	716.2	20	764.8	20.6	21	19.6	1.9	1.8
Metal partitions and fixtures (SIC 2542)	449	32	NA	875.8	24	NA	21.9	22	NA	2.0	NA
Total	1394			3656.7			98.7				

[a]County Business Patterns, 1976. U.S. Summary Statistics, Department of Commerce. Washington, D. C.

[b]Metal Household Furniture. 1977 Census of Manufactures Preliminary Report. Department of Commerce. Washington, D. C. April 1979. p. 2. Metal Office Furniture. 1977 Census of Manufactures Preliminary Report. Department of Commerce, Washington, D.C. July 1979. p. 2. Public Building and Related Furniture. 1977 Census of Manufactures Preliminary Report, Department of Commerce. Washington, D.C. May 1979. p. 2.

[c]Annual Survey of Manufactures. General Statistics for Industry Groups and Industries. Department of Commerce. Washington, D. C. December 1977.

[d]Annual Survey of Manufactures. 1976 Value of Product Shipments. Department of Commerce, Washington, D.C. December 1977.

NOTE: Because 1976 figures for establishments and shipments are from separate sources, they may not be entirely compatible.

The fourth segment - the metal office furniture category - is smaller in terms of number of establishments but operates on a somewhat larger scale than do the other segments.

In 1976, for instance, metal household furniture, public building and related furniture, and metal partitions each had around 400 establishments and between $700 million and one billion dollars in shipments. Metal office furniture had only 177 establishments and over one billion dollars in shipments, putting its average shipments per establishment at over six million dollars, versus approximately two million dollars for the other sectors (Table 7-1). Preliminary figures for 1977 show this trend continuing.

Historical data confirm the disparity between metal office furniture and the other three sectors. In terms of concentration, the industry's shipments are dispersed among a number of companies, with less than 20 percent of shipments made by the top four firms in 1972 (see Table 7-2) except in the case of metal office furniture. Here, concentration is much greater, with 37 percent of shipments made by four firms and 88 percent made by the 50 largest companies.

Metal office furniture is much more heavily weighted towards multi-unit companies than are the other three segments (Table 7-3). Metal office furniture has only 17 percent of its shipments made by single-unit firms versus 40 percent for the other three segments.

Similarly, metal office furniture has fewer firms with a low number of employees. As shown in Table 7-4, the other segments have over 50 percent of their establishments falling into the category of less than 20 employees, while office furniture has only 39.1 percent of its establishments in that category.

Even though office furniture companies tend to operate on a larger scale, private ownership is prevalent in this sector, as it is in the remaining three.[1] In terms of legal organization, approximately 80 percent or more of the firms in all sectors were incorporated in 1972 (see Table 7-5).

7.1.1.1 Geographic Distribution of Industry. Metal furniture manufacturing establishments are spread throughout the United States,

Table 7-2. CONCENTRATION RATIOS IN METAL FURNITURE MANUFACTURING

	Percent of value of shipments accounted for by:			
	4 largest companies	8 largest companies	20 largest companies	50 largest companies
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	39	45	69	88
1958	33	49	73	89
Public building and related 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	31	61
1958	(NA)	(NA)	(NA)	(NA)

Source: U. S. Department of Commerce. Census of Manufactures. 1972.

NA - Not available.

Table 7-3. PERCENT OF VALUE OF INDUSTRY SHIPMENT IN METAL FURNITURE MANUFACTURING MADE BY MULTI-UNIT AND SINGLE-UNIT COMPANIES, 1972

	Multi-unit companies (percent)	Single-unit companies (percent)
Metal household furniture (SIC 2514)	62	38
Metal office furniture (SIC 2522)	83	17
Public building and related furniture (SIC 2531)	56	43
Metal partitions and fixtures (SIC 2542)	58	42

Source: U.S. Department of Commerce. Census of Manufactures. 1972.

Table 7-4. DISTRIBUTION OF ESTABLISHMENTS IN THE METAL FURNITURE MANUFACTURING INDUSTRY BY FIRM SIZE, 1972

Firm size, number of employees per establishment	Metal household furniture (SIC 2514)	Metal office furniture (SIC 2522)	Public building and furniture (SIC 2531	Metal partitions and fixtures (SIC 2542)
1 to 19	50.7	39.1	53.8	52.3
20 to 49	18.0	14.1	20.9	22.5
50 to 99	10.3	15.6	11.4	12.0
100 to 249	13.1	18.2	10.2	8.9
250 to 499	6.2	6.3	2.8	2.4
500 to 999	1.3	4.2	0.7	1.4
1000 to 2499	0.4	2.1	0.2	---
2500 or more	---	0.5	---	---

Source: U. S. Department of Commerce. Census of Manufactures. 1972.

Table 7-5. LEGAL FORM OF ORGANIZATION FOR METAL FURNITURE MANUFACTURERS, 1972

	Metal household furniture		Metal office furniture		Public building and related furniture		Metal partitions and fixtures	
	Number of estabs.	%	Number of estabs.	%	Number of estabs.	%	Number of estabs.	%
Corporate	401	86	167	87	331	78	425	84
Noncorporate total	66	14	26	13	91	22	82	16
Individual	29	6	18	9	52	12	46	9
Partnership	13	3	3	2	15	4	14	3
Other and unknown	24	5	5	2	24	6	22	4

1972 Census of Manufactures. Department of Commerce. Washington, D.C. January 1975. p. SR3-33 to SR3-34.

although there is light representation in Pacific Division states other than California (see Table 7-6). About 70 percent of establishments in 1976 were located in nine states:

New York	16 percent	New Jersey	5 percent
California	16 percent	Texas	4 percent
Illinois	8 percent	Michigan	4 percent
Pennsylvania	7 percent	Florida	4 percent
Ohio	6 percent		

7.1.1.2 Product Mix. Table 7-7 shows the product mix for all sectors from 1963 through 1976. This mix has remained quite stable over time. Tables 7-8, 7-9, and 7-10 give a more detailed product breakdown for each sector in 1977 except metal partitions. The tables help to identify the various surface types that are coated by the industry.

7.1.1.3 Capacity Utilization Rate. Table 7-11 summarizes the capacity utilization situation in the metal furniture industry as of the fourth quarters of 1976 and 1977. This table shows the practical rate of utilization, which is the highest possible percentage utilization, given cost and other constraints. The preferred rate, shown as a percent of the practical rate, is a point between the actual and practical rates which could be defined as optimal.

Because of the standard error of the 1977 practical rate estimates, it is difficult to cite a trend with much confidence. The numbers do indicate that the actual rate of utilization in 1977 is likely to be less than 70 percent for each sector. (This is based on the assumption that the actual rate is lower than the preferred rate, which can be expressed in terms of total available capacity by multiplying the preferred rate in the table by the practical rate).

7.1.2 Trends in the Industry

7.1.2.1 Establishments and Employees. Changes in the number of establishments and employees are depicted in Figure 7-1 through 7-4, plotted from numbers in Table 7-12. These graphs show a downward trend in the number of establishments between 1972 and 1976. Preliminary 1977 figures for the household, office, and public building sectors show an upturn in number of establishments. Although the curves for each sector

Table 7-6. GEOGRAPHIC DISTRIBUTION OF METAL FURNITURE ESTABLISHMENTS, 1976

Region and State	Metal household furniture (SIC 2514)	Metal office furniture (SIC 2522)	Public building and related furniture (SIC 2531)[a]	Metal partitions and fixtures (SIC 2543)	Total
New England					
Maine	---	---	1	---	1
Massachusetts	13	4	8	9	34
Connecticut	5	---	4	---	9
New Hampshire	1	0	1	0	2
Rhode Island	---	---	---	4	4
Middle Atlantic					
New York	66	27	20	93	206
New Jersey	14	9	7	29	59
Pennsylvania	24	17	24	26	91
East North Central					
Ohio	12	9	27	32	80
Indiana	4	6	11	7	28
Illinois	31	11	23	41	105
Michigan	8	8	17	23	56
Wisconsin	6	4	17	6	33
West North Central					
Minnesota	3	3	6	9	21
Iowa	---	1	8	1	10
Missouri	6	6	---	11	23
Kansas	---	3	4	5	12
Nebraska	---	---	---	2	2
South Atlantic					
Maryland	6	---	---	---	6
Delaware	---	1	---	---	1
Virginia	8	3	7	---	19
North Carolina	13	5	16	4	38
South Carolina	3	---	2	4	9
Georgia	5	7	---	7	19
Florida	30	3	12	8	53
West Virginia	---	---	---	3	3
East South Central					
Kentucky	5	2	5	3	15
Tennessee	9	3	18	6	36
Alabama	9	4	6	6	25
Mississippi	4	---	3	3	10

(continued)

Table 7-6. Concluded

Region and State	Metal household furniture (SIC 2514)	Metal office furniture (SIC 2522)	Public building and related furniture (SIC 2531)[a]	Metal partitions and fixtures (SIC 2543)	Total
West South Central					
Arkansas	2	0	19	3	24
Texas	16	6	22	15	59
Oklahoma	4	---	---	2	6
Mountain Division					
Utah	---	---	2	---	2
Colorado	---	---	3	3	6
Pacific Division					
Oregon	---	---	5	3	8
Washington	---	---	7	---	7
California	69	30	50	67	216
United States Total	391	188	377	449	1394

Source: U. S. Department of Commerce. County Business Patterns (by State).

[a]Includes wood, metal, and plastic furniture.

Table 7-7. METAL FURNITURE PRODUCT MIX, 1963-1976
(as a percent of total industry shipments)

	1976[a]	1975[a]	1974[a]	1973[a]	1972[b]	1967[b]	1963[b]
Metal household furniture (SIC 2514)	27.1	28.1	28.1	29.9	30.1	28.3	22.9
Dining, breakfast	7.4	9.2	8.9	8.5	8.6	7.9	9.4
Kitchen	2.0	1.7	1.7	2.7	2.5	2.7	4.2
Porch, lawn, outdoor	7.3	6.8	6.8	6.1	6.2	5.3	6.8
Other	9.7	10.5	10.7	12.5	12.8	12.4	13.5
N.s.k.	0.6	---	---	---	---	---	---
Metal office furniture (SIC 2522)	29.3	27.8	29.5	28.9	27.4	28.2	23.9
Office seating	7.3	7.0	7.7	7.5	6.8	6.4	4.9
Desks	4.6	4.5	5.5	5.5	5.4	7.3	5.9
Cabinets, cases	10.6	10.9	11.2	11.4	10.5	9.6	9.6
Other	6.0	5.4	5.1	4.5	4.8	4.9	3.6
N.s.k.	0.8	---	---	---	---	---	---
Public building related furniture (SIC 2531)	19.6	19.5	17.4	17.3	17.4	18.8	17.6
School furniture	6.6	7.2	6.7	6.3	6.4	7.6	7.9
Non-school furniture	12.5	11.8	10.1	9.7	9.8	10.1	9.0
Other	0.3	0.5	0.6	1.3	1.2	1.0	0.7
Metal partitions and fixtures (SIC 2542)	24.0	24.7	25.0	24.0	25.0	24.7	24.6
Partitions	2.0	3.4	3.1	2.5	2.8	NA	NA
Shelving and lockers	8.2	8.0	7.8	8.2	8.3	NA	NA
Storage racks	5.2	4.7	5.5	3.4	3.3	NA	NA
Fixtures	6.8	6.6	6.6	8.3	7.6	NA	NA
Other	1.6	1.9	2.1	1.5	3.0	NA	NA

N.s.k. = Not specified by kind.

NA = Not available.

[a]Annual survey of Manufactures. 1976 Value of Product Shipments. Department of Commerce, Washington, D.C. December 1977.

[b]Census of Manufactures. 1972 and 1967 (separate volumes). Department of Commerce. Washington, D. C.

Table 7-8. 1977 PRODUCT BREAKDOWN FOR METAL HOUSEHOLD FURNITURE (SIC 2514)

	Shipments (millions of dollars)	Percent (of total)
Total	1147.7	100.0
Metal household dining, dinette, and breakfast furniture	309.1	26.9
Tubular metal, including chairs whether padded or plain:		
• Sets (tables and chairs)	236.1	20.6
• Tables (not sold with a set)	16.9	1.5
• Chairs (not sold with a set)	13.4	1.2
Other metal dining, dinette, and breakfast furniture	35.7	3.1
Metal household dining, dinette, and breakfast furniture, n.s.k.	7.0	0.6
Metal kitchen furniture	73.3	6.4
Kitchen furniture, excluding breakfast furniture reported as "dining, dinette, and breakfast furniture":		
• Cabinets such as base, top, and base wall, utility, etc.	49.5	4.3
• Stools, padded and plain	17.2	1.5
• Tables, including hostess carts	5.5	0.5
Metal kitchen furniture, n.s.k.	1.1	0.1
Metal porch, lawn, outdoor, and casual furniture	262.9	22.9
Tubular aluminum:		
• Chairs, rockers, benches, chaise lounges, and settes	122.5	10.7
• Other tubular aluminum porch, lawn, and outdoor furniture, including gliders, swings, and hammocks	20.0	1.7
Cast and wrought iron:		
• Chairs, rockers, benches, chaise lounges, and settes	44.3	3.9
• Other cast and wrought iron porch, lawn, and outdoor furniture, including gliders, swings, and hammocks	12.6	1.1
Other metal porch, lawn, outdoor, and casual furniture, including picnic tables	37.4	3.3
Metal porch, lawn, outdoor, and casual furniture, n.s.k.	26.1	2.3

(continued)

Table 7-8. Concluded

	Shipments (millions of dollars)	Percent) (of total)
Other metal household furniture	391.2	34.1
Folding cots, rollable cots, army cots, and other metal beds	10.5	0.9
Metal bed frames (complete metal bed frames sold separately, with or without a headboard.	57.0	5.0
Upholstered metal household furniture. . .	12.4	1.1
Card tables and chairs	(a)	
Medicine cabinets, including "wall type" and "insert type".	60.2	5.2
Metal radio, phonograph, TV, and hi-fi cabinets	5.0	0.4
Infants' high chairs	12.1	1.1
Infants' car seats	13.6	1.2
Other infants' and children's metal furniture, including chairs, tables, playpens, play yards, and portable cribs.	46.2	4.0
Metal folding tray tables.	(a)	
Other metal household furniture.	110.1	9.6
Other metal household furniture, n.s.k. .	22.5	2.0
Metal household furniture, n.s.k., typically for companies with 5 employees or more. . . .	81.4	7.1
Metal household furniture, n.s.k., typically for companies with less than 5 employees. . .	29.8	2.6

(a) Withheld to avoid disclosing operations of individual companies.

n.s.k. = Not specified by kind.

Metal Household Furniture. 1977 Census of Manufactures. Preliminary Report. U. S. Department of Commerce, Washington, D.C. April 1976. p. 3.

Table 7-9. 1977 PRODUCT BREAKDOWN FOR METAL OFFICE FURNITURE (SIC 2522)

	Shipments (millions of dollars)	Percent (of total)
Total	1334.6	100.0
Metal office seating, including upholsteres:		
As reported in census of manufactures	386.2	28.9
As reported in Current Industrial Report MA-25H:		
• Office furniture	377.7	28.3
• Stacking chairs	74.6	5.6
• Secretarial posture chairs	59.6	4.5
• Executive chairs	123.4	9.2
• Chairs, side and arm	138.4	10.4
• Sofas, couches, settees, stools, etc. including: Upholstered	11.7	0.9
• Tandem seating	7.8	0.6
• Metal office seating, including upholstered, n.s.k.	(a)	
Desks, including modular unit desks:		
As reported in census of manufactures	226.1	16.9
As reported in Current Industrial Report MA-25H:		
• Office furniture	227.3	17.0
• Executive-type desks	61.8	4.6
• Clerical and secretarial desks, with or without typewriter mechanism	148.7	11.1
• Desks, n.s.k.	16.8	1.3
Filing cabinets and cases:		
As reported in census of manufactures	477.9	35.8
As reported in Current Industrial Report MA-25H:		
• Office furniture	479.0	35.9
• Vertical filing cabinets, noninsulated, nonmechanical, nonvisible, including security files:		
Letter	133.9	10.0
Legal	69.1	5.2
Other, except letter and legal	29.1	2.2
• Horizontal filing cabinets, noninsulated, mechanical, nonvisible, including security files	99.4	7.4
• Mechanical nonvisible files, all sizes, manual and electrical	24.3	1.8
• Insulated filing, film, and tape cabinets, and security files, excluding stores	26.4	2.0

(continued)

Table 7-9. Concluded

	Shipments (millions of dollars)	Percent (of total)
• Visible equipment (other than insulated), including vertical and rotary units:		
Nonmechanical, including cabinets, reference panel type chart boards, book type, etc.	31.9	2.4
• Mechanical, including card size and reference type, manually or electrically operated.	4.5	0.3
• Filing cabinets and cases, n.s.k.	60.4	4.5
Other metal office furniture, including tables, stands, etc.:		
As reported in census of manufactures.	218.0	16.3
As reported in Current Industrial Report MA-25H:		
• Office furniture	211.1	15.8
• Metal tables and stands.	51.6	3.9
Modular service units, except desks.	30.6	2.3
• Metal furniture panel systems:		
Panels or screens as space dividers only		
Panels with capability of accepting hangers.		
Panel-supported work surfaces.		
Panel-supported files.		
Panel-supported storage and accessories.	54.4	4.1
• Metal systems office furniture:		
Systems desk/work surface.		
Systems storage.		
Systems panels		
• Other metal office furniture, including bookcases, storage cabinets, costumers, etc.	91.1	7.2
• Other metal office furniture, including tables, stands, etc., n.s.k.	(a)	
Metal office furniture, n.s.k., typically for establishments with 5 employees or more	12.5	0.9
Metal office furniture, n.s.k., typically for establishments with less than 5 employees	13.9	1.0

[a]To be revised.
n.s.k. = Not specified by kind.

Table 7-10. 1977 PRODUCT BREAKDOWN FOR PUBLIC BUILDING AND RELATED FURNITURE (SIC 2531)

	Shipments (millions of dollars)	Percent (of total)
Total	712.3	100.0
School furniture, except stone, concrete, and library furniture	193.7	27.2
• Single pupil units	34.9	4.9
• Chairs, all purpose (nonfolding)	22.3	3.1
• Storage cabinets	45.3	6.4
• Other school furniture designed specifically for use in schools, including two or more pupil desks and tables, combination folding tables and benches, tables, teacher desks, study carrels, chalk boards, etc.	83.2	11.7
• School furniture, n.s.k.	8.0	1.1
Public building and related furniture, except for school and restaurant	457.2	64.2
• Seats for public conveyances, automobile, trucks, aircraft, and buses	166.2	23.3
• Church pews	32.9	4.6
• Other church furniture (pulpits, altars, lecterns, etc.)	10.9	1.5
• Folding tables, including folding banquet tables	33.0	4.6
• Chairs and seats, including theater and auditorium:		
Fixed	26.8	3.8
Portable folding chairs, single or ganged	21.3	3.0
• Stadium bleacher seating, including grandstands	43.8	6.1
• Library furniture, all types, including chairs, charging desks, study carrels, reading tables, etc.	24.3	3.4
• Other public building furniture	56.6	7.9
• Public building and related furniture, except school, n.s.k.	14.0	2.0
Public building furniture, n.s.k., typically for establishments with 5 employees or more	33.4	4.7
Public building furniture, n.s.k., typically for establishments with less than 5 employees	28.0	3.9

n.s.k. = Not specified by kind.
Public Building and Related Furniture. 1977 Census of Manufactures. Preliminary Report. U.S. Department of Commerce. Washington, D.C. May 1979. P. 3.

Table 7-11. CAPACITY UTILIZATION RATES: FOURTH QUARTERS, 1977 and 1976

	1977		1976	
	Preferred rate[a]	Practical rate	Practical rate	Standard error of 1977 practical rate
Metal household furniture (SIC 2514)	91	77	70	19
Metal office furniture (SIC 2522)	88	73	76	15
Public building and related furniture (SIC 2531)	92	70	69	21
Metal partitions and fixtures (SIC 2542)	90	68	69	19

[a]Shown as a percent of the practical rate.

Survey of Plant Capacity. 1977 Current Industrial Report. U. S. Department of Commerce. Washington, D.C. August 1978. p. 4.

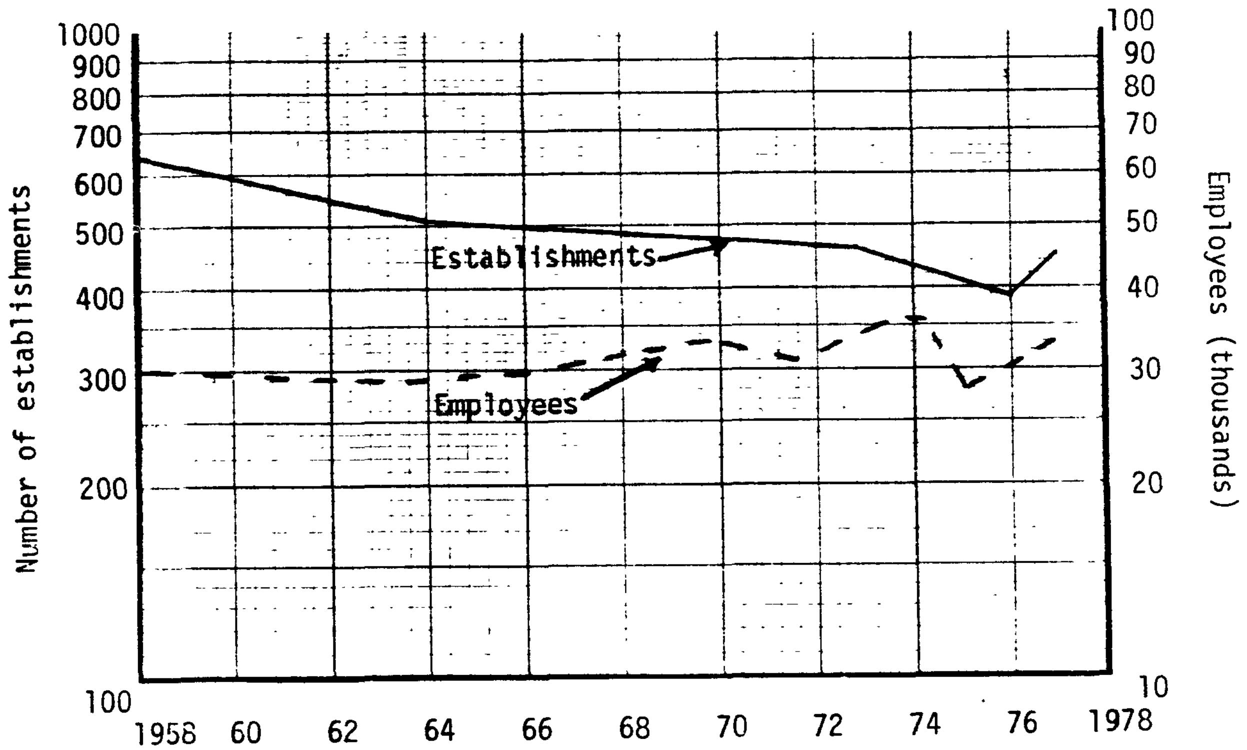

Figure 7-1. Trends in numbers of establishments and employees in the Metal Household Furniture Industry (SIC 2514).

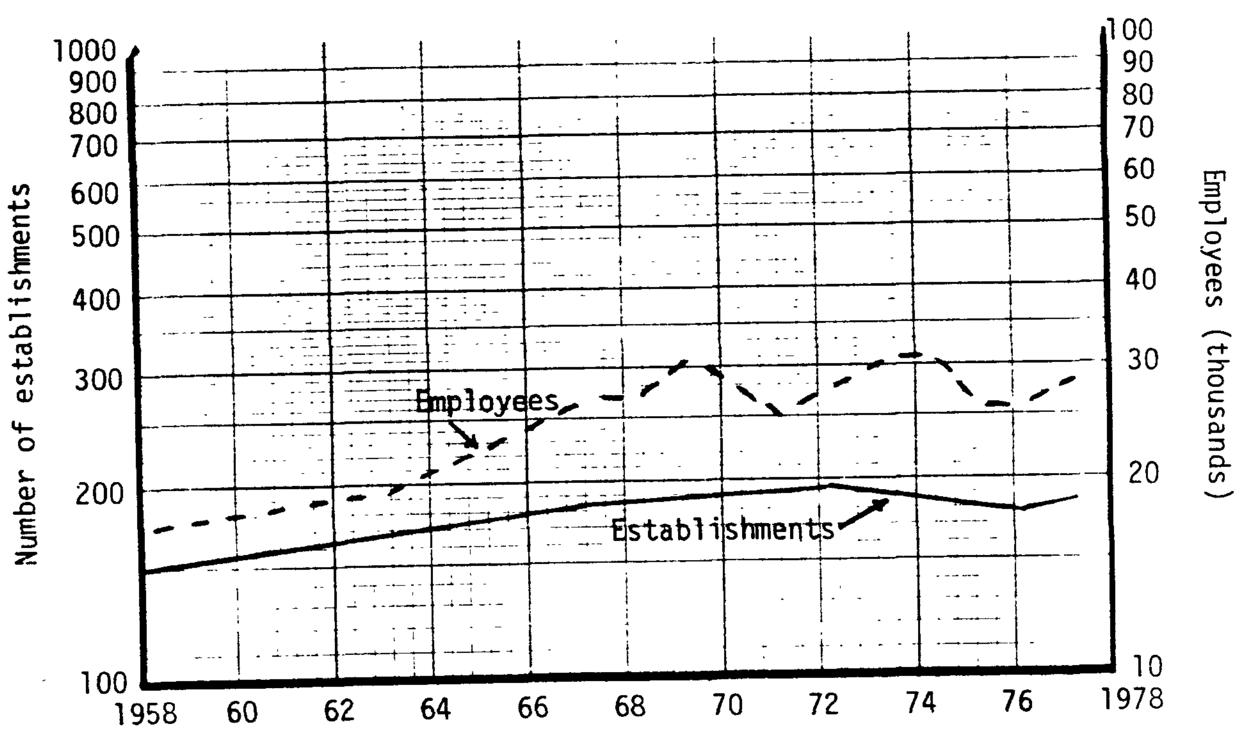

Figure 7-2. Trends in numbers of establishments and employees in the Metal Office Furniture Industry (SIC 2522).

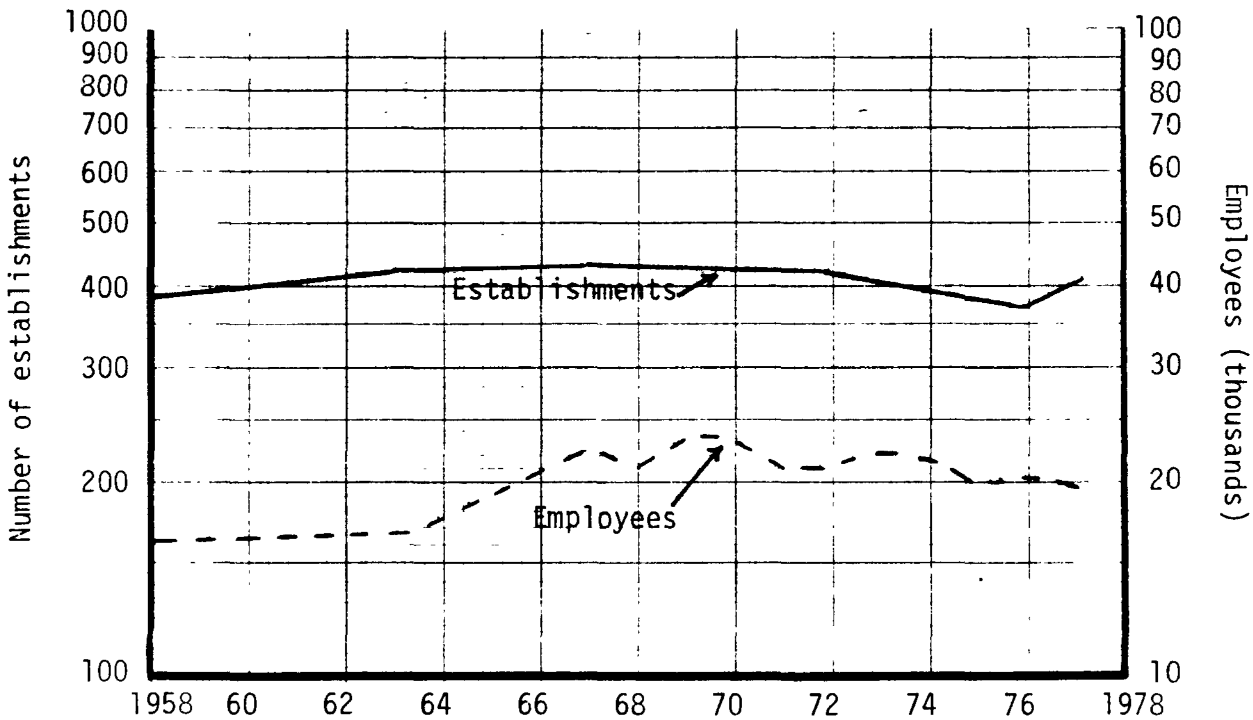

Figure 7-3. Trends in numbers of establishments and employees in the Public Building and Related Furniture Industry (SIC 2531).

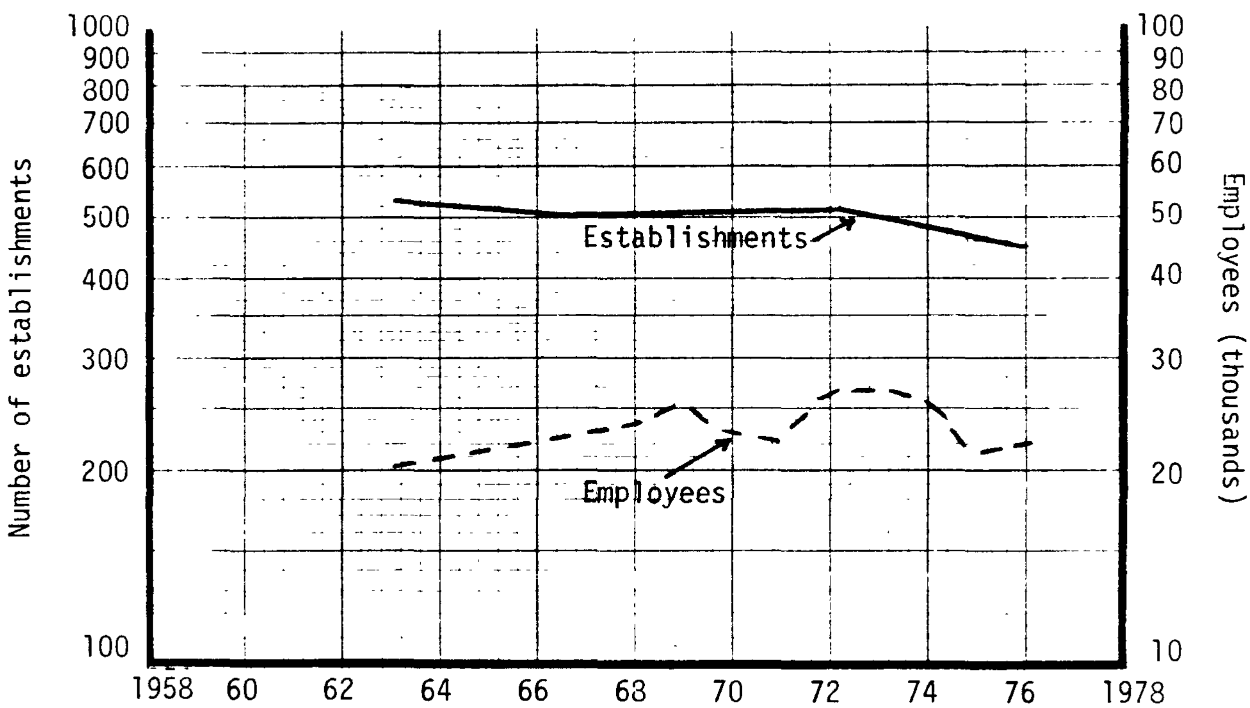

Figure 7-4. Trends in numbers of establishments and employees in the Metal Partitions and Fixtures Industry (SIC 2542).

Table 7-12. NUMBER OF ESTABLISHMENTS AND EMPLOYEES IN METAL FURNITURE MANUFACTURING INDUSTRY, 1958-1977

Year	(SIC 2514) Metal household furniture		(SIC 2522) Metal office furniture		(SIC 2531) Public building related furniture		(SIC 2542) Metal partitions and fixtures	
	Estab.[a]	Emp.[b]	Estab.[a]	Emp.[b]	Estab.[a]	Emp.[b]	Estab.[a]	Emp.[b]
1977	441	32.2	185	28.4	415	19.6	NA	NA
1976[c]	391	30.5	177	25.7	377	20.6	449	21.9
1975	NA	28.1	NA	25.2	NA	20.0	NA	21.0
1974	NA	35.4	NA	31.1	NA	21.6	NA	25.6
1973	NA	36.9	NA	30.1	NA	22.2	NA	26.3
1972	467	34.4	192	27.6	422	21.4	507	26.2
1971	NA	31.5	NA	25.0	NA	21.0	NA	22.2
1970	NA	32.4	NA	27.6	NA	23.1	NA	22.7
1969	NA	32.8	NA	30.5	NA	23.4	NA	25.2
1968	NA	32.1	NA	27.1	NA	21.0	NA	23.4
1967	486	31.0	187	27.0	438	22.6	500	22.7
1963	517	29.3	170	19.9	429	16.9	513	20.3
1958	626	30.3	151	17.5	390	16.0	NA	NA

[a]Establishments

[b]Employees (thousands)

[c]1976 data for establishments: U. S. Department of Commerce. County Business Patterns, 1976.

NA = Not available.

Source for remaining data: U. S. Department of Commerce. Census of Manufactures, 1972. 1977 Preliminary Report. Annual Survey of Manufactures, 1973, 1974, 1975, 1976.

over the past 18 years differ from each other in shape, they are similar in the sense that the percent changes between the points are small. These small differences indicate that the industry is relatively stable with moderate rates of exit and new entry.

Numbers of employees have varied quite a bit over recent years for all sectors. Each sector shows an increase in employees in 1976, signaling an upturn that is mirrowed in large part by industry shipments. For the household and office furniture sectors, this trend continued through 1977.

7.1.2.2 Value of Industry Shipments. Figures 7-5 through 7-8, derived from Table 7-13, show trends in the value of shipments for the four sectors in current dollars and in constant 1967 dollars scaled by the wholesale price indices for household and commercial furniture. The current dollar trend lines show steady growth interrupted in 1970 and 1975 by slowing or a downturn in shipment growth. The public building and related furniture sector shows the effect of slowing the least of any sector, possibly because of its dependence on government spending.

By plotting shipments in constant dollars, the effect of inflation is suppressed and the figures better reflect unit shipments. The trend lines for these values show that there has been little real growth in the industry as a whole over the past ten years. Instead, the value of industry shipments have moved cyclically, with peaks occurring in 1969 and 1972-1973. The average industry growth between those peaks is approximately three percent per year.

In order to evaluate the four sectors' relation to gross national product, the trends in percent changes in real GNP and in constant dollar shipments shown in Table 7-14 are plotted in Figures 7-9 through 7-12. In general, the industry mirrors GNP, but its changes are more volatile, i.e., industry shipments expand more rapidly during a period of growth and contract more quickly during a decline. The metal office furniture sector is the most volatile and the public building sector the least.

7.1.2.3 Factors Affecting Future Growth of the Industry. The factors that affect growth in the future differ for the four sectors. Purchases of metal household furniture are connected to the number of new households and to consumer discretionary income. Patio and recreational furniture, as

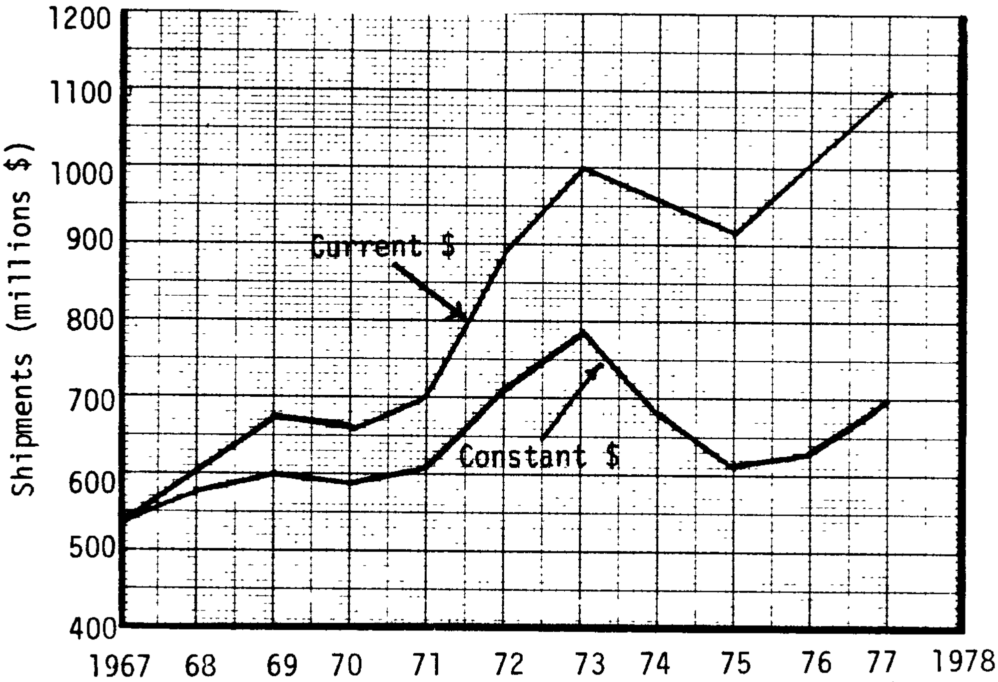

Figure 7-5. Trends in the value of shipments for the Metal Household Furniture Industry (SIC 2514) in current and constant dollars.

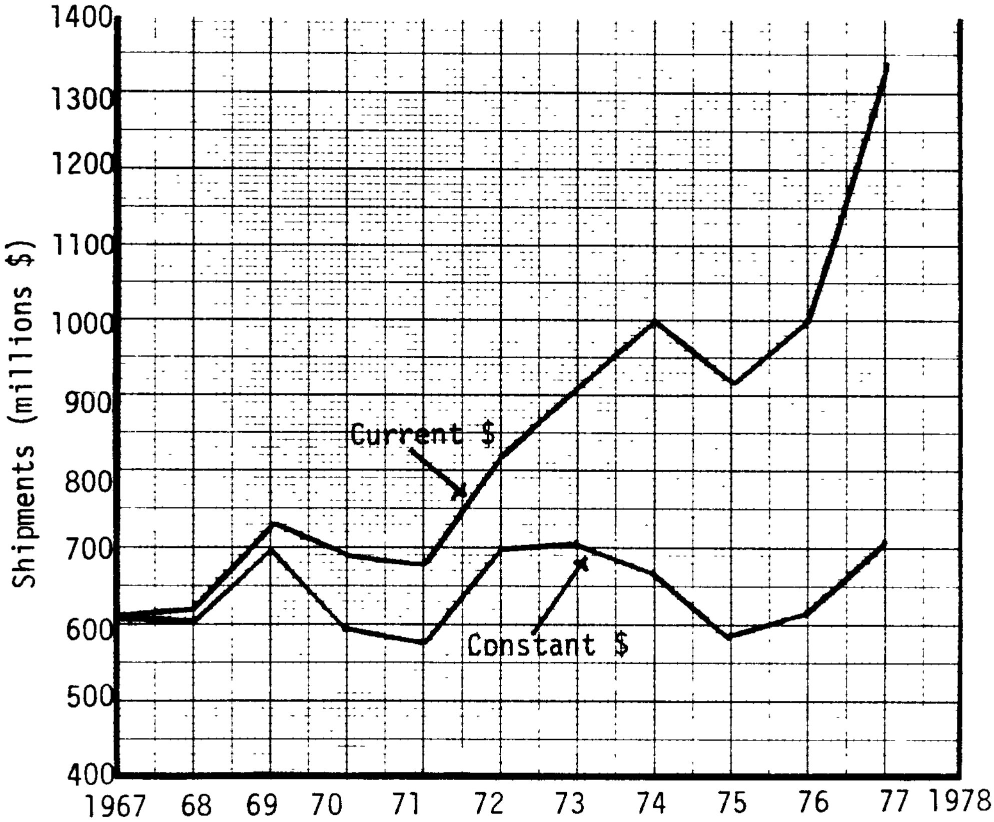

Figure 7-6. Trends in value of shipments for the Metal Office Furniture Industry (SIC 2522) in current and constant dollars.

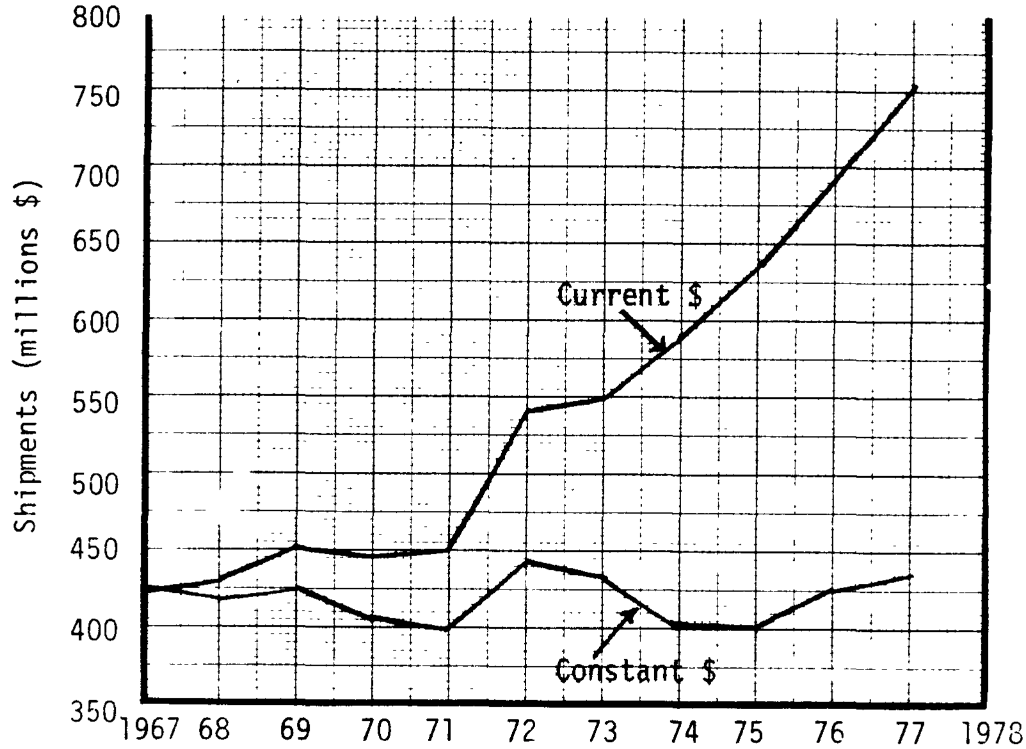

Figure 7-7. Trends in the value of shipments for the Public Building and Related Furniture Industry (SIC 2531) in current and constant dollars.

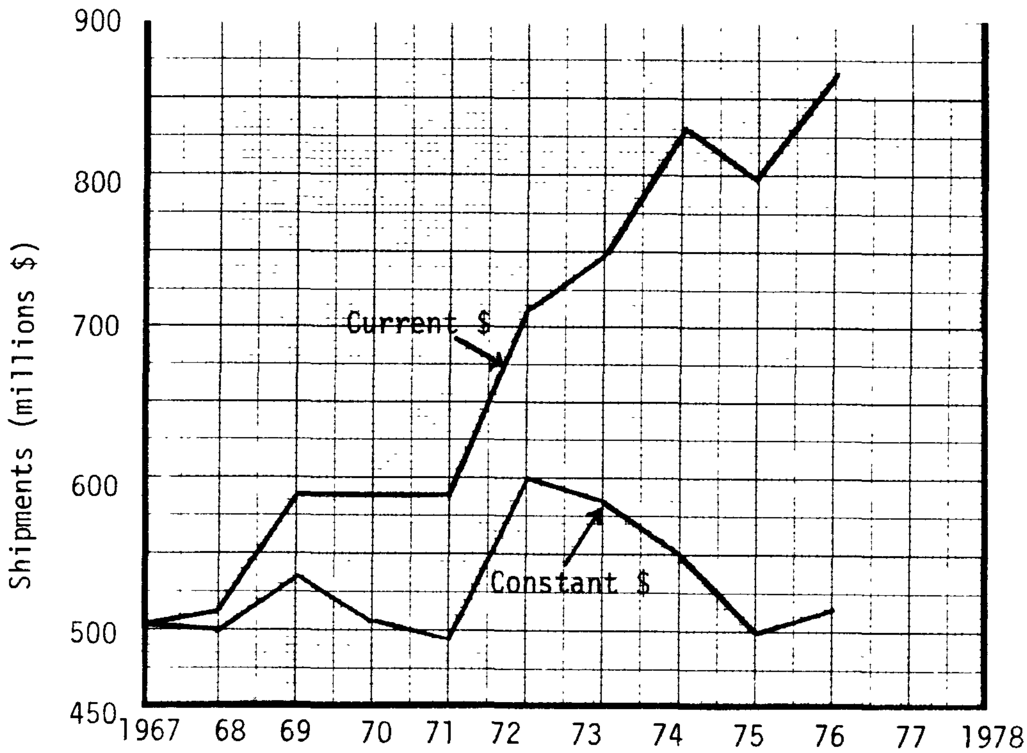

Figure 7-8. Trends in the value of shipments for the Metal Partitions and Fixtures Industry (SIC 2542) in current and constant dollars.

Table 7-13. INDUSTRY SHIPMENTS FOR METAL FURNITURE MANUFACTURING IN CURRENT AND CONSTANT DOLLARS, 1967-1977
(millions of dollars)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Wholesale price index for commercial furniture[a]	100.0	103.8	108.1	114.5	118.1	120.2	129.4	152.4	166.7	173.3	185.9
Industry price index for household furniture[a]	100.0	103.9	108.4	111.7	114.9	117.3	123.0	136.6	146.3	153.6	162.2
Metal household furniture current dollars[b]	537.4	604.3	657.0	650.7	693.1	859.3	970.7	934.0	895.3	991.6	1147.7
Constant dollars (using household furniture index)[c]	537.4	581.6	606.1	582.5	603.2	732.6	789.2	683.8	612.0	645.6	707.6
Metal office furniture current dollars[b]	622.9	654.2	764.5	682.1	682.5	850.7	927.1	1001.8	948.3	1073.1	1375.5
Metal office furniture constant dollars[c]	622.9	630.3	707.2	595.7	577.0	707.7	716.5	657.3	568.9	619.2	739.9
Public building and related current dollars[b]	421.2	432.5	468.5	462.6	471.8	535.3	555.0	592.1	639.2	716.2	764.8
Public building and related constant dollars[c]	421.2	416.5	433.4	404.0	399.5	445.3	428.9	388.5	383.4	413.3	411.4
Metal partitions and fixtures current dollars[b]	512.0	524.1	583.8	579.0	580.1	734.5	771.8	850.0	812.6	875.8	NA
Metal partitions and fixtures constant dollars[c]	512.0	504.9	540.1	505.7	491.2	611.1	596.4	557.7	487.5	505.4	NA

NA = Not available

[a] Statistical abstract of the U.S. Department of Commerce. Washington, D.C.

[b] 1967-1972: Census of Manufactures, 1972.
1973-1976: Annual Survey of Manufactures, (respective years).
1977- : Census of Manufactures, Preliminary Report.

[c] Constant dollars = (current dollars ÷ price index) X 100.

Table 7-14. PERCENT CHANGES FROM PREVIOUS YEAR IN REAL GROSS NATIONAL PRODUCT AND CONSTANT METAL FURNITURE MANUFACTURING INDUSTRY SHIPMENTS

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Percent change in real GNP[a]	4.38	2.57	0.32	2.99	5.74	5.32	- 1.84	- 1.57	6.15	4.90
$ Change in metal household furniture shipments[b]	8.2	4.2	- 3.9	3.6	21.5	7.7	-13.4	-10.5	5.5	9.6
Percent change in metal office furniture shipments[b]	1.1	12.3	-15.8	- 3.0	22.5	1.2	8.2	-13.5	8.8	19.5
Percent change in public building and related furniture shipments[b]	- 1.2	4.2	- 6.9	- 1.1	11.5	- 3.7	- 9.4	- 1.3	7.8	- 0.5
Percent change in metal partitions shipments[b]	- 1.4	7.1	- 6.4	- 2.9	24.5	- 2.4	- 6.5	-12.6	3.7	NA

NA = Not available.

[a]Source: Statistical Abstract of the United States, 1977.

[b]Source: Table 7-13.

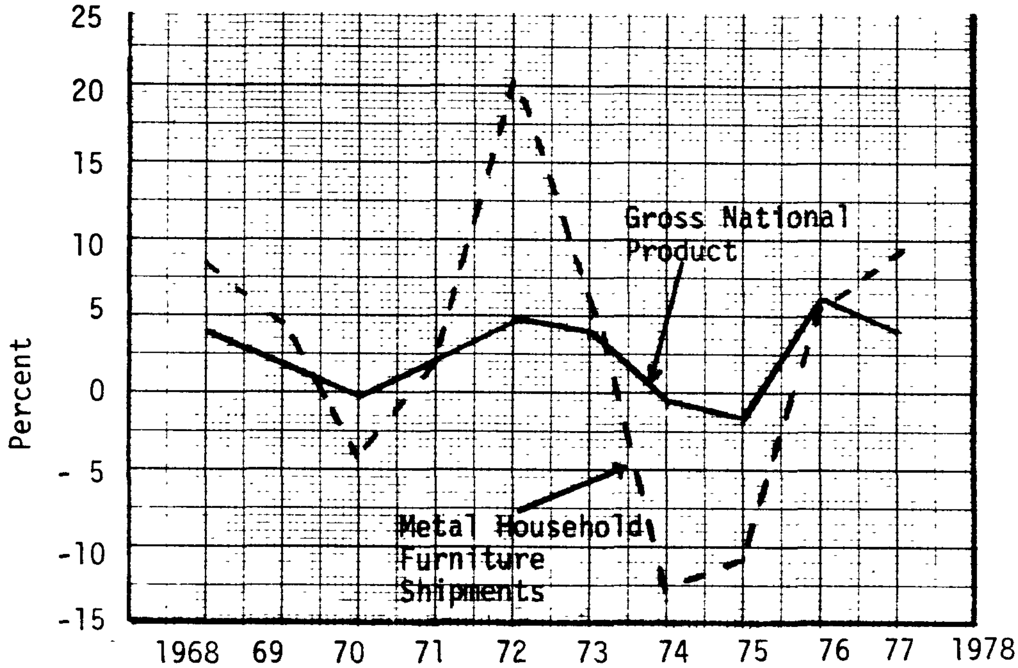

Figure 7-9. Percent changes from previous year in real gross national product and constant Metal Household Furniture Industry shipments (SIC 2514).

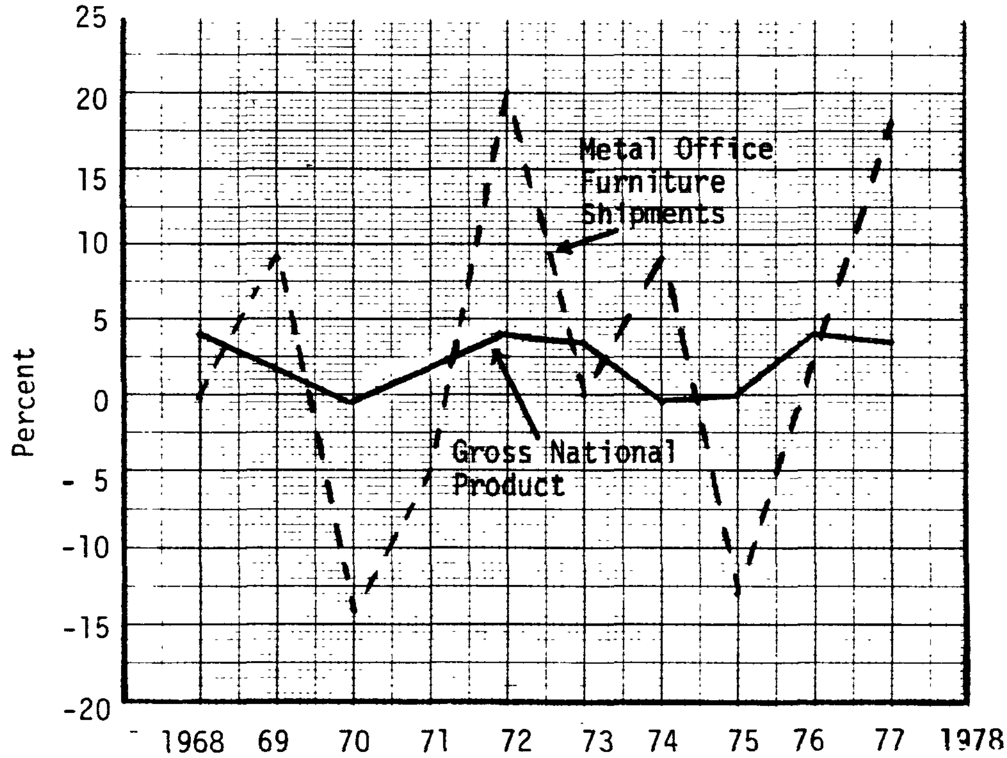

Figure 7-10. Percent changes from previous year in real gross national product and constant Metal Office Furniture Industry shipments (SIC 2522).

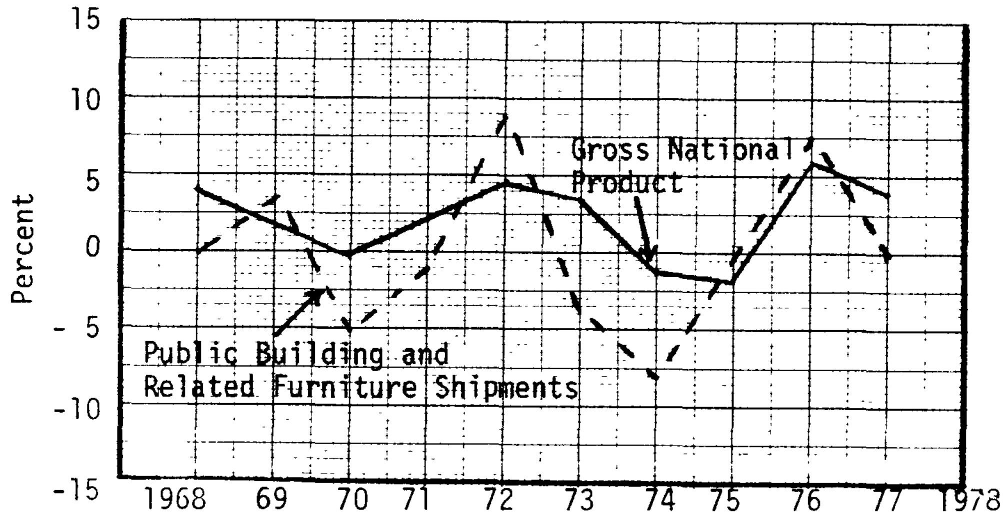

Figure 7-11. Percent changes from previous year in real gross national product and constant Public Building and Related Furniture Industry shipments (SIC 2531).

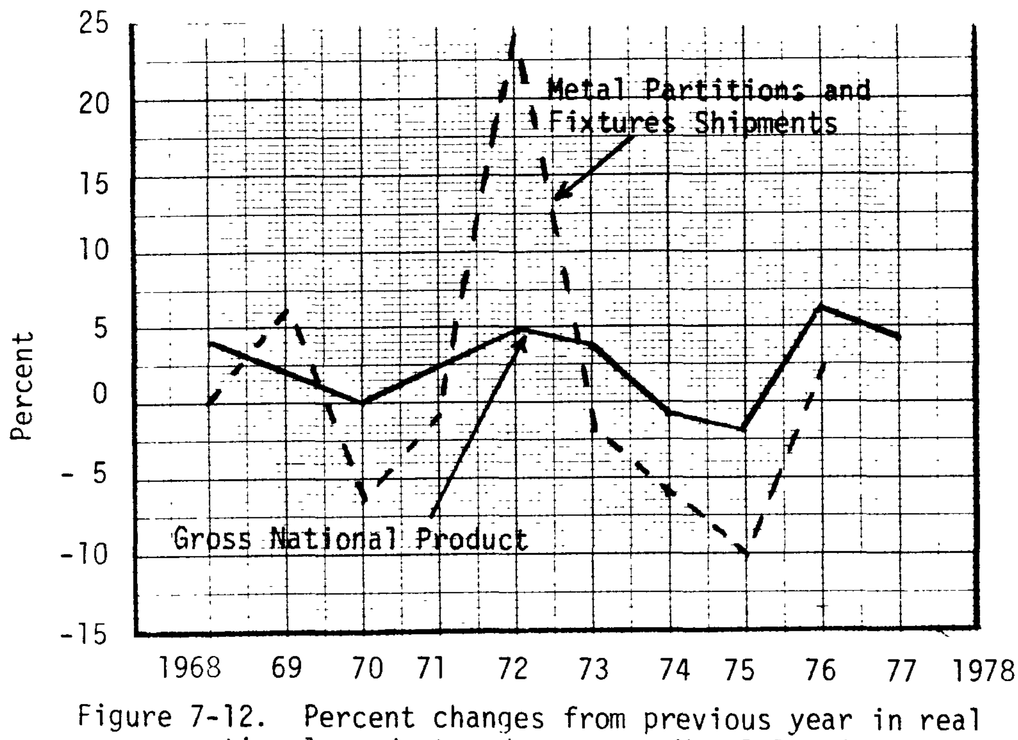

Figure 7-12. Percent changes from previous year in real gross national product and constant Metal Partitions and Fixtures Industry shipments (SIC 2542).

luxury items, may be more susceptible to general economic conditions than kitchen furniture, the other major type of metal household furniture.

Metal office furniture shipments are tied to new office building construction and the financial prospects for businesses considering replacement of old furniture. If necessary, new purchases can be delayed, or old furniture renovated.

As mentioned above, public building and related furniture purchases are related to government spending. For this reason, steady sales seem assured. The only factor that might change this situation is a move toward austerity in government budgets.

Purchases of metal partitions and fixtures may depend on conflicting factors. Partitions may be used to facilitate locating a greater number of workers in a small space as an economy measure. On the other hand, workers can be crowded together without the use of partitions if a business is not concerned with the quality of the work environment.

7.1.2.4 Recent Developments in the Industry. The graphs of industry shipments show a substantial upturn for all four sectors in 1976, even in constant dollars. Preliminary figures for three sectors show that the upturn continued for household and office furniture in 1977. These increases were 9.6 percent and 19.5 percent, respectively, in real terms. Shipments in constant dollars for the public building sector decreased slightly. Figures for 1977 and 1978 are available from the Business and Institutional Furniture Manufacturers Association (BIFMA), whose membership includes firms from each of the sectors except household furniture. These data show a 26.4 percent increase in constant dollar shipments for wood and metal furniture combined during 1977.[2] During the first 11 months of 1978 constant dollar shipments of products other than wood (presumably metal, primarily) were up 10 percent over the first 11 months of 1977.[3]

7.1.3 Industry Operating Statistics

Table 7-15 shows that labor and fuel costs represented roughly a constant percentage of the value of shipments from 1958 to 1975. As shown in Table 7-16, coating material costs decreased between 1967 and 1972 as a percent of cost of materials in all segments except public

Table 7-15. LABOR AND MATERIALS COSTS IN METAL FURNITURE MANUFACTURING RELATIVE TO VALUE OF INDUSTRY SHIPMENTS

Year	Production workers' wages[a]	Cost of materials fuel[a]
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

[a]Percentage of value of shipments.

Source: U. S. Department of Commerce. Census of Manufactures, 1972.

Table 7-16. METAL FURNITURE COATING MATERIALS COSTS VERSUS TOTAL MATERIALS COSTS AND VALUE OF SHIPMENTS, 1972 AND 1967

	Coating Materials Costs			
	1972		1967	
	Percent of cost of materials	Percent of value of industry shipments	Percent of cost of materials	Percent of value of industry shipments
Metal household furniture (SIC 2514)	1.7	0.8	2.1	1.0
Metal office furniture (SIC 2522)	3.2	1.0	4.2	1.3
Public building and related furniture (SIC 2531)	1.9	0.8	1.9	0.8
Metal partitions and fixtures (SIC 2542)	3.6	1.4	4.7	1.8

Source: U. S. Department of Commerce. Census of Manufactures, 1972.

buildings and fixtures, in which they remained constant. The identical phenomenon occurred with respect to coating materials as a percent of value of industry shipments.

The industry as a whole includes many sizes and types of firms so that the financial performance varies widely. Tables 7-17 and 7-18 summarize the historical profitability of the business and institutional/office furniture and metal household furniture sectors, respectively. In general, it can be noted from these figures that for the metal household furniture sector, profitability suffered in 1970 and again in 1974, and recovered in 1976 and 1977. The same phenomenon occurred for the metal office furniture sector in 1974 and 1976/1977. Members of BIFMA, which include wood furniture manufacturers, seem to enjoy consistently higher profitability than the office furniture sector. No real relationship can be assumed, however, because the samples used to derive the figures may not be representative, and may not be comparable to each other. The figures do seem to indicate that when shipments drop, profitability also dips, as would be expected.

7.1.4 Imports and Exports

Exports of metal furniture are in the range of one to two percent of the total value of industry shipments.[4] Imports of metal furniture *per se* are not recorded, but indications are that they have minimal impact on the industry as a whole.

7.1.5 Projections of Affected Facilities

The New Source Performance Standards (NSPS) apply to facilities (defined in this study as individual paint lines) that are constructed in a new plant, as part of an expansion of an existing plant, or as a replacement for retired equipment. In order to assess the impact of the standard on the industry, it is necessary to project how many facilities would be constructed in the absence of a regulation. This section develops a methodology and makes those projections for the four metal furniture SIC categories.

To some extent, new facilities are related to growth in demand for metal furniture. Manufacturers' expectations about future demand are an important factor too, because investment decisions must be made in

Table 7-17. PROFIT BEFORE TAXES OVER TOTAL ASSETS FOR HOUSEHOLD FURNITURE MANUFACTURES
(percent)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
High quartile	NA	NA	NA	NA	NA	NA	15.6	15.5	16.3	19.5	17.8
Median	8.5	13.9	11.3	7.8	8.7	14.1	11.9	5.8	5.5	10.5	13.0
Low quartile	NA	NA	NA	NA	NA	NA	5.8	2.1	0.9	3.4	4.6
No. of firms surveyed	41	30	29	20	25	25	28	34	30	35	35

RMA Annual Statement Studies (respective years). Robert Morris Associates. Philadelphia, Pennsylvania.

NA = Not available.

Table 7-18. PROFIT BEFORE TAXES OVER TOTAL ASSETS FOR METAL OFFICE FURNITURE MANUFACTURERS AND BUSINESS AND INSTITUTIONAL FURNITURE MANUFACTURERS (percent)

	1972	1973	1974	1975	1976	1977
Percent profit before taxes/total assets						
BIFMA members[a]	13.04	19.38	18.64	11.33	11.66	17.51
Metal office furniture[b]						
Upper quartile	NA	12.2	15.5	11.1	9.4	11.7
Median	NA	7.0	6.7	4.8	5.7	6.6
Lower quartile	NA	2.7	2.1	0.3	1.0	0.5
Number of firms surveyed	NA	30	31	38	31	27

[a]BIFMA Annual Statistics. Industry Performance - 1976 and 1977. Business and Institutional Furniture Manufacturers Association. Grand Rapids, Michigan. May 1977 and May 1978.

[b]RMA Annual Statement Studies, 1974-1978. Robert Morris Associates. Philadelphia, Pennsylvania.

NA = Not available.

NOTE: The sample sizes for both sources of data are small and may not be representative of the industry as a whole. BIFMA includes companies that manufacture wood as well as metal furniture.

advance of actual orders. Capacity utilization in the industry also plays a big role in the number of new facilities that could be built. If the industry has been depressed for some time, or if the new facilities were constructed to fill orders that never materialized, the resultant excess capacity can absorb some growth in demand before additional facilities are required.

7.1.5.1 Growth Rates. Most growth projections for the metal furniture industry sectors are made in terms of percent growth in constant dollar shipments. In order to make these projections more reflective of unit shipments, an inflation factor must be subtracted out. Seven percent is generally used to approximate future inflation.

An industry study[5] has projected a six to eight percent per year growth rate for metal office furniture through 1990. The same study estimated growth for the metal household furniture sector at three to four percent per year over the same period. A third designation, "panel systems," was projected at 16.4 percent annual growth. This growth probably will be felt to some degree in the office and public building sectors as well as the partition segment. Several growth estimates for the household sector available from other sources suggest that shipments are likely to increase in the range of six to eight percent per year.[6]

For the purpose of estimating new affected facilities, these estimates have been manipulated somewhat to reflect qualitative concerns. According to an industry spokesman, household furniture growth will probably be lower than that for both office and public sector furniture.[7] In addition to this consideration, some of the growth attributed to the partition sector was shifted to the office and public sector furniture categories. Finally, price increases of approximately seven percent were subtracted out of the growth estimates. The resulting projections are: zero growth through 1980 for the metal household furniture sector followed by one percent growth through 1985; four percent growth through 1985 for the metal office furniture sector; two percent growth through 1985 for the public building furniture sector; seven percent growth through 1985 for the metal partition sector.

7.1.5.2 Projection Methodology. The methodology used to determine the number of affected facilities through 1985 is based in the paint use of a medium size plant in each of the sectors in 1976, which was discussed in Chapter 6. The growth rates developed above were applied to the number of facilities in 1976 to escalate them to 1980 levels. Growth rates were then applied to the 1980 figures to determine an estimate of affected facilities for 1985. The difference between the 1980 and 1985 estimates represent the new affected facilities. To account for replacement of retired lines, one-third of the 1980 number was added to the total new facilities (the one-third arises from the assumption that equipment life is fifteen years; if one-fifteenth of the equipment is retired each year, then between 1980 and 1985, five-fifteenths or one-third will be retired or replaced).

7.1.5.3 Results. The calculation of affected facilities in each sector is shown in Table 7-19. The results show 338 new lines in the household sector, 254 lines in the office sector, 400 lines in the public building sector, and 971 lines in the metal parition sector for a total of 1 963 total new lines between 1980 and 1985. An industry spokesman for business and institutional furniture manufacturers indicates that in general, small firms tend to increase capacity by means of on-site expansions whereas larger firms are more likely to build new plants.[8]

7.2 METAL FURNITURE COST ANALYSIS

This section develops cost estimates for emission control techniques that can be applied to the model plants described in Chapter 5. These costs are based on engineering estimates that were made using vendor quotes, figures from actual installations and previous studies, and adjusting formulas for plant capacity. For the model plant assumptions made, the estimates are considered accurate to within ± 30 percent.

This section also estimates the cost effectiveness of each alternative. Cost effectiveness is estimated by dividing the total annualized control cost by the annual reduction of emissions achieved. In this way, the various control alternatives may be ranked on a relative basis.

7.2.1 New Facilities

7.2.1.1 Model Plants/Control Options Description. As is explained in Chapter 5, the ten model plants were developed to be representative of metal furniture coating facilities that will be built in the future. The models cover three capacity sizes, three coating application methods,

Table 7-19. CALCULATION OF TOTAL AFFECTED FACILITIES, 1980-1985

① Total paint used per yr mil. liters (mil. gal)	② Paint used per yr in medium size plant liters (gallons)	③ No. of lines in medium size plant	④ Lines in 1976 ① ÷ ② x ③	⑤ Growth rate thru 1980	⑥ Lines in 1980 ③ x $(1 + ⑤)^4$	⑦ Growth rate thru 1985	⑧ Lines in 1985 ⑥ x $(1 + ⑦)^5$	⑨ New lines 1980-1985 ⑧ - ⑥	⑩ Lines in 1980 x 5/15 replacement	⑪ Total affected facilities 1980-1985 ⑨ + ⑩
Household SIC 2514										
34.24 (10.12)	87,055 (23,000)	2	880	0	880	1%	925	45	293	338
Office SIC 2522										
20.82 (6.15)	117,335 (31,000)	2	396	4%	463	4%	563	100	154	254
Public SIC 2531										
29.14 (8.61)	77,290 (20,420)	2	844	2%	914	2%	1,009	95	305	400
Partitions SIC 2541										
45.99 (13.59)	102,195 (27,000)	2	1,006	7%	1,319	7%	1,850	531	440	971
										1,963

and two types of furniture - flat and complex. All uncontrolled plants are assumed to use 35 percent solids (as applied) organic solvent-based paint.

The purpose of the three size categories is to cover the size diversity of the industry. The reason for estimating the costs of the three application techniques is to show the difference in annualized capital and operating costs among the various techniques. In addition, there are some control alternatives which are applicable to only one application technique. It is necessary, therefore, to estimate the costs for spray, dip, and flow coating separately.

The effect of metal furniture part complexity on the annualized capital and operating costs of spray coating lines is substantial and is therefore presented in the cost analysis. Complex parts generally require more space on a coating line and as a result, fewer items can be coated per day for each line. More capital equipment is needed, therefore, to paint complex items than is needed to paint flat items. In addition, spray coating transfer efficiency is lower for complex items than for flat items. Paint consumption is, therefore, higher resulting in higher operating costs.

7.2.1.2 Base Case Model Plants. The Clean Air Act Amendments of 1977 require the states to develop revisions to their State Implementation Plans (SIPs). Many of the SIP revisions (including those for states having the majority of the metal furniture manufacturing facilities) submitted for Federal approval include standards of metal furniture coating emissions. Therefore, this analysis estimates the incremental costs incurred above the SIP for several control options. To measure that incremental cost, a "base case" that meets SIP levels was developed and costed for each model plant.

An SIP level of 0.36 kg of organic solvent per liter of coating (3.0 pounds per gallon) at application was assumed because that level has been proposed by several heavily industrialized states (see section 7.3). To meet that level, the base cases are assumed to use 60 percent solids paint (as applied) for spraying and 63/37 waterborne paint for dip and flow coating, rather than the 35 percent solids paint associated with the uncontrolled model plants. The paint substitution necessitates equipment changes that are reflected in the costs developed for each base case.

7.2.1.3 Control Cost Bases. This section summarizes the assumptions used in developing the control costs for the model plants and control options. The technical operating parameters which serve as the basis for the cost estimates (i.e., coating thickness, exhaust flow rates, line configuration, etc.) are presented in Chapter 5 and are not repeated here.

Several types of costs are included in the total cost for a control option. The first is the initial investment required for equipment and installation. From this investment one can estimate such capital related charges as depreciation, interest, property taxes, insurance and general administration. Expressed on an annual basis, these charges are called annualized capital costs. To them are added recurring costs such as utilities, materials, and labor for operation and maintenance of the equipment during its life. The sum of these capital related costs and operating costs is the total annualized cost of the control alternative. Coating line and control equipment costs are estimated on the basis of vendor estimates on the basis of trade association and industry survey data. The remaining assumptions used in calculating control costs are shown in Table 7-20.[9-17]

The annual cost factors used for the model plant cost analysis are presented in Table 7-21.

7.2.1.4 Control Costs and Cost Effectiveness. Tables 7-22 through 7-31 display the control cost estimates for each plant. The use of high solids content paint appears to result in a lower total annualized cost than the uncontrolled model plants, even though the coating material is more expensive on a volume basis than low solids paint.[18-23] This savings results mainly because high solids paint covers a greater area per unit of volume applied.

Cost effectiveness plots for controls applied to the base case model plants are presented in Figures 8-13 and 8-14. As can be seen, the cost effectiveness ratios for the waterborne option is much higher for the spray coating lines than are the other control options. The powder option is

Table 7-20. BASES FOR CONTROL COST ESTIMATES

Control technique	Capital costs		Operating costs	
	Equipment	Building	Electricity	Fuel
Powder	Vendor estimates	Equal to uncontrolled	Uncontrolled - 5 percent	Uncontrolled - 50 percent
Waterborne	Uncontrolled + 30 percent	Uncontrolled + 10 percent	Uncontrolled + 15 percent	Uncontrolled - 33 percent
60% and 70% High solids	Equal to uncontrolled	Equal to uncontrolled	Uncontrolled - 5 percent	Uncontrolled - 33 percent
Thermal incinerator	Vendor estimates	Equal to uncontrolled	Base case + 5 percent	Vendor estimates
Fluidized bed	Vendor estimates	Equal to base case	Uncontrolled + 30 percent	Uncontrolled - 50 percent
Electrodeposition	Vendor estimates	Base case + 10 percent	5 X Uncontrolled	Equal to base case
Base case (SIP level)	Vendor estimates	Equal to Uncontrolled	Uncontrolled - 5 percent	Uncontrolled - 33 percent
Uncontrolled	Vendor estimates	Survey information	Survey information	Survey information

Table 7-21. MODEL PLANT ANNUAL CONTROL COST FACTORS[a]

Operating schedule	2 000 hours/year
Electricity	$0.08/10^7 joule ($0.03/KWH)
Natural Gas	$1.89/10^9 joule ($2.00/10^6 Btu)
Paint:	
Conventional solvent-borne (35% solids)	$1.85/liter ($7.00/gallon)
High solids (60 to 70% solids)	$2.80/liter ($10.75/gallon)
63/37 Waterborne	$1.98/liter ($7.50/gallon)
80/20 Waterborne	$2.10/liter ($8.00/gallon)
Powder[b]	$3.53/kg ($1.60/pound)
Labor	$6.70/manhour
Capital recovery factor assumptions (Equipment life and interest rate):	
Coating line equipment	15 years at 10% interest
Building	25 years at 10% interest
Add-on control equipment	10 years at 10% interest
Taxes, insurance and G&A	4% of total installed cost
Maintenance labor	10% of direct labor
Maintenance material	1.5% of equipment cost
Overhead	80% of direct labor cost

[a]See Appendix E to this BID for additional cost and economic analyses.

[b]Powder costs presented in Tables 7-22 through 7-50 are based on a film thickness of 6.35×10^{-3} cm (2.5 mil). However, based on the data presented in Appendix E powder costs are reduced significantly at a film thickness of 3.81×10^{-3} cm (1.5 mil).

Table 7-22. CONTROL COSTS FOR MODEL PLANT A - LARGE SPRAY COATING FACILITY FOR FLAT METAL FURNITURE SURFACES

	Control options[a]						
	A-1	A-2	A-3	A-4	A-5	A-6	A-U
INSTALLED CAPITAL COSTS ($ 1000)							
Line(s)	1810	2041	1570	1570	1570	1570	1570
Add-on control equipment	----	----	----	130	----	----	----
Building	2063	2270	2063	2063	2063	2063	2063
Total capital costs	3873	4311	3633	3763	3633	3633	3633
Annualized capital costs	444	495	413	433	413	413	413
Insurance, taxes and G & A	155	172	145	151	145	145	145
Total annualized capital costs	599	667	558	584	558	558	558
OPERATING COSTS ($ 1000/yr)							
Direct labor	600	600	600	600	600	600	600
Maintenance labor	60	60	60	60	60	60	60
Overhead	480	480	480	480	480	480	480
Maintenance Materials	27	31	24	26	24	24	24
Paint	1295[b]	760	507	593	546	593	632
Electricity	69	84	69	69	69	69	73
Natural gas	34	45	45	49	45	45	67
Total operating costs	2565	2060	1785	1881	1824	1871	1936
TOTAL ANNUALIZED COSTS ($ 1000/yr)	3164	2727	2343	2465	2382	2429	2494
Cost (credit) per kg of emission reduction versus uncontrolled plant ($/kg)	3.4	1.5	(1.0)	(0.2)	(0.8)	(0.5)	N/A
Cost (credit) per kg of emission reduction versus base case ($/kg)	10.3	8.0	(3.2)	1.6	(3.3)	N/A	N/A
Cost per area covered ($/1000 m^2)	791	682	586	616	596	607	624

[a]A-1 Powder
A-2 Waterborne
A-3 70 percent high solids
A-4 Incinerator on base case line(s)
A-5 65 percent high solids
A-6 Base case--typical SIP
A-U Uncontrolled plant
N/A Not applicable

[b]This cost for powder is based on a film thickness of 6.35×10^{-3} cm (2.5 mil). However, at a film thickness of 3.81×10^{-3} cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-23. CONTROL COSTS FOR MODEL PLANT B - LARGE SPRAY COATING FACILITY FOR COMPLEX METAL FURNITURE SURFACES

	Control options[a]						
	B-1	B-2	B-3	B-4	B-5	B-6	B-U
INSTALLED CAPITAL COSTS ($ 1000)							
Lines(s)	3197	3614	2780	2780	2780	2780	2780
Add-on control equipment	----	----	----	130	----	----	----
Building	2096	2306	2096	2096	2096	2096	2096
Total capital costs	5293	5920	4876	5006	4876	4876	4876
Annualized capital costs	630	706	575	595	575	575	575
Insurance, taxes and G&A	212	237	195	200	195	195	195
Total annualized captial costs	842	943	770	795	770	770	770
OPERATING COSTS ($ 1000/yr)							
Direct labor	1000	1000	1000	1000	1000	1000	1000
Maintenance labor	100	100	100	100	100	100	100
Overhead	800	800	800	800	800	800	800
Maintenance materials	48	54	42	44	42	42	42
Paint	1295[b]	1014	675	790	725	790	826
Electricity	116	140	116	116	116	116	122
Natural gas	56	74	74	78	74	74	116
Total operating costs	3415	3182	2807	2928	2857	2922	3001
TOTAL ANNUALIZED COSTS ($1000/yr)	4257	4125	3577	3723	3627	3692	3771
Cost (credit) per kg of emission reduction versus uncontrolled plant ($/kg)	1.9	1.7	(1.0)	(0.3)	(0.8)	(0.5)	N/A
Cost (credit) per kg of emission reduction versus base case ($/kg)	5.9	8.9	(3.2)	1.1	(3.4)	N/A	N/A
Cost per area covered ($/1000 m^2)	1064	1031	894	931	907	923	943

[a]B-1 Powder
B-2 Waterborne
B-3 70 percent high solids
B-4 Incinerator on base case line(s)
B-5 65 percent high solids
B-6 Base case--typical SIP
B-U Uncontrolled plant
N/A Not applicable

[b]This cost for powder is based on a film thickness of 6.35 x 10^{-3}cm (2.5 mil). However, at a film thickness of 3.81 x 10^{-3}cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-24. CONTROL COSTS FOR MODEL PLANT C - MEDIUM SIZE SPRAY COATING FACILITY FOR FLAT METAL FURNITURE SURFACES

	Control options[a]						
	C-1	C-2	C-3	C-4	C-5	C-6	C-U
INSTALLED CAPITAL COSTS ($ 1000)							
Line(s)	626	706	543	543	543	543	543
Add-on control equipment	----	----	----	110	----	----	----
Building	402	442	402	402	402	402	402
Total capital costs	1028	1148	945	1055	945	945	945
Annualized capital costs	127	137	112	129	112	112	112
Insurance, taxes and G&A	41	46	38	42	38	38	38
Total annualized capital costs	164	183	150	171	150	150	150
OPERATING COSTS ($ 1000/yr)							
Direct labor	150	150	150	150	150	150	150
Maintenance labor	15	15	15	15	15	15	15
Overhead	120	120	120	120	120	120	120
Maintenance materials	9	10	8	10	8	8	8
Paint	253[b]	139	99	116	106	116	123
Electricity	9	10	9	9	9	9	9
Natural gas	8	11	11	12	11	11	16
Total operating costs	564	455	412	432	419	429	441
TOTAL ANNUALIZED COSTS ($ 1000/yr)	728	638	562	603	569	579	591
Cost (credit) per kg of emission reduction versus uncontrolled plant ($/kg)	3.7	1.5	(1.0)	0.4	(0.9)	(0.6)	N/A
Cost (credit) per kg of emission reduction versus base case ($/kg)	10.8	8.4	(3.3)	5.9	(3.7)	N/A	N/A
Cost per area covered ($/1000 m^2)	933	818	721	779	729	742	758

[a]C-1 Powder
C-2 Waterborne
C-3 70 percent high solids
C-4 Incinerator on base case line(s)
C-5 65 percent high solids
C-6 Base case--typical SIP
C-U Uncontrolled plant
N/A Not applicable

[b]This cost for powder is based on a film thickness of 6.35 x 10^{-3}cm (2.5 mil). However, at a film thickness of 3.81 x 10^{-3}cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-25. CONTROL COSTS FOR MODEL PLANT D - MEDIUM SIZE SPRAY COATING FACILITY FOR COMPLEX METAL FURNITURE SURFACES

	Control options[a]						
	D-1	D-2	D-3	D-4	D-5	D-6	D-U
INSTALLED CAPITAL COSTS ($ 1000)							
Line(s)	644	728	560	560	560	560	560
Add-on control equipment	----	----	----	110	----	----	----
Building	402	442	402	402	402	402	402
Total capital costs	1046	1170	962	1072	962	962	962
Annualized capital costs	125	140	114	131	114	114	114
Insurance, taxes and G&A	42	47	38	43	38	38	38
Total annualized capital costs	167	187	152	174	152	152	152
OPERATING COSTS ($ 1000/yr)							
Direct labor	150	150	150	150	150	150	150
Maintenance labor	15	15	15	15	15	15	15
Overhead	120	120	120	120	120	120	120
Maintenance materials	10	11	8	10	8	8	8
Paint	253[b]	198	132	154	142	154	161
Electricity	9	10	9	9	9	9	9
Natural gas	8	11	11	12	11	11	16
Total operating costs	565	515	445	470	455	467	479
TOTAL ANNUALIZED COSTS ($ 1000/yr)	732	702	597	644	607	619	631
Cost (credit) per kg of emission reduction versus uncontrolled plant ($/kg)	2.1	1.8	(0.9)	0.4	(0.7)	(0.4)	N/A
Cost (credit) per kg of emission reduction versus base case ($/kg)	6.0	9.0	(3.1)	4.6	(3.2)	N/A	N/A
Cost per area covered ($/1000 m^2)	938	900	765	832	778	794	809

[a] D-1 Powder
D-2 Waterborne
D-3 70 percent high solids
D-4 Incinerator on base case line(s)
D-5 65 percent high solids
D-6 Base case--typical SIP
D-U Uncontrolled plant
N/A Not applicable

[b] This cost for powder is based on a film thickness of 6.35×10^{-3} cm (2.5 mil). However, at a film thickness of 3.81×10^{-3} cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-26. CONTROL COSTS FOR MODEL PLANT E - SMALL SPRAY COATING FACILITY FOR FLAT METAL FURNITURE SURFACES

	Control options[a]					
	E-1	E-2	E-3	E-4	E-5	E-U
INSTALLED CAPITAL COSTS ($ 1000)						
Line(s)	225	225	196	196	196	196
Add-on control equipment	---	---	---	---	---	---
Building	23	25	23	23	23	23
Total capital costs	248	250	219	219	219	219
Annualized capital costs	32	32	28	28	28	28
Insurance, taxes and G&A	10	11	9	9	9	9
Total annualized capital costs	42	43	37	37	37	37
OPERATING COSTS ($ 1000/yr)						
Direct labor	40	40	40	40	40	40
Maintenance labor	4	4	4	4	4	4
Overhead	32	32	32	32	32	32
Maintenance materials	3	4	3	3	3	3
Paint	14[b]	7	6	6	6	7
Electricity	4	5	4	4	4	4
Natural gas	4	5	5	5	5	7
Total operating costs	101	97	94	94	94	97
TOTAL ANNUALIZED COSTS ($ 1000/yr)	143	140	131	131	131	134
Cost (credit) per kg of emission reduction versus uncontrolled plant ($/kg)	4.2	3.4	(1.8)	(2.0)	(2.2)	N/A
Cost (credit) per kg of emission reduction versus base case ($/kg)	15.1	22.2	0.0	0.0	N/A	N/A
Cost per area covered ($/1000 m^2)	3178	3111	2911	2911	2911	2977

[a] E-1 Powder
E-2 Waterborne
E-3 70 percent high solids
E-4 65 percent high solids
E-5 Base case--typical SIP
E-U Uncontrolled plant
N/A Not applicable

[b] This cost for powder is based on a film thickness of 6.35×10^{-3}cm (2.5 mil). However, at a film thickness of 3.81×10^{-3}cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-27. CONTROL COSTS FOR MODEL PLANT F - SMALL SPRAY COATING FACILITY FOR COMPLEX METAL FURNITURE SURFACES

	Control options[a]					
	F-1	F-2	F-3	F-4	F-5	F-U
INSTALLED CAPITAL COSTS ($ 1000)						
Line(s)	248	281	216	216	216	216
Add-on control equipment	---	---	---	---	---	---
Building	23	25	23	23	23	23
Total capital costs	271	306	239	239	239	239
Annualized capital costs	35	39	31	31	31	31
Insurance, taxes and G&A	11	12	10	10	10	10
Total annualized capital costs	46	51	41	41	41	41
OPERATING COSTS ($ 1000/yr)						
Direct labor	40	40	40	40	40	40
Maintenance labor	4	4	4	4	4	4
Overhead	32	32	32	32	32	32
Maintenance materials	4	4	3	3	3	3
Paint	14[b]	13	9	9	9	9
Electricity	4	5	4	4	4	4
Natural gas	4	5	5	5	5	7
Total operating costs	102	103	97	97	97	99
TOTAL ANNUALIZED COSTS ($ 1000/yr)	148	154	138	138	138	140
Cost (credit) per kg of emission reduction versus uncontrolled plant ($/kg)	2.9	6.3	(1.0)	(1.1)	(1.2)	N/A
Cost (credit) per kg of emission reduction versus base case ($/kg)	9.3	22.1	0.0	0.0	N/A	N/A
Cost per area covered ($/1000 m^2)	3289	3422	3067	3067	3067	3111

[a]F-1 Powder
F-2 Waterborne
F-3 70 percent high solids
F-4 65 percent high solids
F-5 Base case--typical SIP
F-U Uncontrolled plant
N/A Not applicable

[b]This cost for powder is based on a film thickness of 6.35×10^{-3} cm (2.5 mil). However, at a film thickness of 3.81×10^{-3} cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-28. CONTROL COSTS FOR MODEL PLANT G - LARGE DIP COATING FACILITY FOR METAL FURNITURE

	Control options					
	G-1	G-2	G-3	G-4	G-5	G-U
INSTALLED CAPITAL COSTS ($ 1000)						
Line(s)	2600	5000	2710	2710	2710	2085
Add-on control equipment	----	----	130	----	----	----
Building	1258	1384	1258	1258	1258	1140
Total capital costs	3858	6384	4078	3968	3968	3225
Annualized capital costs	468	796	502	482	482	388
Insurance, taxes and G&A	154	255	166	159	159	129
Total annualized capital costs	622	1051	665	641	641	517
OPERATING COSTS ($ 1000/yr)						
Direct labor	800	800	800	800	800	800
Maintenance labor	80	80	80	80	80	80
Overhead	640	640	640	640	640	640
Maintenance materials	47	75	42	41	41	31
Paint	1335	498	639	676	639	615
Electricity	10	40	8	9	8	8
Natural gas	53	71	76	71	71	106
Total operating costs	2965	2204	2285	2317	2279	2280
TOTAL ANNUALIZED COSTS ($ 1000/yr)	3587	3255	2950	2958	2920	2797
Cost (credit) per kg of emission reduction versus uncontrolled plant ($/kg)	4.5	2.6	1.0	1.1	1.1	N/A
Cost (credit) per kg of emission reduction versus base case ($/kg)	10.0	5.1	0.7	0.9	N/A	N/A
Cost per area covered ($/1000 m^2)	897	814	738	739	730	699

G-1 Fluidized bed
G-2 Electrodeposition
G-3 Incinerator on base case line(s)
G-4 Waterborne
G-5 Base case--typical SIP
G-U Uncontrolled plant
N/A Not applicable

Table 7-29. CONTROL COSTS FOR MODEL PLANT H - MEDIUM SIZE DIP COATING FACILITY FOR METAL FURNITURE

	Control options					
	H-1	H-2	H-3	H-4	H-5	H-U
INSTALLED CAPITAL COSTS ($ 1000)						
Line(s)	520	1100	540	540	540	415
Add-on control equipment	----	----	110	----	----	----
Building	240	264	240	240	240	218
Total capital costs	760	1364	890	780	780	633
Annualized capital costs	92	171	112	95	95	79
Insurance, taxes and G&A	30	55	35	31	31	25
Total annualized capital costs	122	226	147	126	126	104
OPERATING COSTS ($ 1000/yr)						
Direct labor	150	150	150	150	150	150
Maintenance labor	15	15	15	15	15	15
Overhead	120	120	120	120	120	120
Maintenance	8	17	9	8	8	6
Paint	158	97	124	132	124	116
Electricity	1	5	1	1	1	1
Natural gas	8	11	13	11	11	16
Total operating costs	460	415	432	437	429	424
TOTAL ANNUALIZED COSTS ($ 1000/yr)	582	641	579	563	555	528
Cost (credit) per kg of emission reduction versus uncontrolled plant ($/kg)	1.6	3.3	1.7	1.2	1.3	N/A
Cost (credit) per kg of emission reduction versus base case ($/kg)	2.1	6.8	2.9	1.0	N/A	N/A
Cost per area covered ($/1000 m^2)	746	822	742	722	712	677

H-1 Fluidized bed
H-2 Electrodeposition
H-3 Incinerator on base case line(s)
H-4 Waterborne
H-5 Base case--typical SIP
H-U Uncontrolled plant
N/A Not applicable

Table 7-30. CONTROL COSTS FOR MODEL PLANT I - SMALL DIP COATING FACILITY FOR METAL FURNITURE

	Control options				
	I-1	I-2	I-3	I-4	I-U
INSTALLED CAPITAL COSTS ($ 1000)					
Line(s)	225	420	250	250	192
Add-on control equipment	---	---	---	---	---
Building	14	15	14	14	13
Total capital costs	239	435	264	264	205
Annualized capital costs	31	57	34	34	27
Insurance, taxes and G&A	10	17	11	11	8
Total annualized capital costs	41	74	45	45	35
OPERATING COSTS ($ 1000/yr)					
Direct labor	40	40	40	40	40
Maintenance labor	4	4	4	4	4
Overhead	32	32	32	32	32
Maintenance materials	3	6	4	4	3
Paint	32	6	8	8	7
Electricity	0	4	0	0	0
Natural gas	4	5	5	5	7
Total operating costs	115	97	93	93	93
TOTAL ANNUALIZED COSTS ($ 1000/yr)	156	171	138	138	128
Cost (credit) per kg of emission reduction versus uncontrolled plant ($/kg)	14.1	21.8	5.9	8.1	N/A
Cost (credit) per kg of emission reduction versus base case ($/kg)	24.0	45.0	0.0	N/A	N/A
Cost per area covered ($/1000 m^2)	3467	3800	3067	3067	2844

L-1 Fluidized bed
I-2 Electrodeposition
I-3 Waterborne
I-4 Base case--typical SIP
I-U Uncontrolled plant
N/A Not applicable

Table 7-31. CONTROL COSTS FOR MODEL PLANT J - SMALL FLOW COATING FACILITY FOR METAL FURNITURE

	Control options		
	J-1	J-2	J-U
INSTALLED CAPITAL COSTS ($ 1000)			
Line(s)	250	250	192
Add-on control equipment	---	---	---
Building	14	14	13
Total capital costs	264	264	205
Annualized capital costs	34	34	27
Insurance, taxes and G&A	11	11	8
Total annualized capital costs	45	45	35
OPERATING COSTS ($ 1000/yr)			
Direct labor	40	40	40
Maintenance labor	4	4	4
Overhead	32	32	32
Maintenance materials	4	4	3
Paint	8	8	7
Electricity	0	0	0
Natural gas	5	5	7
Total operating costs	93	93	93
TOTAL ANNUALIZED COSTS ($ 1000/yr)	138	138	128
Cost (credit) per kg of emission reduction versus uncontrolled plant ($/kg)	5.9	8.1	N/A
Cost (credit) per kg of emission reduction versus base case ($/kg)	0.0	N/A	N/A
Cost per area covered ($/1000 m^2)	3067	3067	2844

J-1 Waterborne
J-2 Base case--typical SIP
J-U Uncontrolled plant
N/A Not applicable

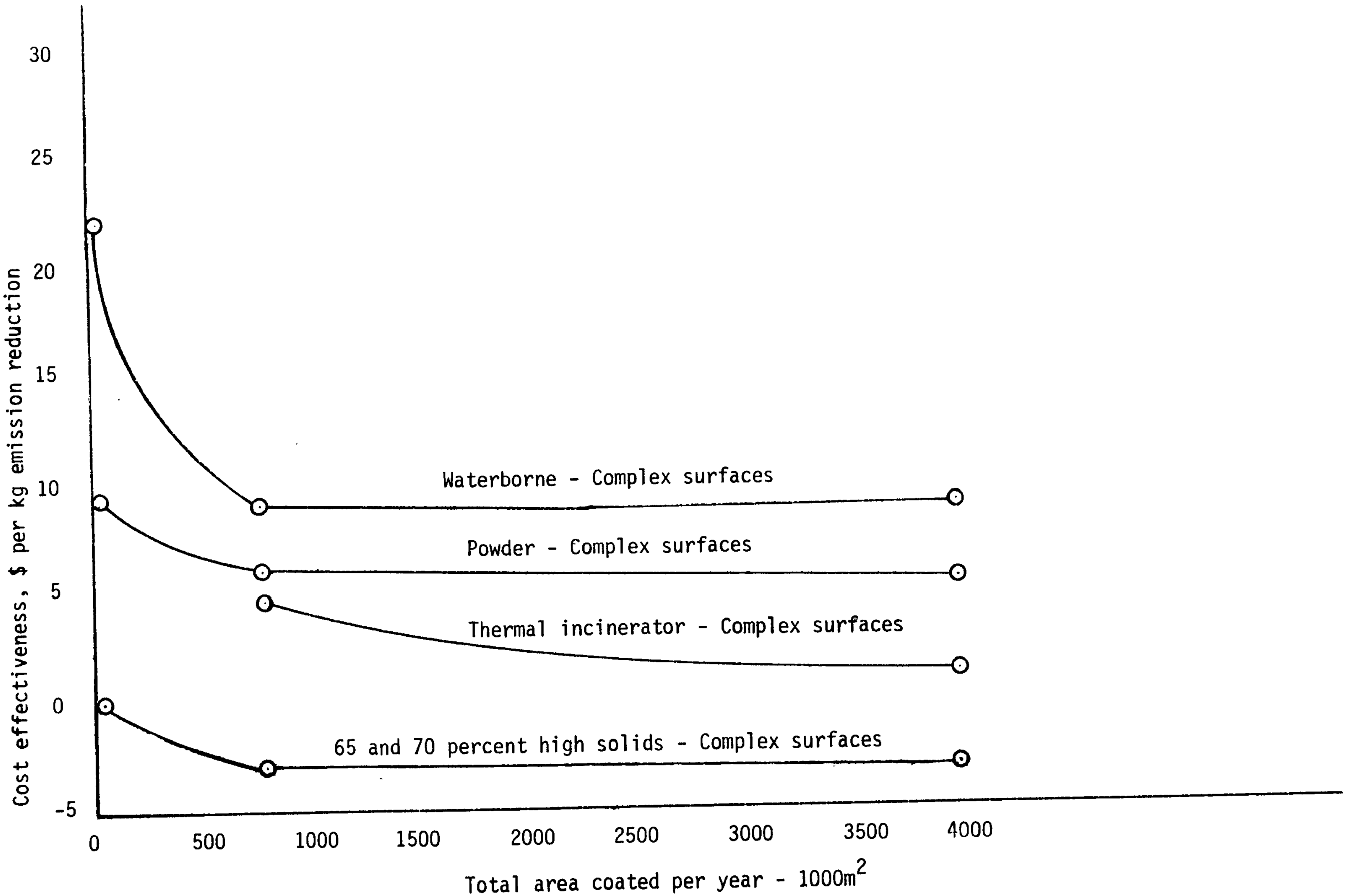

Figure 7-13. Spray coating cost effectiveness vs. base case.

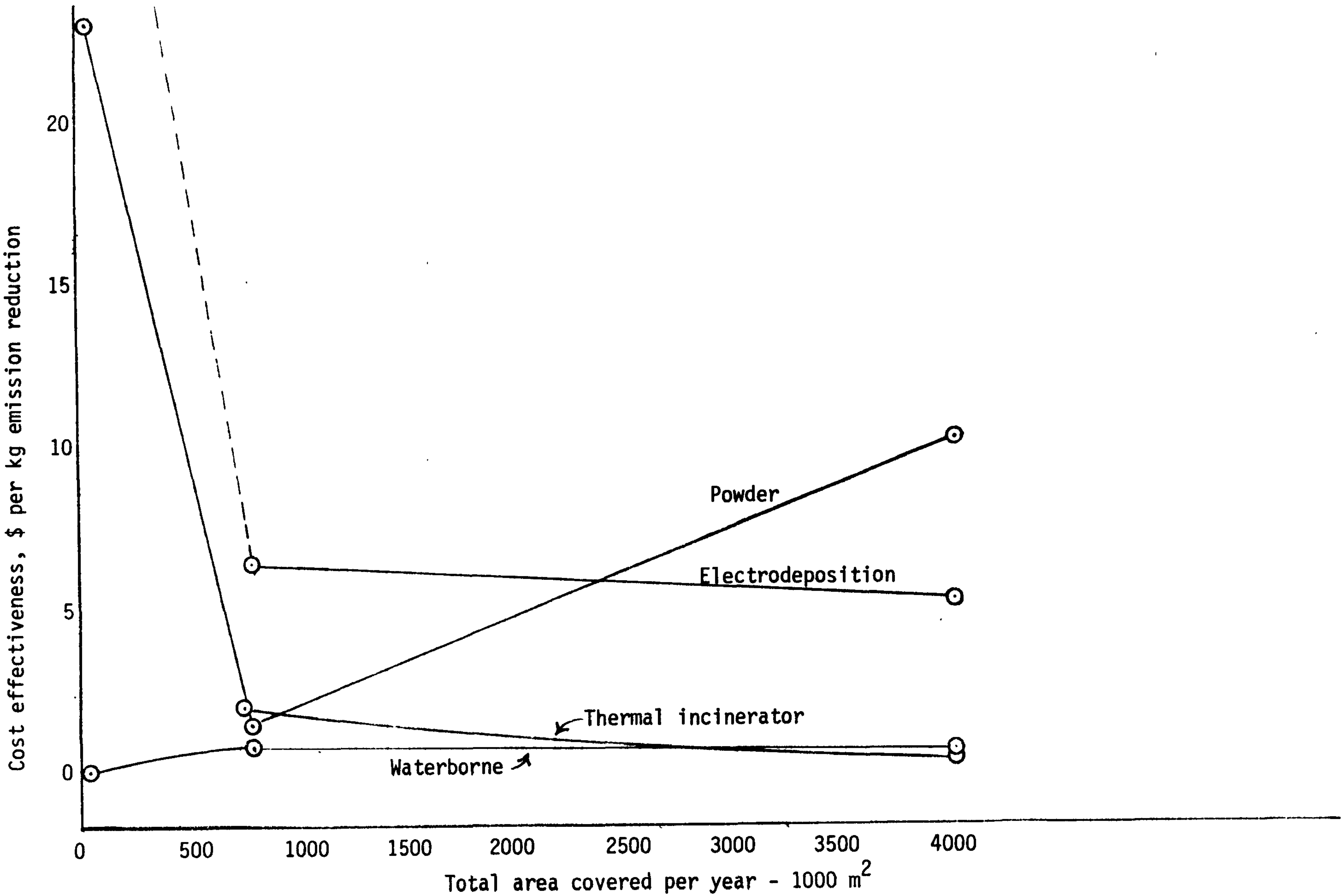

Figure 7-14. Dip and flow coating cost effectiveness vs. base case.

the second highest for spray coating lines but costs for the control option can change significantly depending upon coating thickness and complexity of the part coated. The material costs for powder are based upon 6.35 x 10^{-3} cm (2.5 mil) film thickness. As a result of this film thickness, the powder costs are high. However, based on a film thickness of 3.81 x 10^{-3} cm (1.5 mil) powder can produce a savings for the metal furniture manufacturer. This information is presented in Appendix E. For dip coating lines the control options of electrodeposition and powder produce the highest cost effectiveness ratios.

In almost all cases, the curves slope downward with increasing plant size. This is particularly true for electrodeposition and incineration. The reason for this phenomenon is that these options are rather capital intensive. As plant size increases, the impact of the capital costs decreases thereby decreasing the cost effectiveness ratio.

7.2.2 Modified or Reconstruction Facilities

As defined in Chapter 4 of this report, metal furniture coating facilities may undergo "modification" or "reconstruction" thereby bringing the facility under the purview of the NSPS. As a result of such actions, the facility would incur certain costs or savings from the conversion to the mode of operation necessary to achieve the standard. Presented in Tables 7-32 through 7-41 are the costs for each model plant associated with a switch from the base (CTG) level to each of the control options presented in Chapter 5. The costs involved in a switch from the uncontrolled state to each of the control options are presented in Tables 7-42 through 7-51.

All control cost factors presented in Table 7-21 are valid for the conversion costs presented in this section. Capital costs are estimated on the basis of the amount of coating line equipment that would have to be replaced to comply with each control option. For spray coating lines there are three options which would required a capital investment to switch from the base case. Powder coating would require a complete change of the spray coating equipment and spray booths. Waterborne coatings would require modifications of the spray equipment (including insulation and isolation), extension of the flash-off area, and an increase in the amount of climate control equipment in the plant. The incineration option would require the

Table 7-32. PLANT A - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF SIP LEVEL FACILITIES

	Control options[a] A-1	A-2	A-3	A-4	A-5
INSTALLED CAPITAL COSTS ($ 1000)					
Line(s)	750	500	0	0	0
Add-on control equipment	0	0	0	130	0
Building	0	207	0	0	0
Total capital costs	750	707	0	130	0
Annualized capital costs	99	87	0	20	0
Insurance, taxes and G&A	30	28	0	5	0
Total annualized capital costs	129	115	0	25	0
OPERATING COSTS (SAVINGS) ($ 1000)					
Direct labor	0	0	0	0	0
Maintenance labor	0	0	0	0	0
Overhead	0	0	0	0	0
Maintenance materials	11	8	0	2	0
Paint	702[b]	167	(86)	0	(47)
Electricity	0	15	0	0	0
Natural gas	(22)	0	0	5	0
Total operating costs	691	190	(86)	7	(47)
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	820	305	(86)	30	(47)
Cost (savings) per area covered ($/1000 m^2)	205	76	(22)	8	(12)

[a]A-1 Powder
A-2 Waterborne
A-3 70 percent high solids
A-4 Incinerator on base line(s)
A-5 65 percent high solids

[b]This cost for powder is based on a film thickness of 6.35 x 10^{-3}cm (2.5 mil). However, at a film thickness of 3.81 x 10^{-3}cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-33. PLANT B - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF SIP LEVEL FACILITIES

	Control options[a]				
	B-1	B-2	B-3	B-4	B-5
INSTALLED CAPITAL COSTS ($ 1000)					
Line(s)	1325	900	0	0	0
Add-on control equipment	0	0	0	130	0
Building	0	210	0	0	0
Total capital costs	1325	1110	0	130	0
Annualized capital costs	174	139	0	20	0
Insurance, taxes and G&A	53	44	0	5	0
Total annualized capital costs	227	183	0	25	0
OPERATING COSTS (SAVINGS) ($ 1000)					
Direct labor	0	0	0	0	0
Maintenance labor	0	0	0	0	0
Overhead	0	0	0	0	0
Maintenance materials	20	14	0	2	0
Paint	505[b]	224	(115)	0	(65)
Electricity	0	26	0	0	0
Natural gas	(37)	0	0	6	0
Total operating costs	488	264	(115)	8	(65)
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	715	447	(115)	33	(65)
Cost (savings) per area covered ($/1000 m^2)	179	112	(29)	8	(16)

[a]B-1 Powder
B-2 Waterborne
B-3 70 percent high solids
B-4 Incinerator on base case line(s)
B-5 65 percent high solids

[b]This cost for powder is based on a film thickness of 6.35×10^{-3} cm (2.5 mil). However, at a film thickness of 3.81×10^{-3} cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-34. PLANT C - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF SIP LEVEL FACILITIES

	Control options[a]				
	C-1	C-2	C-3	C-4	C-5
INSTALLED CAPITAL COSTS ($ 1000)					
Line(s)	250	175	0	0	0
Add-on control equipment	0	0	0	110	0
Building	0	40	0	0	0
Total capital costs	250	215	0	110	0
Annualized capital costs	39	27	0	17	0
Insurance, taxes and G&A	10	9	0	4	0
Total annualized capital costs	49	36	0	21	0
OPERATING COSTS (SAVINGS) ($ 1000)					
Direct labor	0	0	0	0	0
Maintenance labor	0	0	0	0	0
Overhead	0	0	0	0	0
Maintenance materials	4	3	0	2	0
Paint	137[b]	23	(17)	0	(10)
Electricity	0	2	0	0	0
Natural gas	(5)	0	0	1	0
Total operating costs	136	28	(17)	3	(10)
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	185	64	(17)	24	(10)
Cost (savings) per area covered ($/1000 m^2)	237	82	(22)	31	(13)

[a]C-1 Powder
C-2 Waterborne
C-3 70 percent high solids
C-4 Incinerator on base case line(s)
C-5 65 percent high solids

[b]This cost for powder is based on a film thickness of 6.35×10^{-3}cm (2.5 mil). However, at a film thickness of 3.81×10^{-3}cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-35. PLANT D - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF SIP LEVEL FACILITIES

	Control options[a]				
	D-1	D-2	D-3	D-4	D-5
INSTALLED CAPITAL COSTS ($ 1000)					
Line(s)	260	182	0	0	0
Add-on control equipment	0	0	0	110	0
Building	0	40	0	0	0
Total capital costs	260	222	0	110	0
Annualized capital costs	34	28	0	17	0
Insurance, taxes and G&A	10	9	0	4	0
Total annualized capital costs	44	37	0	21	0
OPERATING COSTS (SAVINGS) ($ 1000)					
Direct labor	0	0	0	0	0
Maintenance labor	0	0	0	0	0
Overhead	0	0	0	0	0
Maintenance materials	4	3	0	2	0
Paint	99[b]	44	(22)	0	(12)
Electricity	0	2	0	0	0
Natural gas	(5)	0	0	1	0
Total operating costs	98	49	(22)	3	(12)
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	144	86	(22)	24	(12)
Cost (savings) per area covered ($/1000 m^2)	185	110	(28)	31	(15)

[a]D-1 Powder
D-2 Waterborne
D-3 70 percent high solids
D-4 Incinerator on base case line(s)
D-5 65 percent high solids

[b]This cost for powder is based on a film thickness of 6.35×10^{-3}cm (2.5 mil). However, at a film thickness of 3.81×10^{-3}cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-36. PLANT E - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF SIP LEVEL FACILITIES

	Control options[a]			
	E-1	E-2	E-3	E-4
INSTALLED CAPITAL COSTS ($ 1000)				
Line(s)	90	55	0	0
Add-on control equipment	0	0	0	0
Building	0	2	0	0
Total capital costs	90	57	0	0
Annualized capital costs	11	7	0	0
Insurance, taxes and G&A	4	2	0	0
Total annualized capital costs	15	9	0	0
OPERATING COSTS (SAVINGS) ($ 1000)				
Direct labor	0	0	0	0
Maintenance labor	0	0	0	0
Overhead	0	0	0	0
Maintenance materials	1	1	0	0
Paint	8[b]	1	0	0
Electricity	0	1	0	0
Natural gas	(2)	0	0	0
Total operating costs	7	3	0	0
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	22	12	0	0
Cost (savings) per area covered ($/1000 m^2)	489	267	0	0

[a] E-1 Powder
E-2 Waterborne
E-3 70 percent high solids
E-4 65 percent high solids

[b] This cost for powder is based on a film thickness of 6.35×10^{-3} cm (2.5 mil). However, at a film thickness of 3.81×10^{-3} cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-37. PLANT F - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF SIP LEVEL FACILITIES

	Control options[a]			
	F-1	F-2	F-3	F-4
INSTALLED CAPITAL COSTS ($ 1000)				
Line(s)	100	70	0	0
Add-on control equipment	0	0	0	0
Building	0	2	0	0
Total capital costs	100	72	0	0
Annualized capital costs	13	9	0	0
Insurance, taxes and G&A	4	3	0	0
Total annualized capital costs	17	12	0	0
OPERATING COSTS (SAVINGS) ($ 1000)				
Direct labor	0	0	0	0
Maintenance labor	0	0	0	0
Overhead	0	0	0	0
Maintenance materials	2	1	0	0
Paint	5[b]	4	0	0
Electricity	0	1	0	0
Natural gas	(2)	0	0	0
Total operating costs	5	6	0	0
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	22	18	0	0
Cost (savings) per area covered ($/1000 m^2)	489	400	0	0

[a]F-1 Powder
F-2 Waterborne
F-3 70 percent high solids
F-4 65 percent high solids

[b]This cost for powder is based on a film thickness of 6.35×10^{-3} cm (2.5 mil). However, at a film thickness of 3.81×10^{-3} cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-38. PLANT G - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF SIP LEVEL FACILITIES

	Control options			
	G-1	G-2	G-3	G-4
INSTALLED CAPITAL COSTS ($ 1000)				
Line(s)	1040	2500	0	0
Add-on control equipment	0	0	130	0
Building	0	126	0	0
Total capital costs	1040	2626	130	0
Annualized capital costs	137	342	20	0
Insurance, taxes and G&A	42	105	5	0
Total annualized capital costs	179	447	25	0
OPERATING COSTS (SAVINGS) ($ 1000)				
Direct labor	0	0	0	0
Maintenance labor	0	0	0	0
Overhead	0	0	0	0
Maintenance materials	16	38	2	0
Paint	696	(141)	0	37
Electricity	1	32	0	0
Natural gas	(39)	0	5	0
Total operating costs	674	(71)	7	37
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	853	376	32	37
Cost (savings) per area covered ($/1000 m^2)	213	94	8	9

G-1 Fluidized bed
G-2 Electrodeposition
G-3 Incinerator on base case line(s)
G-4 Waterborne

Table 7-39. PLANT H - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF SIP LEVEL FACILITIES

	Control options			
	H-1	H-2	H-3	H-4
INSTALLED CAPITAL COSTS ($ 1000)				
Line(s)	210	550	0	0
Add-on control equipment	0	0	110	0
Building	0	354	0	0
Total capital costs	210	904	110	0
Annualized capital costs	28	107	17	0
Insurance, taxes and G&A	8	36	4	0
Total annualized capital costs	36	143	21	0
OPERATING COSTS (SAVINGS) ($ 1000)				
Direct labor	0	0	0	0
Maintenance labor	0	0	0	0
Overhead	0	0	0	0
Maintenance materials	3	8	2	0
Paint	34	(27)	(8)	8
Electricity	1	8	0	0
Natural gas	(6)	0	2	0
Total operating costs	32	(11)	(4)	8
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	68	132	17	8
Cost (savings) per area covered ($/1000 m^2)	87	169	22	10

H-1 Fluidized bed
H-2 Electrodeposition
H-3 Incinerator on base case line(s)
H-4 Waterborne

Table 7-40. PLANT I - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF SIP LEVEL FACILITIES

	Control options		
	I-1	I-2	I-3
INSTALLED CAPITAL COSTS ($ 1000)			
Line(s)	90	210	0
Add-on control equipment	0	0	0
Building	0	1	0
Total capital costs	90	211	0
Annualized capital costs	12	28	0
Insurance, taxes and G&A	4	8	0
Total annualized capital costs	16	36	0
OPERATING COSTS (SAVINGS) ($ 1000)			
Direct labor	0	0	0
Maintenance labor	0	0	0
Overhead	0	0	0
Maintenance materials	1	3	0
Paint	24	(2)	0
Electricity	0	3	0
Natural gas	(2)	0	0
Total operating costs	23	4	0
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	39	40	0
Cost (savings) per area covered ($/1000 m^2)	867	889	0

I-1 Fluidized bed
I-2 Electrodeposition
I-3 Waterborne

Table 7-41. PLANT J - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF SIP LEVEL FACILITIES

	Control options J-1
INSTALLED CAPITAL COSTS ($ 1000)	
Line(s)	0
Add-on control equipment	0
Building	0
Total capital costs	0
Annualized capital costs	0
Insurance, taxes and G&A	0
Total annualized capital costs	0
OPERATING COSTS (SAVINGS) ($ 1000)	
Direct labor	0
Maintenance labor	0
Overhead	0
Maintenance materials	0
Paint	0
Electricity	0
Natural gas	0
Total operating costs	0
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	0
Cost (savings) per area covered ($/1000 m^2)	0

J-1 Waterborne

Table 7-42. PLANT A - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF UNCONTROLLED FACILITIES

	Control options[a]				
	A-1	A-2	A-3	A-4	A-5
INSTALLED CAPITAL COSTS ($ 1000)					
Line(s)	750	500	180	180	180
Add-on control equipment	0	0	0	130	0
Building	0	207	0	0	0
Total capital costs	750	707	180	310	180
Annualized capital costs	99	87	24	44	24
Insurance, taxes and G&A	30	28	7	12	7
Total annualized capital costs	129	115	31	56	31
OPERATING COSTS (SAVINGS) ($ 1000)					
Direct labor	0	0	0	0	0
Maintenance labor	0	0	0	0	0
Overhead	0	0	0	0	0
Maintenance materials	11	8	3	5	3
Paint	663[b]	128	(125)	(39)	(86)
Electricity	(4)	11	(4)	(4)	(4)
Natural gas	(42)	(20)	(20)	(15)	(20)
Total operating costs	628	127	(146)	(53)	(107)
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	757	242	(115)	(3)	(76)
Cost (savings) per area covered ($/1000 m^2)	189	61	(29)	1	(19)

[a]A-1 Powder
A-2 Waterborne
A-3 70 percent high solids
A-4 Incinerator on base case line(s)
A-5 65 percent high solids

[b]This cost for powder is based on a film thickness of 6.35×10^{-3} cm (2.5 mil). However, at a film thickness of 3.81×10^{-3} cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-43. PLANT B - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF UNCONTROLLED FACILITIES

	Control options[a]				
	B-1	B-2	B-3	B-4	B-5
INSTALLED CAPITAL COSTS ($ 1000)					
Line(s)	1325	900	300	300	300
Add-on control equipment	0	0	0	130	0
Building	0	210	0	0	0
Total capital costs	1325	1110	300	430	300
Annualized capital costs	174	139	39	59	39
Insurance, taxes and G&A	53	44	12	17	12
Total annualized capital costs	227	183	51	76	51
OPERATING COSTS (SAVINGS) ($ 1000)					
Direct labor	0	0	0	0	0
Maintenance labor	0	0	0	0	0
Overhead	0	0	0	0	0
Maintenance materials	20	14	5	6	5
Paint	469[b]	188	(151)	(36)	(101)
Electricity	(7)	19	(7)	(7)	(7)
Natural gas	(70)	(33)	(33)	(27)	(33)
Total operating costs	412	188	(186)	(64)	(136)
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	639	371	(135)	12	(85)
Cost (savings) per area covered ($/1000 m^2)	150	93	(34)	3	(21)

[a]B-1 Powder
B-2 Waterborne
B-3 70 percent high solids
B-4 Incinerator on base case line(s)
B-5 65 percent high solids

[b]This cost for powder is based on a film thickness of 6.35×10^{-3}cm (2.5 mil). However, at a film thickness of 3.81×10^{-3}cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-44. PLANT C - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF UNCONTROLLED FACILITIES

	Control options[a]				
	C-1	C-2	C-3	C-4	C-5
INSTALLED CAPITAL COSTS ($ 1000)					
Line (s)	250	175	60	60	60
Add-on control equipment	0	0	0	110	0
Building	0	40	0	0	0
Total capital costs	250	215	60	170	60
Annualized capital costs	39	27	8	25	8
Insurance, taxes and G&A	10	9	2	7	2
Total annualized capital costs	49	36	10	32	10
OPERATING COSTS (SAVINGS) ($ 1000)					
Direct labor	0	0	0	0	0
Maintenance labor	0	0	0	0	0
Overhead	0	0	0	0	0
Maintenance materials	4	3	1	3	1
Paint	130[b]	16	(24)	(7)	(17)
Electricity	(1)	1	(1)	(1)	(1)
Natural gas	(10)	(5)	(5)	(4)	(5)
Total operating costs	123	15	(17)	(9)	(22)
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	172	51	(7)	23	(12)
Cost (savings) per area covered ($/1000 m^2)	221	65	(9)	29	(15)

[a]C-1 Powder
C-2 Waterborne
C-3 70 percent high solids
C-4 Incinerator on base case line(s)
C-5 65 percent high solids

[b]This cost for powder is based on a film thickness of 6.35×10^{-3}cm (2.5 mil). However, at a film thickness of 3.81×10^{-3}cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-45. PLANT D - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF UNCONTROLLED FACILITIES

	Control options[a]				
	D-1	D-2	D-3	D-4	D-5
INSTALLED CAPITAL COSTS ($ 1000)					
Line(s)	260	182	60	60	60
Add-on control equipment	0	0	0	110	0
Building	0	40	0	0	0
Total capital costs	260	222	60	170	60
Annualized capital costs	34	28	8	25	8
Insurance, taxes and G&A	10	9	2	7	2
Total annualized capital costs	44	37	10	32	10
OPERATING COSTS (SAVINGS) ($ 1000)					
Direct labor	0	0	0	0	0
Maintenance labor	0	0	0	0	0
Overhead	0	0	0	0	0
Maintenance materials	4	3	1	3	1
Paint	92[b]	37	(29)	(7)	(19)
Electricity	(1)	1	(1)	(1)	(1)
Natural gas	(10)	(5)	(5)	(4)	(5)
Total operating costs	85	36	(34)	(9)	(24)
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	129	73	(24)	23	(14)
Cost (savings) per area covered ($/1000 m^2)	165	94	(31)	29	(18)

[a]D-1 Powder
D-2 Waterborne
D-3 70 percent high solids
D-4 Incinerator on base case line(s)
D-5 65 percent high solids

[b]This cost for powder is based on a film thickness of 6.35×10^{-3} cm (2.5 mil). However, at a film thickness of 3.81×10^{-3} cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-46. PLANT E - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF UNCONTROLLED FACILITIES

	Control options[a]			
	E-1	E-2	E-3	E-4
INSTALLED CAPITAL COSTS ($ 1000)				
Line(s)	90	55	5	5
Add-on control equipment	0	0	0	0
Building	0	2	0	0
Total capital costs	90	57	5	5
Annualized capital costs	11	7	1	1
Insurance, taxes and G&A	4	2	0	0
Total annualized capital costs	15	9	1	1
OPERATING COSTS (SAVINGS) ($ 1000)				
Direct labor	0	0	0	0
Maintenance labor	0	0	0	0
Overhead	0	0	0	0
Maintenance materials	1	1	0	0
Paint	7[b]	0	(1)	(1)
Electricity	0	1	0	0
Natural gas	(4)	(2)	(2)	(2)
Total operating costs	4	0	(3)	(3)
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	19	9	(2)	(2)
Cost (savings) per area covered ($/1000 m^2)	422	200	(44)	(44)

[a]E-1 Powder
E-2 Waterborne
E-3 70 percent high solids
E-4 65 percent high solids

[b]This cost for powder is based on a film thickness of 6.35×10^{-3}cm (2.5 mil). However, at a film thickness of 3.81×10^{-3}cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-47. PLANT F - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF UNCONTROLLED FACILITIES

	Control options[a]			
	F-1	F-2	F-3	F-4
INSTALLED CAPITAL COSTS ($ 1000)				
Line(s)	100	70	5	5
Add-on control equipment	0	0	0	0
Building	0	2	0	0
Total capital costs	100	72	5	5
Annualized capital costs	13	9	1	1
Insurance, taxes and G&A	4	3	0	0
Total annualized capital costs	17	12	1	1
OPERATING COSTS (SAVINGS) ($ 1000)				
Direct labor	0	0	0	0
Maintenance labor	0	0	0	0
Overhead	0	0	0	0
Maintenance materials	2	1	0	0
Paint	5[b]	4	0	0
Electricity	0	1	0	0
Natural gas	(4)	(2)	(2)	(2)
Total operating costs	3	4	(2)	(2)
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	20	16	(1)	(1)
Cost (savings) per area covered ($/1000 m^2)	444	356	(22)	(22)

[a]F-1 Powder
F-2 Waterborne
F-3 70 percent high solids
F-4 65 percent high solids

[b]This cost for powder is based on a film thickness of 6.35×10^{-3} cm (2.5 mil). However, at a film thickness of 3.81×10^{-3} cm (1.5 mil) the cost changes significantly (see Appendix E).

Table 7-48. PLANT G - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF UNCONTROLLED FACILITIES

	Control options			
	G-1	G-2	G-3	G-4
INSTALLED CAPITAL COSTS ($ 1000)				
Line(s)	1040	2500	625	625
Add-on control equipment	0	0	130	0
Building	0	126	118	118
Total capital costs	1040	2626	873	743
Annualized capital costs	137	342	114	94
Insurance, taxes and G&A	42	105	35	30
Total annualized capital costs	179	447	149	124
OPERATING COSTS (SAVINGS) ($ 1000)				
Direct labor	0	0	0	0
Maintenance labor	0	0	0	0
Overhead	0	0	0	0
Maintenance materials	16	38	11	11
Paint	720	(117)	24	61
Electricity	1	32	0	0
Natural gas	(73)	(34)	(29)	(34)
Total operating costs	664	(81)	6	38
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	843	366	155	162
Cost (savings) per area covered ($/1000 m^2)	211	92	39	41

G-1 Fluidized bed
G-2 Electrodeposition
G-3 Incinerator on base case line(s)
G-4 Waterborne

Table 7-49. PLANT H - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF UNCONTROLLED FACILITIES

	Control options			
	H-1	H-2	H-3	H-4
INSTALLED CAPITAL COSTS ($ 1000)				
Line(s)	210	550	125	125
Add-on control equipment	0	0	110	0
Building	0	354	22	22
Total capital costs	210	904	257	147
Annualized capital costs	28	107	35	18
Insurance, taxes and G&A	8	36	10	6
Total annualized capital costs	36	143	45	24
OPERATING COSTS (SAVINGS) ($ 1000)				
Direct labor	0	0	0	0
Maintenance labor	0	0	0	0
Overhead	0	0	0	0
Maintenance materials	3	8	2	2
Paint	42	(19)	8	8
Electricity	1	8	0	0
Natural gas	(11)	(5)	(3)	(5)
Total operating costs	35	(8)	7	5
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	71	135	52	29
Cost (savings) per area covered ($/1000 m^2)	91	173	67	37

H-1 Fluidized bed
H-2 Electrodeposition
H-3 Incinerator on base case line(s)
H-4 Waterborne

Table 7-50. PLANT I - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF UNCONTROLLED FACILITIES

	Control options		
	I-1	I-2	I-3
INSTALLED CAPITAL COSTS ($ 1000)			
Line(s)	90	210	58
Add-on control equipment	0	0	0
Building	0	1	1
Total capital costs	90	211	59
Annualized capital costs	12	28	8
Insurance, taxes and G&A	4	8	2
Total annualized capital costs	16	36	10
OPERATING COSTS (SAVINGS) ($ 1000)			
Direct labor	0	0	0
Maintenance labor	0	0	0
Overhead	0	0	0
Maintenance materials	1	3	1
Paint	25	(1)	1
Electricity	0	3	0
Natural gas	(4)	(2)	(2)
Total operating costs	22	3	0
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	38	39	10
Cost (savings) per area covered ($/1000 m^2)	844	867	222

I-1 Fluidized bed
I-2 Electrodeposition
I-3 Waterborne

Table 7-51. PLANT J - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF UNCONTROLLED FACILITIES

	Control options J-1
INSTALLED CAPITAL COSTS ($ 1000)	
Line(s)	58
Add-on control equipment	0
Building	1
Total capital costs	59
Annualized capital costs	8
Insurance, taxes and G&A	2
Total annualized capital costs	10
OPERATING COSTS (SAVINGS) ($ 1000)	
Direct labor	0
Maintenance labor	0
Overhead	0
Maintenance materials	1
Paint	1
Electricity	0
Natural gas	(2)
Total operating costs	0
TOTAL ANNUALIZED COSTS (SAVINGS) ($ 1000)	10
Cost (savings) per area covered ($/1000 m^2)	222

J-1 Waterborne

addition of a thermal incinerator to the curing oven exhaust. All other costs associated with the change would be related to operating costs.

There are also three options for dip coating lines which would require capital expenditures. For the fluidized bed powder coating option most of the line would have to be replaced with the exception of the pretreatment area. Electrodeposition (EDP) requires a large capital investment due to the need for more pretreatment and the great expense of an EDP tank and filtration system. As with spray lines, the only capital expense associated with the incineration option is the incinerator itself.

The flow coating model plant has only one option which would require no investment when switching from the base case.

7.3 OTHER COST CONSIDERATIONS

This section deals with two subjects: the costs borne by metal furniture coating facilities in complying with current regulatory requirements and the impact of a New Source Performance Standard on state and local regulatory enforcement agencies.

7.3.1 Water Treatment

As explained in Chapter 6, metal furniture coating facilities have a limited potential to pollute water. For economic reasons, water which is used in the pretreatment section of the coating line and in the water wash spray booths is recirculated with only make-up water being added, as needed, due to evaporation. One source of water pollution is clean-up water which falls through process area drains.

The overall cost of water treatment to the metal furniture coater is minimal. There is a possibility of a slight increase due to the use of waterborne paint, however, this has no appreciable impact on the overall cost of operation of a coating line.

7.3.2 Solid Waste Disposal

Solid waste disposal which results from overspray in the application area of a coating line must be collected and disposed of periodically. As with water treatment, these disposal costs are minimal. The use of high solids paint results in a more difficult clean-up, however, there is no significant increase in the actual amount of solid waste which must be disposed of. Waterborne paints may create somewhat more solid waste however the increase is not significant.

7.3.3 OSHA Requirements

Occupational Safety and Health Administration (OSHA) regulations for metal furniture coating facilities specify air flow requirements through spray booths in order to keep the VOC concentration below the threshold limit value (TLV). In addition, oven exhaust flow rates are regulated in order to keep VOC concentrations below the lower explosive limit (LEL).

Waterborne paints present a problem for spray coating facilities due to the electrical shock potential. Certain costs would be incurred in providing proper insulation from such hazards. These costs are also included in the overall costs presented in Section 7.2.

7.3.4 Regulatory Agency Manpower Requirements

The burden of enforcement of NSPS falls on state and local agencies. In accordance with the Clean Air Act amendments of 1977, states are already under obligation to propose, adopt, and enforce State Implementation Plans for the reduction of VOC emissions. Most of these SIPs include regulations on emissions from metal furniture painting operations. At least six states have proposed a level of permissible emissions of 0.36 kilograms of organic solvent per liter of coating (3.0 pounds per gallon) at application. These states are highly industrialized, as are the states in which most metal furniture manufacturers are located (see Section 2.1 and 7.1). It is expected that such states will already have a regulatory framework for the enforcement of state environmental laws either previous to or as a result of the Clean Air Act amendments. In the event that the NSPS is less strict than an existing state regulation, the regulatory agency manpower impact will be negligible. In states where NSPS is stricter than the state regulation the incremental manpower requirements should be minimal.

7.4 ECONOMIC IMPACT ASSESSMENT

7.4.1 Introduction and Summary

7.4.1.1 Introduction. This section analyzes the potential inhibiting effects of NSPS controls on investment in new, modified, and reconstructed surface coating facilities in the metal furniture industry. Two measures of potential impacts used in the analysis are changes to profit and capital availability.

As part of the analysis, several basic questions are addressed:

- Which of the control options have the greatest impacts upon the industry?
- How do impacts vary from one type of plant to another?
- How do impacts vary by size of plant?
- How might the structure of the industry be affected by the control options?
- What magnitude of industry-wide compliance costs might be anticipated?

The analysis is divided into four major sections. Section 7.4.2 establishes the general context for the analysis by covering the subject of industry expansion. Section 7.4.3 summarizes the methodology used in the analysis. Section 7.4.4 discusses the results of the analysis. Finally, Section 7.4.5 summarizes industry-wide compliance costs. Aggregate effects on industry structure, employment, inflation, and energy are analyzed in Section 7.5.

7.4.1.2 Summary. The impact assessment was performed using a model plant approach. Ten model plants were employed. Of this total, three were shelving plants, and seven were chair plants. Shelves and chairs were chosen to represent the flat and complex surfaces that would be coated. The characteristics of the plants in terms of size and coating method used are given in Tables 7-52 and 7-53.

All of the shelving plants are spray-coating operations, while the chair plants are divided between spray coating, dip coating, and flow coating operations. Only one model plant (Plant J) is used for flow coating.

The impact analysis was performed for both new and modified/reconstructed facilities, and compared estimated profit and capital availability after NSPS controls to both SIP and uncontrolled baseline.

The potential of the control options for reducing plant profits was examined using a form of "worst case" analysis which assumed that incremental annualized control costs would be fully absorbed by the model plants. The analysis indicated major profit reduction for all shelving plants (Plants A, C, and E) for the powder options. (A "major" impact is defined as an

Table 7-52. MODEL SHELVING PLANTS

Plant	Size	Area coated per year	Coating method
A	Large	4,000,000 m^2	Spray
C	Medium	780,000 m^2	Spray
E	Small	45,000 m^2	Spray

Table 7-53. MODEL CHAIR PLANTS

Plant	Size	Area coated per year	Coating method
B	Large	4,000,000 m^2	Spray
D	Medium	780,000 m^2	Spray
F	Small	45,000 m^2	Spray
G	Large	4,000,000 m^2	Dip
H	Medium	780,000 m^2	Dip
I	Small	45,000 m^2	Dip
J	Small	45,000 m^2	Flow

impact which can result in a decision not to invest in a new source.) However, based upon data presented in Appendix E, this is not true if powder is applied at film thickness of 3.81×10^{-3}cm (1.5 mil) or less. In the case of Plant A, major profit reductions were exhibited for modified/ reconstructed facilities relative to both the SIP and uncontrolled baselines. For Plants C and E, major impacts were indicated for both new and modified/ reconstructed facilities, relative to both baselines. (A profit reduction of 15 percent or more was determined as constituting a "major" impact. The rationale for this criterion is developed in Section 7.4.3.3.) Plant E, the smallest shelving plant, was also found to be subject to major impact by the waterborne options for new facilities relative to the SIP baseline, and for modified/reconstructed facilities relative to both baselines. In the case of the 70 percent high solids options, none of the shelving plants were subject to major impacts - in fact, profits in all situations were either favorably affected or not affected at all. The results were similar for the 65 percent high solids option. For incineration with RACT coating, profit reductions were relatively small (largest reduction was 2.79 percent). A summary of the major impacts is given in Table 7-54.

Of the seven chair plants, Plant I (small dip-coating plant) was the only one found to be subject to major profit impacts. These impacts were associated with the powder and electrodeposition control options. In the case of powder, the major impacts were exhibited for modified/ reconstructed facilities relative to both the SIP and uncontrolled baselines. For electrodeposition, major profit reductions were indicated for both new and modified/ reconstructed facilities relative to both baselines. Among all of the chair plants, no profit reduction was associated with the 70 percent and 65 percent high solids options. For incineration with RACT coating, the largest impact was relatively minor (only 2.56 percent). With respect to waterborne, the greatest profit reduction was 8.60 percent. A summary of the major impacts is given in Table 7-55.

In general, for both shelves and chairs, it was found that the severity of profit reduction associated with a given control option tends to vary inversely with the size of the plant. Thus, in a situation where two plants of unequal size employ the same control option, the smaller is likely to be at a competitive disadvantage relative to the larger.

Table 7-54 SUMMARY OF MAJOR IMPACTS[a]

SHELVING PLANTS

		Profit impact				Capital availability impact			
		New		Modified/ Reconstruc.		New		Modified/ Reconstruc.	
Plant	Control Option	SIP	Uncon	SIP	Uncon.	SIP	Uncon.	SIP	Uncon.
A	Powder (spray)[b]			x	x				
	Waterborne								
Large	70% High solids								
Spray	Incinerator & RACT coating								
	65% High solids								
C	Powder (spray)[b]	x	x	x	x				
	Waterborne								
Medium	70% High solids								
Spray	Incinerator & RACT coating								
	65% High solids								
E	Powder (spray)[b]	x	x	x	x			x	x
	Waterborne	x		x	x			x	x
Small	70% High solids								
Spray	65% High solids								

[a]"X" indicates major impact.

NOTE: Under each of the impact headings in the table, a distinction is made between new facilities and modified/reconstructed facilities. In turn, within each of these categories of facilities, a further distinction is made between impacts relative to the SIP baseline, and those relative to the uncontrolled baseline.

[b]This is not the case for powder applied at a film thickness of 3.81×10^{-3} cm (1.5 mil) or less (see Appendix E).

Table 7-55. SUMMARY OF MAJOR IMPACTS[a] CHAIR PLANTS

		Profit impact				Capital availability impact			
		New		Modified/ Reconstruc.		New		Modified/ Reconstruc.	
Plant	Control Option	SIP	Uncon	SIP	Uncon.	SIP	Uncon.	SIP	Uncon
B	Powder (spray)								
	Waterborne								
Large	70% High solids								
Spray	Incinerator & RACT coating								
	65% High solids								
D	Powder (spray)								
	Waterborne								
Medium	70% High solids								
Spray	Incinerator & RACT coating								
	65% High solids								
F	Powder (spray)								
	Waterborne								
Small	70% High solids								
Spray	65% High solids								
G	Powder (fld.bed)								
	Electrodeposition								
Large	Incinerator &								
Dip	RACT coating								
	Waterborne(conv.)								
H	Powder(fld.bed)								
	Electrodeposition								
Medium	Incinerator &								
Dip	RACT coating								
	Waterborne(conv.)								
I	Powder(fld.bed)			x	x				
Small	Electrodeposition	x	x	x	x		x	x	x
Dip	Waterborne(conv.)								
J	Waterborne								
Small Flow									

[a]"X" indicates major impact.

NOTE: Under each of the impact headings in the table, a distinction is made between new facilities and modified/reconstructed facilities. In turn, within each of these categories of facilities, a further distinction is made between impacts relative to the SIP baseline, and those relative to the uncontrolled baseline.

In analyzing the effects of the control options on capital availability, associated increases in capital requirements of 10 percent or more were considered to be major. (The rationale for this criterion is developed in Section 7.4.4.4.) For shelving, the smallest plant (Plant E) was subject to major impact by the waterborne options and by powder (spray) if applied at 6.35×10^{-3}cm (2.5 mil). In both situations, this was for modified/reconstructed facilities relative to both baselines. For chairs, the small dip-coating plant (Plant I) was subject to major impact by electrodeposition for new facilities relative to the uncontrolled baseline, and for modified/reconstructed facilities relative to both baselines. Again for any given control option, the magnitude of impacts tended to vary inversely with plant size. The phenomenon is especially pronounced with Plants E and I.

Based on the results obtained in the analyses of profit reduction and capital availability, another analysis was performed to assess differentials in impacts between the smallest and largest plants producing the same product for each of the control options. In virtually all cases, for both profit reduction and capital availability, the impact for the smallest plant was found to be greater than the impact for the largest plant. In several cases, the differences in impacts were large. For example, in comparing Plant I (small dip-coating plant) with Plant G (large dip-coating plant) with regard to the electrodeposition option, the following types of differences were found for the modified/reconstructed facilities - SIP baseline combination:

<u>Profit reduction</u>:

Plant I:	17.29 percent
Plant G:	1.88 percent
Difference:	15.41 percent

<u>Capital availability</u>:

Plant I:	7.98 percent
Plant G:	1.13 percent
Difference:	6.85 percent

These differences underscore the fact that Plant I is clearly disadvantaged relative to its larger dip-coating competitors. As Table 7-55 shows, Plant I is already subject to major profit impacts for powder and electrodeposition, and major capital availability impacts for electrodeposition. Waterborne is the only control option available to Plant I which is not connected with some form of major impact.

With regard to the case of shelving plants, one effect of the major impacts (either profit or capital availability) is that either small shelving plants would be built or reconstructed having fewer control options available, or that the tendency would be to build or modify/reconstruct larger shelving plants. Similarly, new small dip-coating plants (like Plant I) would have only one control option available, or the tendency would be to build or reconstruct larger dip-coating plants.

It should be noted that even in situations where major impacts are not involved, the existence of large differentials are likely to lead to shifts within the size distribution of plants towards greater proportional representation by larger plants.

In summary, as Tables 7-54 and 7-55 show, the powder options (spray and fluidized bed) cause major impacts for four of the model plants (A, C, E, and I). However, this is only true if powder is applied at a film thickness of 6.35×10^{-3} cm (2.5 mil) or greater (see Appendix E). In only one case (Plant I) does electrodeposition cause major impacts. Likewise, waterborne cause major impacts only in the case of Plant E. No major impacts are associated with the other control options.

In order to provide an estimate of the range over which industrywide compliance costs might vary, cost calculations were carried out for four of the various combinations of control options that might be employed. The combinations are as follows:

- Combination #1

Spray-coating plants:	all six types of plants (A-F) use 70 percent high solids.
Dip-coating plants:	all three types of plants (G, H, I) use conventional waterborne.
Flow-coating plants:	the one type of plant (J) uses waterborne.

- <u>Combination #2</u>

Spray-coating plants:	all six types of plants (A-F) use powder.
Dip-coating plants:	all three types of plants (G, H, I) use electrodeposition.
Flow-coating plants:	the one type of plant (J) uses waterborne.

- <u>Combination #3</u>

Spray-coating plants:	four types of plants (A-D) use incinerator with RACT coating, the other two types of plants (E & F) use waterborne.
Dip-coating plants:	all three types of plants (G, H, I) use conventional waterborne.
Flow-coating plants:	the one type of plant (J) uses waterborne.

- <u>Combination #4</u>

Spray-coating plants:	all six types of plants (A-F) use 70 percent high solids, powder, and waterborne (options equally represented).
Dip-coating plants:	all three types of plants (G, H, I) use conventional waterborne.
Flow-coating plants:	the one type of plant (J) uses waterborne.

Through the use of a methodology described in Section 7.4.5, industrywide incremental annualized control costs (relative to the SIP baseline) were estimated for each of the above combinations of control options, with the estimations being based upon the number of new and replacement coating lines projected for 1985 (as presented in Section 7.1.5.3). The costs are as follows:

	From Tables 7-78, 7-79, and 7-80	From Tables 7-78, E-8, and E-9 of Appendix E
Combination #1:	($14.7 million)	($18 million)
Combination #2:	$126 million	($1.7 million)
Combination #3:	$17.6 million	$17 million
Combination #4:	$54.8 million	$11 million

At \$126 million, Combination #2 is by far the most costly of the four, and exceeds by \$26 million the threshold for a Significant Action Analysis (as articulated in Executive Order 12044). However, costs associated with Combination #2 change significantly if powder is applied at film thicknesses of 3.81×10^{-3}cm (1.5 mil) or less (see Appendix E).

7.4.2 Industry Expansion

A detailed profile of the metal furniture industry has been presented in Section 7.1 of this document. This section builds upon that material and presents an examination of factors which will have an important bearing upon the future expansion of the industry. The purpose of the discussion is to provide baseline context for the impact analysis which follows in Section 7.4.4.

This section is divided into two parts, one dealing with the household furniture component of the industry (SIC 2514), and the other with the business and institutional furniture component (comprised of SIC groups 2522, 2531, and 2542).

7.4.2.1 Metal Household Furniture. The metal household furniture industry (SIC 2514) is comprised of nearly 400 establishments.[24] Major products of the industry include: indoor dining, dinette, and breakfast furniture; porch, lawn, outdoor, and casual seating and tables; kitchen cabinets and stools; bed frames; medicine cabinets; and infants' furniture.

Demand. As discussed in Section 7.1.5.1, it is anticipated that between now and 1985, shipments of metal household furniture will exhibit a pattern of no growth through 1980, followed by growth on the order of one percent per year through 1985.

Looking at the growth potential of particular product areas, it appears likely that the fastest growth will occur in the area of summer and casual furniture.[7] Two basic reasons for this expectation are the trend towards increasingly casual lifestyles, and the relatively low prices charged for this type of furniture.

There are several critical factors underlying the overall demand for metal househould furniture. These include: demographic trends influencing the rate of new household formation; disposable personal income and consumer spending on durable goods; housing starts and sales; interest rates; consumer confidence; and, outstanding consumer installment debt.

Due to a lack of quantitative studies on the subject, nothing definite can be said about the price elasticity of demand for metal household furniture. On the basis of economic principles, however, one might expect that the elasticity could vary somewhat from one type of metal household furniture to another. Generally speaking, the more substitutes a particular type of furniture has, and the higher its price, the greater will tend to be the price elasticity of demand. Variation is also possible within a given type of furniture -- i.e., the price elasticity of demand for the product of one manufacturer may differ from the elasticity for the product of another manufacturer.

From the standpoint of the impact analysis which follows, price elasticity of demand is an important factor in two respects. First, the extent to which a firm can pass through incremental control costs to the consumer is reflective of the price elasticity of demand for the particular product which the firm manufactures. If the demand for the firm's product is inelastic, the firm may be able to pass through much or all of the incremental costs to the consumer. The extent to which this is possible would depend upon intra-industry competitive factors. Locational considerations would be most important in this regard. If the demand for the firm's product tends to be elastic, the potential for cost pass-through is reduced.

The second reason why price elasticity of demand is important to the impact analysis is that it has a major bearing on the inflationary effects of NSPS regulations. If the demand for metal household furniture tended to be inelastic with respect to price increases, the inflationary impact upon the economy would be greater than if the demand were elastic (since price increases would be resisted in the latter situation).

According to a U.S. Department of Commerce representative, price has not been a critical factor in demand for metal furniture versus furniture of other materials. One reason given is that in the past, metal household furniture price increases have been consistent with price increases for household furniture made from other materials. Another is that the general state of the economy is typically a more important factor in demand shifts than price increases.[25]

Supply. The metal household furniture industry is characterized by diversification and a small business orientation. In 1976, the industry had 391 establishments and employed approximately 31,000 workers, with shipments valued at $992 million.[26] Vertical integration is not common within the industry. The majority of firms purchase raw materials and other inputs from external sources, and are not forwardly integrated into marketing.

According to a trade association representative, the future size distribution of firms within the industry will consist predominately of large and small firms, with the number of medium-sized companies substantially reduced.[7] Small firms will continue to exist because of the ease of entry characteristic of certain types of metal household furniture manufacture (for example, the capital requirements of the manufacture of tubular aluminum lawn furniture are relatively modest) and transportation cost advantages stemming from plant location near retail markets.

As discussed in Section 7.1.1.3, the actual rate of capacity utilization in the metal household furniture industry was perhaps less than 70 percent in 1977. Given this level of utilization and the anticipated demand trends discussed above, it would appear that no additional capacity will be needed until after 1980.

7.4.2.2 Business and Institutional Furniture. The business and institutional component of the metal furniture industry is comprised of three SIC groups: SIC 2522 (metal office furniture); SIC 2531 (public building and related furniture); and SIC 2542 (metal partitions and fixtures). Major products of the office furniture component include chairs, desks, filing and storage cabinets, and panel systems. The public building and related component produces items such as benches, bleacher seating, folding chairs, and seating for automobiles and public conveyances. The metal partitions and fixtures component produces items including room dividers, shelves, lockers, and storage bins.

Demand. In recent years, the business and institutional furniture industry (including both wood and metal furniture) has enjoyed a steady growth in demand. As mentioned in Section 7.1.2.4, following a substantial upturn in 1976, shipments of business and institutional furniture in constant dollars continued to increase through 1977 and 1978. The trend is expected to continue at least through the near future. According to the Business and Institutional Furniture Manufacturers' Association (BIFMA), the market is likely to remain strong, given the general trend towards increasing construction of commercial office buildings in many cities across the country.[2] Superimposed upon this general trend, however, are the high interest rates which have resulted from the federal government's efforts to strengthen the dollar. These rates will probably have a dampening effect upon the rate of new office building construction. In the opinion of BIFMA, however, this impact may be partially offset by increased demands for remodeled facilities since there still appears to be a shortage of office space. As discussed earlier in Section 7.1.5.1, the anticipated annual growth rates for demand through 1985 are four percent for metal office furniture, two percent for the public building component, and seven percent for the metal partition component.

By all indications, the industry's growth potential is greatest in the area of panel systems. A recent development, such systems are modular units containing panels, desks or work surfaces, files, and storage accessories. One study projects growth in value of shipments through 1990 at 16.4 percent on a current dollar basis.[5]

The factors underlying the demand for business and institutional furniture are varied. In the case of office furniture for example, some of the more important factors include: construction of new office buildings and renovation of existing facilities; growth of the white collar work force; prospects for replacement of old furniture; and concern over the quality of the white collar working environment.

As was the case with metal household furniture, there are no quantitative studies available on the price elasticity of demand for business and institutional furniture. No definite statement can therefore be made as to whether demand tends to be elastic or inelastic. It would seem, however, that purchases of business and institutional furniture tend to be influenced more by factors relating to operational necessity and general business and economic conditions rather than changes in price. The implications of price elasticity with respect to cost pass through and inflation are the same as those discussed above in connection with metal household furniture.

The price cross-elasticity of demand for metal office furniture is relatively low with respect to office furniture made from other materials (mainly wood). According to a BIFMA representative, consumers do not choose between metal and wood business and institutional furniture on the basis of price alone.[1] Design and material itself are critical relative demand factors. Wood is a prestige item, valued for its rich appearance, and tends to be purchased for upper level management only. Although substitution may take place if there are supply shortages, the markets for wood and metal business and institutional furniture are essentially segmented.

Supply. In 1976, there were 1,003 manufacturing establishments in the business and institutional component of the metal furniture industry. The breakdown was as follows: metal office furniture (SIC 2522), 177; public building and related furniture (SIC 2531), 377; and metal partitions and fixtures (SIC 2542), 449. Together, the three SIC groups employed approximately 68,000 workers and had shipments valued at nearly $2.7 billion.[24]

Of the three industry groups, metal office furniture (SIC 2522) is by far the most concentrated. In 1972, 37 percent of the value of shipments for the metal office furniture component was accounted for by the four largest companies. The comparable figures for the public building and related component and the metal partitions and fixtures component were 18 percent and 13 percent, respectively. The metal office furniture component is also much more heavily weighted towards multi-plant firms than are the other two components. Census data show that in 1972, 83 percent of the value of shipments for the metal office furniture component was accounted for by multi-plant companies. The comparable figures for the public building and metal partitions components were 56 percent and 58 percent, respectively.[27]

Vertical integration is not widespread in any of the three industry groups. Raw materials and other inputs tend to be obtained largely from external sources, and only the largest companies are forwardly integrated into marketing. Distribution to end users is generally accomplished through local dealers who handle the products of a number of different manufacturers.

The business and institutional furniture industry is currently stable. There have been few entries or exits of firms.[1]

According to BIFMA, manufacturers of business and institutional furniture have been operating at near capacity levels.[29] Additional capacity is now required not only to meet anticipated growth in demand, but to also create a sufficient buffer. No serious production bottlenecks are anticipated, however, supply is expected to keep up with demand. It is likely that much of the new capacity in the industry will be devoted to the manufacture of panel systems.

7.4.3 Methodology

This section presents a summary of the steps and procedures used in assessing the potential impacts of the control options at the level of the individual plant.

The assessment was performed using a model plant approach, in which ten different model plants were subjected to analysis. Details of these plants are given in Table 7-56. Three of the model plants are shelving plants, while the other seven are chair plants. Shelves and chairs were chosen to represent the flat and complex surfaces that would be coated. Plant size is expressed in terms of surface area coated per year and the equivalent number of shelves or chairs (assuming coated areas of 1.0 m^2 for shelves, and 0.33 m^2 for chairs). The shelving plants are of three different sizes. All, however, are spray-coating operations. The chair plants are differentiated in terms of both size and coating method. Three types of coating methods are represented: spray, dip, and flow. The spray and dip categories are each represented by three different sizes of plants. There is only one plant for the flow category.

The analysis examines impacts on both new facilities and modified/reconstructed facilities. Within each of these categories of facilities, the impacts are measured relative to both an SIP baseline and an "uncontrolled" baseline. As discussed in Chapter 5, a total of six different control options are considered.

Two types of impacts are examined in the analysis:

- Profit impairment
- Adverse effects upon capital availability.

The methodologies used in examining these impacts are described fully in Sections 7.4.4.3 and 7.4.4.4, and need not be detailed at this point. A few words are in order, however. In the analysis of profit impairment, the objective is to determine the extent to which the profits of the model plants would be reduced under the various NSPS control options. To simplify

Table 7-56. MODEL SHELVING AND CHAIR PLANTS

Shelving Plants:

Plant	Coating method	Area coated per year (sq. meters)	No. of shelves coated per year	Corresponding SIC group
A	Spray	4,000,000	4,000,000	2522
C	Spray	780,000	780,000	2514,2522,2531,2542
E	Spray	45,000	45,000	2514,2522,2531,2542

Chair Plants:

Plant	Coating method	Area coated per year (sq. meters)	No. of chairs coated per year	Corresponding SIC group
B	Spray	4,000,000	12,000,000	2522
D	Spray	780,000	1,181,800	2514,2522,2531,2542
F	Spray	45,000	136,360	2514,2522,2531,2542
G	Dip	4,000,000	12,000,000	2522
H	Dip	780,000	1,181,800	2514,2522,2531,2542
I	Dip	45,000	136,360	2514,2522,2531,2542
J	Flow	45,000	136,360	2514,2522,2531,2542

the analysis, the impacts are examined using a "worst case" approach which assumes that incremental annualized control costs are fully absorbed by the plants. In evaluating the impacts, a profit reduction of 15 percent or more is judged to be a major impact. (The derivation of this criterion is discussed in Section 7.4.4.3.) A "major" impact is here defined as an impact which could result in a decision not to invest in a new source.

In the analysis of capital availability, effort focuses on determining the extent to which the capital requirements of the model plants would be increased under the various control options. For purposes of evaluation, increases in capital requirements of 10 percent or more are considered to be major. (The derivation of this criterion is discussed in Section 7.4.4.4.)

Based on results obtained from the analyses of profit reduction and capital availability, another analysis is performed to assess differentials in impacts between the smallest and largest plants producing the same product for each of the control options. The discussion is presented in Section 7.4.4.5.

7.4.4 Plant-Level Impact Analysis

7.4.4.1 Product Price Determination. One of the basic preliminary steps in the model plant analysis was that of determining prices for the shelves and chairs manufactured by the model plants.

Two types of prices were determined - F.O.B. (i.e. producer price at the plant) and retail list. In the sections which follow, the F.O.B. prices are used in estimating model plant revenues, and determining the extent of profit impairment associated with the various control options. The retail list prices are used in measuring the inflationary impacts of the control options.

Shelves. The shelf size assumed for the model plant is 1.2 m x 0.5 m, or approximately 4' x 20". The surface coating area is approximately one square meter.

The F.O.B. and retail list prices for shelving of this size were developed from information contained in the GSA Federal Supply Schedule.[28] On the basis of an examination of three different sets of prices contained in the Schedule, a representative F.O.B. price of $25.55 was developed. Given this F.O.B. price, a retail list price of $38.33 was derived by assuming a markup of 50 percent. This markup was determined as being representative on the basis of industry information.

Chairs. The type of chair assumed for the model plants is a stackable stationary (i.e., not a swivel or rolling model) office chair with arms. Only the frame, and not the seat or back, is assumed to be painted. The surface coating area is 0.33 square meters.

Prices were determined from a survey of retail prices as presented in office furniture catalogues. Only chairs having roughly the same surface coating requirements as those specified in the model plant parameters were considered. In all, 21 different prices were obtained. The price of $52.50 was the representative mean. An F.O.B. price of $35.00 was obtained by assuming that the retail list price represented a 50 percent markup.

7.4.4.2 Comparison of Per-Unit-Of-Product Costs for Control Options. As pointed out in Section 7.4.3, six types of control options are considered in the analysis. In this section, the costs of these options are compared on a per-unit-of-product basis (i.e., per shelf or chair). The comparisons are intended to provide a frame of reference for the impact analyses which follow. The cost data are presented in Tables 7-57 to 7-64. The data are in incremental form, and express additional costs or savings per shelf or chair relative to the baseline (SIP or uncontrolled). The data were derived from the control costs presented in Section 7.2, by dividing the total incremental annualized costs for each model plant by the number of items coated per year (as obtained from Chapter 5). The shelves and chairs are the same as those defined in Section 7.4.4.1.

Cost for shelving plants. Powder (spray) applied at a film thickness of 6.35×10^{-3}cm (2.5 mil) is the most expensive of the control options, with incremental costs per shelf ranging from $.17 to $.49. However, at a film thickness of 3.81×10^{-3}cm (1.5 mil) the incremental costs change significantly (see Appendix E). This is followed by waterborne, for which figures vary from $.06 to $.27. In the case of the 70 percent high solids control option, cost savings are experienced in all of the situations except one, in which there is no change in cost from the baseline case. The costs for incineration plus RACT coating are relatively low, and in two situations (involving Plants A and E) cost savings are experienced. With

Table 7-57. PROFIT IMPACT

SHELVING PLANTS - NEW FACILITIES

SIP BASELINE

Plant	Control Option	Incremental annualized control cost[a] ($000)	# Shelves coated (000)	Incremental annualized control cost per shelf coated[a] ($)	Profit margin impact F.O.B. price per shelf ($)	$
A	Powder (spray)[b]	735	4000	.18	25.55	.70
	Waterborne	298	4000	.07	25.55	.27
	70% High solids	(86)	4000	(.02)	25.55	d
	Incinerator & RACT coating	36	4000	.01	25.55	.04
	65% High solids	(47)	4000	(.01)	25.55	d
C	Powder (spray)[b]	149	780	.19	25.55	.74
	Waterborne	59	780	.08	25.55	.31
	70% High solids	(17)	780	(.02)	25.55	d
	Incinerator & RACT coating	24	780	.03	25.55	.12
	65% High solids	(10)	780	(.01)	25.55	d
E	Powder (spray)[b]	12	45	.27	25.55	1.06
	Waterborne	9	45	.20	25.55	.78
	70% High solids	0	45	c	25.55	d
	65% High solids	0	45	c	25.55	d

[a]Parentheses indicate decrease from baseline case.
[b]The profit impact changes significantly from the powder option based on data presented in Appendix E.
[c]No change in cost from baseline case.
[d]No negative impact on profit margin.

Table 7-58. PROFIT IMPACT

SHELVING PLANTS - NEW FACILITIES

UNCONTROLLED BASELINE

Plant	Control Option	Incremental annualized control cost[a] ($000)	# Shelves coated (000)	Incremental annualized control cost per shelf coated[a] ($)	Profit margin impact: F.O.B. price per shelf ($)	Profit margin impact: %
A	Powder (spray)[b]	670	4000	.17	25.55	.67
	Waterborne	233	4000	.06	25.55	.23
	70% High solids	(151)	4000	(.04)	25.55	c
	Incinerator & RACT coating	(29)	4000	(.01)	25.55	c
	65% High solids	(112)	4000	(.03)	25.55	c
C	Powder (spray)[b]	137	780	.18	25.55	.70
	Waterborne	47	780	.06	25.55	.23
	70% High solids	(29)	780	(.04)	25.55	c
	Incinerator & RACT coating	12	780	.02	25.55	.08
	65% High solids	(22)	780	(.03)	25.55	c
E	Powder (spray)[b]	9	45	.20	25.55	.78
	Waterborne	6	45	.13	25.55	.51
	70% High solids	(3)	45	(.07)	25.55	c
	65% High solids	(3)	45	(.07)	25.55	c

[a]Parentheses indicate decrease from baseline case.
[b]The profit impact changes significantly from the powder option based on data presented in Appendix E.
[c]No change in cost from baseline case.
[d]No negative impact on profit margin.

Table 7-59. PROFIT IMPACT

SHELVING PLANTS - MODIFIED/RECONSTRUCTED FACILITIES

SIP BASELINE

Plant	Control Option	Incremental annualized control cost[a] ($000)	# Shelves coated (000)	Incremental annualized control cost per shelf coated[a] ($)	Profit margin impact: F.O.B. price per shelf ($)	Profit margin impact: %
A	Powder (spray)[b]	820	4000	.21	25.55	.82
	Waterborne	305	4000	.08	25.55	.31
	70% High solids	(86)	4000	(.02)	25.55	d
	Incinerator & RACT coating	30	4000	.01	25.55	.04
	65% High solids	(47)	4000	(.01)	25.55	d
C	Powder (spray)[b]	185	780	.24	25.55	.94
	Waterborne	64	780	.08	25.55	.31
	70% High solids	(17)	780	(.02)	25.55	d
	Incinerator & RACT coating	24	780	.03	25.55	.12
	65% High solids	(10)	780	(.01)	25.55	d
E	Powder (spray)[b]	22	45	.49	25.55	1.92
	Waterborne	12	45	.27	25.55	1.06
	70% High solids	0	45	c	25.55	d
	65% High solids	0	45	c	25.55	d

[a]Parentheses indicate decrease from baseline case.
[b]The profit impact changes significantly from the powder option based on data presented in Appendix E.
[c]No change in cost from baseline case.
[d]No negative impact on profit margin.

Table 7-60. PROFIT IMPACT

SHELVING PLANTS - MODIFIED/RECONSTRUCTED FACILITIES

UNCONTROLLED BASELINE

Plant	Control Option	Incremental annualized control cost[a] ($000)	# Shelves coated (000)	Incremental annualized control cost per shelf coated[a] ($)	Profit margin impact F.O.B. price per shelf ($)	Profit margin impact %
A	Powder (spray)[b]	757	4000	.19	25.55	.74
	Waterborne	242	4000	.06	25.55	.23
	70% High solids	(115)	4000	(.03)	25.55	c
	Incinerator & RACT coating	(3)	4000	d	25.55	c
	65% High solids	(76)	4000	(.02)	25.55	c
C	Powder (spray)[b]	172	780	.22	25.55	.86
	Waterborne	51	780	.07	25.55	.27
	70% High solids	(7)	780	(.01)	25.55	c
	Incinerator & RACT coating	23	780	.03	25.55	.12
	65% High solids	(12)	780	(.02)	25.55	c
E	Powder (spray)[b]	19	45	.42	25.55	1.64
	Waterborne	9	45	.20	25.55	.78
	70% High solids	(2)	45	(.04)	25.55	c
	65% High solids	(2)	45	(.04)	25.55	c

[a]Parentheses indicate decrease from baseline case.
[b]The profit impact changes significantly from the powder option based on data presented in Appendix E.
[c]No change in cost from baseline case.
[d]No negative impact on profit margin.

Table 7-61. PROFIT IMPACT

CHAIR PLANTS - NEW FACILITIES

SIP BASELINE

Plant	Control Option	Incremental annualized control cost[a] ($000)	# Chairs coated (000)	Incremental annualized control cost per chair coated[a] ($)	Profit margin impact: F.O.B. price per chair ($)	Profit margin impact: %
B	Powder (spray)[b]	565	12,000	.05	35.00	.14
	Waterborne	433	12,000	.04	35.00	.11
	70% High solids	(115)	12,000	(.01)	35.00	d
	Incinerator & RACT coating	31	12,000		35.00	.01
	65% High solids	(65)	12,000	(.01)	35.00	d
D	Powder (spray)[b]	113	1,182	.10	35.00	.29
	Waterborne	85	1,182	.07	35.00	.20
	70% High solids	(22)	1,182	(.02)	35.00	d
	Incinerator & RACT coating	25	1,182	.02	35.00	.06
	65% High solids	(12)	1,182	(.01)	35.00	d
F	Powder (spray)[b]	10	136	.07	35.00	.20
	Waterborne	16	136	.12	35.00	.34
	70% High solids	0	136	c	35.00	d
	65% High solids	0	136	c	35.00	d
G	Powder (Fld. Bd.)	667	12,000	.06	35.00	.17
	Electrodeposition	335	12,000	.03	35.00	.09
	Incinerator & RACT coating	30	12,000	e	35.00	.01
	Waterborne (Convent.)	38	12,000	e	35.00	.01
H	Powder (Fld. Bd.)	27	1,182	.02	35.00	.06
	Electrodeposition	86	1,182	.07	35.00	.20
	Incinerator & RACT coating	24	1,182	.02	35.00	.06
	Waterborne (Convent.)	8	1,182	.01	35.00	.03

Table 7-61. PROFIT IMPACT

CHAIR PLANTS - NEW FACILITIES

SIP BASELINE

(Continued)

Plant	Control Option	Incremental annualized control cost[a] ($000)	# Chairs coated (000)	Incremental annualized control cost per chair coated[a] ($)	Profit margin impact F.O.B. price per chair ($)	Profit margin impact %
I	Powder (Fld. Bd.)	18	136	.13	35.00	.37
	Electrodeposition	33	136	.24	35.00	.69
	Waterborne (Convent.)	0	136	b	35.00	c
J	Waterborne	0	136	b	35.00	c

[a]Parentheses indicate decrease from baseline case.
[b]The profit impact changes significantly from the powder option based on data presented in Appendix E.
[c]No change in cost from baseline case.
[d]No negative impact on profit margin.
[e]Less than $.01.

Table 7-62. PROFIT IMPACT

CHAIR PLANTS - NEW FACILITIES

UNCONTROLLED BASELINE

Plant	Control Option	Incremental annualized control cost[a] ($000)	# Chairs coated (000)	Incremental annualized control cost per chair coated[a] ($)	Profit margin impact F.O.B. price per chair ($)	Profit margin impact %
B	Powder (spray) [b]	486	12,000	.04	35.00	.11
	Waterborne	354	12,000	.03	35.00	.09
	70% High solids	(194)	12,000	(.02)	35.00	d
	Incinerator & RACT coating	(48)	12,000	c	35.00	d
	65% High solids	(144)	12,000	(.01)	35.00	d
D	Powder (spray) [b]	101	1,182	.09	35.00	.26
	Waterborne	73	1,182	.06	35.00	.17
	70% High solids	(34)	1,182	(.03)	35.00	d
	Incinerator & RACT coating	13	1,182	.01	35.00	.03
	65% High solids	(24)	1,182	(.02)	35.00	d
F	Powder (spray) [b]	8	136	.06	35.00	.17
	Waterborne	14	136	.10	35.00	.29
	70% High solids	(2)	136	(.01)	35.00	d
	65% High solids	(2)	136	(.01)	35.00	d
G	Powder (Fld. Bd.)	790	12,000	.07	35.00	.20
	Electrodeposition	458	12,000	.04	35.00	.11
	Incinerator & RACT coating	153	12,000	.01	35.00	.03
	Waterborne (Convent.)	161	12,000	.01	35.00	.03
H	Powder (Fld. Bd.)	54	1,182	.05	35.00	.14
	Electrodeposition	113	1,182	.10	35.00	.29
	Incinerator & RACT coating	51	1,182	.04	35.00	.11
	Waterborne (Convent.)	35	1,182	.03	35.00	.09

Table 7-62. PROFIT IMPACT

CHAIR PLANTS - NEW FACILITIES

UNCONTROLLED BASELINE

(Continued)

Plant	Control Option	Incremental annualized control cost[a] ($000)	# Chairs coated (000)	Incremental annualized control cost per chair coated[a] ($)	Profit margin impact: F.O.B. price per chair ($)	Profit margin impact: %
I	Powder (Fld. Bd.)	28	136	.21	35.00	.60
	Electrodeposition	43	136	.32	35.00	.91
	Waterborne (Convent.)	10	136	.07	35.00	.20
J	Waterborne	10	136	.07	35.00	.20

[a]Parentheses indicate decrease from baseline case.
[b]The profit impact changes significantly from the powder option based on data presented in Appendix E.
[c]Decrease less than $.01.
[d]No negative impact on profit margin.

Table 7-63. PROFIT IMPACT

CHAIR PLANTS - MODIFIED/RECONSTRUCTED FACILITIES

SIP BASELINE

Plant	Control Option	Incremental annualized control cost[a] ($000)	# Chairs coated (000)	Incremental annualized control cost per chair coated[a] ($)	Profit margin impact: F.O.B. price per chair ($)	Profit margin impact: %
B	Powder (spray)[b]	715	12,000	.06	35.00	.17
	Waterborne	447	12,000	.04	35.00	.11
	70% High solids	(115)	12,000	(.01)	35.00	d
	Incinerator & RACT coating	33	12,000	e	35.00	.01
	65% High solids	(65)	12,000	(.01)	35.00	d
D	Powder (spray)[b]	144	1,182	.12	35.00	.34
	Waterborne	86	1,182	.07	35.00	.20
	70% High solids	(22)	1,182	(.02)	35.00	d
	Incinerator & RACT coating	24	1,182	.02	35.00	.06
	65% High solids	(12)	1,182	(.01)	35.00	d
F	Powder (spray)[b]	22	136	.16	35.00	.46
	Waterborne	18	136	.13	35.00	.37
	70% High solids	0	136	c	35.00	d
	65% High solids	0	136	c	35.00	d
G	Powder (Fld. Bd.)	853	12,000	.07	35.00	.20
	Electrodeposition	376	12,000	.03	35.00	.09
	Incinerator & RACT coating	32	12,000	e	35.00	.01
	Waterborne (Convent.)	37	12,000	e	35.00	.01
H	Powder (Fld. Bd.)	68	1,182	.06	35.00	.17
	Electrodeposition	132	1,182	.11	35.00	.31
	Incinerator & RACT coating	.17	1,182	.01	35.00	.03
	Waterborne (Convent.)	8	1,182	.01	35.00	.03

Table 7-63. PROFIT IMPACT

CHAIR PLANTS - MODIFIED/RECONSTRUCTED FACILITIES

SIP BASELINE

(Continued)

Plant	Control Option	Incremental annualized control cost[a] ($000)	# Chairs coated (000)	Incremental annualized control cost per chair coated[a] ($)	Profit margin impact: F.O.B. price per chair ($)	Profit margin impact: %
I	Powder (Fld. Bd.)	39	136	.29	35.00	.83
	Electrodeposition	40	136	.29	35.00	.83
	Waterborne (Convent.)	0	136	c	35.00	d
J	Waterborne	0	136	c	35.00	d

[a]Parentheses indicate decrease from baseline case.
[b]The profit impact changes significantly from the powder option based on data presented in Appendix E.
[c]No negative impact on profit margin.
[d]Less than $.01.

Table 7-64. PROFIT IMPACT

CHAIR PLANTS - MODIFIED/RECONSTRUCTED FACILITIES

UNCONTROLLED BASELINE

Plant	Control Option	Incremental annualized control cost[a] ($000)	# Chairs coated (000)	Incremental annualized control cost per chair coated[a] ($)	Profit margin impact: F.O.B. price per chair ($)	Profit margin impact: %
B	Powder (spray)[b]	639	12,000	.05	35.00	.14
	Waterborne	371	12,000	.03	35.00	.09
	70% High solids	(135)	12,000	(.01)	35.00	d
	Incinerator & RACT coating	12	12,000	c	35.00	e
	65% High solids	(85)	12,000	(.01)	35.00	d
D	Powder (spray)[b]	129	1,182	.11	35.00	.31
	Waterborne	73	1,182	.06	35.00	.17
	70% High solids	(24)	1,182	(.02)	35.00	d
	Incinerator & RACT coating	23	1,182	.02	35.00	.06
	65% High solids	(14)	1,182	(.01)	35.00	d
F	Powder (spray)[b]	20	136	.15	35.00	.43
	Waterborne	16	136	.12	35.00	.34
	70% High solids	(1)	136	(.01)	35.00	d
	65% High solids	(1)	136	(.01)	35.00	d
G	Powder (Fld. Bd.)	843	12,000	.07	35.00	.20
	Electrodeposition	366	12,000	.03	35.00	.09
	Incinerator & RACT coating	155	12,000	.01	35.00	.03
	Waterborne (Convent.)	162	12,000	.01	35.00	.03
H	Powder (Fld. Bd.)	71	1,182	.06	35.00	.17
	Electrodeposition	135	1,182	.11	35.00	.31
	Incinerator & RACT coating	52	1,182	.04	35.00	.11
	Waterborne (Convent.)	29	1,182	.02	35.00	.06

Table 7-64. PROFIT IMPACT

CHAIR PLANTS - MODIFIED/RECONSTRUCTED FACILITIES

UNCONTROLLED BASELINE

(Continued)

Plant	Control Option	Incremental annualized control cost[a] ($000)	# Chairs coated (000)	Incremental annualized control cost per chair coated[a] ($)	Profit margin impact: F.O.B. price per chair ($)	Profit margin impact: %
I	Powder (Fld. Bd.)	38	136	.28	35.00	.80
	Electrodeposition	39	136	.29	35.00	.83
	Waterborne (Convent.)	10	136	.07	35.00	.20
J	Waterborne	10	136	.07	35.00	.20

[a]Parentheses indicate decrease from baseline case.
[b]The profit impact changes significantly from the powder option based on data presented in Appendix E.
[c]Less than $.01.
[d]No negative impact on profit margin.
[e]Negative impact on profit margins less than .01 percent.

the 65 percent high solids option, savings are experienced in all but two situations, in which there is no change in cost from the baseline case. For any given control option, costs tend to vary inversely with the size of the plant.

Cost for chair plants. As pointed out earlier, in the case of the chair plants, separate models have been developed for spray, dip-coating, and flow-coating operations.

Plants B, D, and F employ the spray-coating method. For Plants B and D, the most expensive control option is powder, (applied at a film thickness of 2.5 mil) for which the incremental costs per chair range from $.04 to $.12. However, based on data presented in Appendix E, the powder option may produce a savings for Plant D. This is followed by waterborne whose costs vary from $.03 to $.07 per chair coated. In the case of Plant F, the most expensive option for new facilities is waterborne ($.12 per chair for SIP baseline and $.10 per chair for uncontrolled baseline). Among the three plants, savings are experienced with the 70 percent high solids option in all but two situations, where there is no change in cost from the baseline case. For incineration plus RACT coating (does not apply to Plant F), costs range from a saving in one situation to a maximum of $.02 per chair. The 65 percent high solids option results in savings in all but two situations where there is no change in cost from the baseline situation.

Plants G, H, and I employ the dip-coating method. The control options are conventional waterborne, incinerator plus RACT coating, powder (fluidized bed), and waterborne with electrodeposition. For Plant G, the most expensive option is powder (fluidized bed), for which the incremental cost per chair coated is $.06 for new facilities relative to the SIP baseline, and $.07 for the other three facility/baseline combinations. This is followed by electrodeposition, the costs of which $.04 per chair in one case, and $.03 in the other three cases. With respect to Plants H and I, the most expensive control option is electrodeposition. Among these two plants, the cost of this option ranges from $.07 to $.32 per chair coated. Powder is next, with costs ranging from $.02 to $.29 per chair. For all three of the plants, the costs of the conventional waterborne option are relatively low, ranging from a situation of no change in cost from the baseline to $.07 per chair coated. The option involving incineration plus RACT coating has costs varying from less than \$.01 to \$.04 (this option does not apply to Plant I).

In the case of Plant J, which employs dip-coating, the only control option considered is conventional waterborne. The incremental costs for this option range from zero to \$.07 per chair.

7.4.4.3 Profit Impact. The impact of the control options on model plant profits was examined using a form of "worst case" analysis which assumed that the incremental annualized control costs would be fully absorbed by the plants. Measurement of impact was carried out in two steps. The first step involved calculating the extent to which the profit margin on sales for each shelf or chair would be affected by the incremental control costs. This was done as follows:

$$\frac{\text{Incremental Annualized Control Cost Per Shelf or Chair}}{\text{F.O.B. Price Per Shelf or Chair}} \times 100 = \text{Profit Margin Impact Per Shelf or Chair}$$

The data used for this calculation are presented in the third through sixth columns in Tables 7-57 to 7-64. The F.O.B. price used for shelves is \$25.55; for chairs; \$35.00. The impacts, expressed as percentages, are given in the seventh column in each of the tables. These percentages are the amounts by which the profit margins for the shelves or chairs would be reduced if the incremental control costs were fully absorbed, rather than being passed on to the consumer in the form of a price increases. (Note that when interpreted differently, this type of calculation can be used to determine maximum price increase.) It will be noted that in the seventh column, impact figures are not given for some of the control options. In these cases, the impact of the option on the profit margin is either positive because of attendant cost savings or neutral because of there being no change in cost from the baseline case.

In the second step, the impact on total model plant profits was determined as follows:

$$\frac{\text{Profit Margin Impact Per Shelf or Chair}}{\text{Average Profit Rate on Sales for Industry}} \times 100 = \text{Impact on Model Plant Profits}$$

This calculation was performed for every plant control option combination exhibiting impairment of profit in the first step above. The profit rate (on sales) used in the divisor were determined by the industry group affiliation of the model plant in question. The profit rates were obtained from the 1978 edition of Annual Statement Studies, published by Robert Morris Associates. The rates used were as follows: SIC 2514, 5.6 percent; SIC 2522, 4.8 percent; and SIC 2542, 4.3 percent. No rate for SIC 2531 was available. With the exception of cases involving Plants A, B, and G, the figures on profit margin impact per shelf or chair were divided by all three of the profit rates. This is due to the fact that with the exception of A, B, and G, all of the model plants are associated with all four of the SIC groups comprising the metal furniture industry. Plants A, B, and G are associated only with SIC 2522. The percentage figures resulting from the calculations are indicative of the extent to which plant profits would be reduced as a result of having to fully absorb the incremental control costs involved.

The results of the analysis are presented in Tables 7-65 to 7-68. An impact on a plant was said to be "major" if the impairment to profits amounted to 15 percent or more. The rationale for determining that a 15 percent reduction in profits constitutes a major impact was established as follows: A general criterion applicable to the four SIC groups and the control options involved was established on the basis of the degree of impact that would lead to a decision not to invest in a new source in the most marginal of the four SIC groups. After selecting the least profitable SIC group (as based on the published data), a discounted cash flow (DCF) analysis was performed to determine what percent increase in operating costs would cause the investment to be rejected on economic grounds, when it would otherwise be justified before controls.

The DCF technique estimates and compares cash inflows and outflows over the life of the project (i.e., new, modified, or reconstructed metal furniture coating lines). The changing value of money over time is considered in the comparisons by discounting those cash flows to the present time. The discount rate used is the firm's cost of capital. If the present value of the discounted cash outflows, the project is economically justified.

Table 7-65. PROFIT IMPAIRMENT

SHELVING PLANTS - NEW FACILITIES

SIP AND UNCONTROLLED BASELINES

Plant	Control Option	% Impairment at profit rates below					
		SIP baseline			Uncontrolled baseline		
		4.3%	4.8%	5.6%	4.3%	4.8%	5.6%
A	Powder (spray)[a]	b	14.58	b	b	13.95	b
	Waterborne	b	5.63	b	b	4.79	b
	70% High solids	b	c	b	b	c	b
	Incinerator & RACT coating	b	0.83	b	b	c	b
	65% High solids	b	c	b	b	c	b
C	Powder (spray)[a]	17.20	15.41	13.21	16.28	14.58	12.50
	Waterborne	7.21	6.46	5.54	5.35	4.79	4.11
	70% High solids	c	c	c	c	c	c
	Incinerator & RACT coating	2.79	2.50	2.14	1.86	1.67	1.43
	65% High solids	c	c	c	c	c	c
E	Powder (spray)[a]	24.65	22.08	18.93	18.13	16.25	13.93
	Waterborne	18.14	16.25	13.73	11.86	10.63	9.11
	70% High solids	d	d	d	c	c	c
	65% High solids	d	d	d	c	c	c

[a] The profit impairment changes significantly for the powder option based on data presented in Appendix E.
[b] Profit rate does not apply to this plant.
[c] No profit impairment involved. Incremental annualized cost for this control option is negative - i.e., there is a decrease in cost from the baseline case.
[d] No profit impairment involved. Incremental annualized cost for this control option is zero - i.e., there is no change in cost from the baseline case.

Table 7-66. PROFIT IMPAIRMENT

SHELVING PLANTS - MODIFIED/RECONSTRUCTED FACILITIES

SIP AND UNCONTROLLED BASELINES

Plant	Control Option	% Impairment at profit rates below					
		SIP baseline			Uncontrolled baseline		
		4.3%	4.8%	5.6%	4.3%	4.8%	5.6%
A	Powder (spray)[a]	b	17.08	b	b	15.42	b
	Waterborne	b	6.46	b	b	4.79	b
	70% High solids	b	c	b	b	c	b
	Incinerator & RACT coating	b	0.83	b	b	c	b
	65% High solids	b	c	b	b	c	b
C	Powder (spray)[a]	21.86	19.58	16.79	20.00	17.92	15.36
	Waterborne	7.21	6.46	5.54	6.28	5.63	4.82
	70% High solids	c	c	c	c	c	c
	Incinerator & RACT coating	2.79	2.50	2.14	2.79	2.50	2.14
	65% High solids	c	c	c	c	c	c
E	Powder (spray)[a]	44.65	40.00	34.29	38.14	34.17	29.29
	Waterborne	24.65	22.08	18.93	18.14	16.25	13.93
	70% High solids	d	d	d	c	c	c
	65% High solids	d	d	d	c	c	c

[a]The profit impairment changes significantly for the powder option based on data presented in Appendix E.
[b]Profit rate does not apply to this plant.
[c]No profit impairment involved. Incremental annualized cost for this control option is negative - i.e., there is a decrease in cost from the baseline case.
[d]No profit impairment involved. Incremental annualized cost for this control option is zero - i.e., there is no change in cost from the baseline case.

Table 7-67. PROFIT IMPAIRMENT

CHAIR PLANTS - NEW FACILITIES

SIP AND UNCONTROLLED BASELINES

Plant	Control Option	% Impairment at profit rates below: SIP baseline 4.3%	SIP baseline 4.8%	SIP baseline 5.6%	Uncontrolled baseline 4.3%	Uncontrolled baseline 4.8%	Uncontrolled baseline 5.6%
B	Powder (spray) [a]	b	2.92	b	b	2.29	b
	Waterborne	b	2.29	b	b	1.88	b
	70% High solids	b	c	b	b	c	b
	Incinerator & RACT coating	b	0.21	b	b	c	b
	65% High solids	b	c	b	b	c	b
D	Powder (spray) [a]	6.74	6.04	5.18	6.05	5.42	4.64
	Waterborne	4.65	4.17	3.57	3.95	3.54	3.04
	70% High solids	c	c	c	c	c	c
	Incinerator & RACT coating	1.40	1.25	1.07	0.70	0.63	0.54
	65% High solids	c	c	c	c	c	c
F	Powder (spray) [a]	4.65	4.17	3.57	3.95	3.54	3.04
	Waterborne	7.91	7.08	6.07	6.74	6.04	5.18
	70% High solids	d	d	d	c	c	c
	65% High solids	d	d	d	c	c	c
G	Powder (fluidized bed)	b	3.54	b	b	4.17	b
	Electrodeposition	b	1.88	b	b	2.29	b
	Incinerator & RACT coating	b	0.23	b	b	0.63	b
	Waterborne (Convent.)	b	0.23	b	b	0.63	b
H	Powder (fluidized bed)	1.40	1.25	1.07	3.26	2.92	2.50
	Electrodeposition	4.65	4.17	3.57	6.74	6.04	5.18
	Incinerator & RACT coating	1.40	1.25	1.07	2.56	2.29	1.96
	Waterborne (Convent.)	0.70	0.63	0.54	2.09	1.88	1.61

Table 7-67. PROFIT IMPAIRMENT

CHAIR PLANTS - NEW FACILITIES

SIP AND UNCONTROLLED BASELINES

(Continued)

		% Impairment at profit rates below					
	Control	SIP baseline			Uncontrolled baseline		
Plant	Option	4.3%	4.8%	5.6%	4.3%	4.8%	5.6%
I	Powder (fluidized bed)	8.60	7.71	6.61	13.95	12.50	10.71
	Electrodeposition	16.05	14.38	12.32	21.16	18.96	16.25
	Waterborne (Convent.)	d	d	d	4.65	4.17	3.57
J	Waterborne	d	d	d	4.65	4.17	3.57

[a]The profit impairment changes significantly for the powder option based on data presented in Appendix E.
[b]Profit rate does not apply to this plant.
[c]No profit impairment involved. Incremental annualized cost for this control option is negative - i.e., there is a decrease in cost from the baseline case.
[d]No profit impairment involved. Incremental annualized cost for this control option is zero - i.e., there is no change in cost from the baseline case.

Table 7-68. PROFIT IMPAIRMENT

CHAIR PLANTS - MODIFIED/RECONSTRUCTED FACILITIES

SIP AND UNCONTROLLED BASELINES

Plant	Control Option	% Impairment at profit rates below: SIP baseline 4.3%	SIP baseline 4.8%	SIP baseline 5.6%	Uncontrolled baseline 4.3%	Uncontrolled baseline 4.8%	Uncontrolled baseline 5.6%
B	Powder (spray)[a]	b	3.54	b	b	2.92	b
	Waterborne	b	2.29	b	b	1.88	b
	70% High solids	b	c	b	b	c	b
	Incinerator & RACT coating	b	0.21	b	b	0.06	b
	65% High solids	b	c	b	b	c	b
D	Powder (spray)[a]	7.91	7.08	6.07	7.21	6.46	5.54
	Waterborne	4.65	4.17	3.57	3.95	3.54	3.04
	70% High solids	c	c	c	c	c	c
	Incinerator & RACT coating	1.40	1.25	1.07	1.40	1.25	1.07
	65% High solids	c	c	c	c	c	c
F	Powder (spray)[a]	10.70	9.58	8.21	10.00	8.96	7.68
	Waterborne	8.60	7.71	6.61	7.91	7.08	6.07
	70% High solids	d	d	d	c	c	c
	65% High solids	d	d	d	c	c	c
G	Powder (fluidized bed)	b	4.17	b	b	4.17	b
	Electrodeposition	b	1.88	b	b	1.88	b
	Incinerator & RACT coating	b	0.21	b	b	0.63	b
	Waterborne (Convent.)	b	0.21	b	b	0.63	b
H	Powder (fluidized bed)	3.95	3.54	3.04	3.95	3.54	3.04
	Electrodeposition	7.21	6.46	5.54	7 21	6.46	5.54
	Incinerator & RACT coating	0.70	0.63	0.54	2.56	2.29	1.96
	Waterborne (Convent.)	0.70	0.63	0.54	0.70	0.63	0.54

Table 7-68. PROFIT IMPAIRMENT

CHAIR PLANTS - MODIFIED/RECONSTRUCTED FACILITIES

SIP AND UNCONTROLLED BASELINES

(Continued)

Plant	Control Option	% Impairment at profit rates below					
		SIP baseline			Uncontrolled baseline		
		4.3%	4.8%	5.6%	4.3%	4.8%	5.6%
I	Powder (fluidized bed)	19.30	17.29	14.82	18.60	16.67	14.29
	Electrodeposition	19.30	17.29	14.82	19.30	17.29	14.82
	Waterborne (Convent.)	d	d	d	4.65	4.17	3.57
J	Waterborne	d	d	d	4.65	4.17	3.57

[a]The profit impairment changes significantly for the powder option based on data presented in Appendix E.
[b]Profit rate does not apply to this plant.
[c]No profit impairment involved. Incremental annualized cost for this control option is negative - i.e., there is a decrease in cost from the baseline case.
[d]No profit impairment involved. Incremental annualized cost for this control option is zero - i.e., there is no change in cost from the baseline case.

The DCF technique is considered appropriate for decision-making on a profit maximizing basis, and has the capacity to address all of the important economic variables involved in such a decision context. It is recognized that factors other than profit maximization may exert considerable influence in individual plant investment decision (maintenance or enhancement of market share is one example); however, such factors are generally not amenable to objective analysis.

According to Robert Morris Associates (RMA) data, SIC 2522 (metal office furniture) has the lowest pre-tax profit rate on sales -- 5.7 percent -- as averaged over the past four years. Based on this profit rate and other RMA financial ratios for the same SIC group, a DCF analysis was performed to compare the investment decision before and after the imposition of pollution control. The analysis indicated that before controls the investment in a metal furniture coating line would be justified. However, if a 15 percent profit reduction were to occur after controls the project would only return the minimum acceptable rate of return on the investment and therefore be considered in the realm of indifference. The calculations are shown in Table 7-69.

The table shows the derivation of cash flow estimates before and after pollution control. The "after" column differences from the "before" column occur in annualized costs, depreciation, interest, working capital, and capital (investment) costs, and are all attributable to the control costs. All the costs are expressed on a per unit chair basis.

The first cash inflow to derive is profit after taxes before and after control. In the table, revenue remains constant before and after since it is assumed that control costs will be absorbed. Production costs and depreciation are subtracted from revenue to obtain profits before taxes. The higher production cost figure "after" control is attributable to control costs. The specific figure was derived on a trial and error basis. The higher "after" depreciation figure was based on an average (for the control options) of 15 percent of annualized control costs being comprised of depreciation. The increase in annual control costs (shown on the table as an increase in production costs) is \$.19. Depreciation is therefore 15 percent of \$.19, or \$.03.

Table 7-69. DCF ANALYSIS FOR DETERMINING GENERAL CRITERIA FOR MAJOR PROFIT IMPAIRMENT

	Before pollution control	After pollution control
Revenue Per Chair	$ 25.55	$ 25.55
- Prod. costs	23.58	23.77[a,b]
- Depr. (2% of revenue; before control	.51	.54[a,c]
= Profits before taxes (5.7% of sales, before control)	1.46	1.24
- Taxes (46%)	.67	.57
= Profit after taxes	.79	.67
+ Depr.	.51	.54[a]
+ Interest x (1 - tax rate)[f]	.37	.39[a]
= Net cash inflow/year	1.67	1.60
x Discount factor for 15 years at 10% discount rate	7.7688 12.97	7.7688 12.43
+ Working capital recovery	.73	.75[a]
+ Pollution control investment tax credit		.05[a,e]
Net present value of cash inflows	$ 13.70	$ 13.23
Investment (cash outflow) at 2:1 sales to assets ratio (before control)	$ 12.78	$ 13.23[a,d]
Decision:	Invest	Indifferent

[a]Including pollution control

[b]Increase derived on iterative basis, i.e., trial and error.

[c]Based on control depreciation being an average of 15% of annualized control costs.

[d]Incremental investment (i.e. difference between $13.23 and $12.78) equals yearly increase in depreciation at $.03 times 15 years = $.45.

[e]10% times incremental investment cost of $.45.

[f]Tax rate = 46%

Source of Data: Annual Statement Sudies, Robert Morris Associates, Philadelphia, PA.

Since the DCF analysis is based on cash flows, the tax savings from depreciation and the interest on borrowed money must be added to profits after taxes. The higher "after" control figures for depreciation and interest are attributable to pollution control.

The next cash inflow figure is on a yearly basis and must be multiplied by the discount factor for 15 years. The figure is multiplied by 7.7688 years versus 15 years to take into account the reduced value of money over time represented by the discount factor of 10 percent, which was not derived but adopted as a reasonable cost of capital. Added to this running cash flow figure is the present value of the working capital which is initially invested and then recovered at the end of fifteen years. The $.73 is derived as 25 percent of the initial investment times the 15-year discount rate. The higher "after" figure for working capital recovery is that which is added for control. The last cash inflow is the investment tax credit attributable to the control capital (investment) cost of 10 percent times $.45. The $.45 represents the average yearly depreciation of $.03 times 15 years.

The cash outflow line is represented by the initial investment which on a per unit chair basis is one-half of the revenue. To that must be added the $.45 investment derived above to reflect the incremental control capital costs.

The last line of the table indicates a decision to invest before control since the 13.70 cash inflow exceeds the 12.78 cash outflow. However, the after control line shows indifference since cash outflows after control equal the cash inflow. A 15 percent reduction in profits is what provided the indifference level and is thus adopted as the criterion for major profitability impact.

As can be seen in Tables 7-65 and 7-66, all shelving plants are subject to a major profit impairment when powder is applied at a film thickness of 6.35×10^{-3}cm (2.5 mil). However, the profit impairment is not significant (see Appendix E) if powder (spray) is applied at a film thickness of 3.81×10^{-3}cm (1.5 mil). For the waterborne option, Plant E (the smallest) is the only one subject to major impacts. In the case of the 70 percent high solids option, none of the plants are subject to major impacts -- in fact, all of the plants are either favorably impacted or not impacted at all. The situation is similar for the 65 percent high solids option. For incineration plus RACT coating (which does not apply to Plant E), the profit reductions are relatively small. In general, for any given control option, the magnitude of the impact tends to vary inversely with the size of the plant. For example, in the case of new facilities relative to the SIP baseline, the impact of the waterborne option varies (assuming a 4.8 percent profit rate) from 16.25 percent for Plant E (45,000m^2/year coated), to 6.46 percent for Plant C (780,000m^2/year coated), to 5.63 percent for Plant A (4,000,000m^2/year coated). Thus, assuming that two plants of unequal size employ the same control option, the smaller plant will usually be at a disadvantage relative to the larger.

Profit impacts for the chair plants are presented in Tables 7-67 and 7-68. Of the seven chair plants, Plant I (small dip-coating plant) is the only one subject to major impacts. These impacts are associated with the powder and electrodeposition control options. In the case of powder, the major impacts are exhibited for modified/reconstructed facilities relative to both the SIP and uncontrolled baselines, and range in magnitude from 16.67 percent to 19.30 percent. In the case of electrodeposition, major profit reductions are indicated for both new and modified/reconstructed facilities, relative to both baselines. The reductions range in value from 16.05 percent to 21.16 percent. Among all of the chair plants, no profit reduction is associated with the 70 percent and 65 percent high solids options. For incineration with RACT coating, the largest impact is relatively minor (only 2.56 percent). In the case of waterborne, the greatest profit reduction is 8.60 percent. As with the shelving plants, for any given control option, the severity of profit impairment exhibited among the chair plants tends to vary inversely with plant size. For instance, in the case of new facilities relative to the SIP baseline, the impact of the electrodeposition control option ranges (assuming a 4.8 percent profit rate) from 14.38 percent for Plant I (780,000 m^2/year coated), to 1.88 percent for Plant G (4,000 m^2/year coated).

7.4.4.4 <u>Impact on Capital Availability</u>. The impact of the control options on the availability of capital was determined in the following way.

First, annual sales were calculated for each of the ten model plants. This was done by multiplying the number of shelves or chairs produced per year by the F.O.B. price - \$25.55 for shelves and \$35.00 for chairs.

Next, the assets for each of the model plants were derived by utilizing sales/total assets ratios obtained from the 1978 edition of Annual Statement Studies, published by Robert Morris Associates. In situations where a given model plant was said to correspond to more than one SIC group, different ratios were applied to account for this factor. The ratios used were as follows: SIC 2514, 2.2; SIC 2522, 1.8; and SIC 2542, 2.5. No ratio was available for SIC 2531. The asset bases computed by this method are shown in Table 7-70.

For each model plant, the impact of a given regulatory alternative on capital availability was determined as follows:

$$\frac{\text{Incremental Capital Cost of Regulatory Alternative}}{\text{Total Assets}} \times 100 = \text{Impact on Capital Availability}$$

The incremental capital cost for a regulatory alternative is obtained by subtracting the capital cost for the baseline case from the capital cost for the alternative. The incremental costs are presented in Tables 7-71 and 7-72.

Results of the analysis are presented in Tables 7-73 and 7-74. Increases in capital requirements of 10 percent or more were considered to be major. The rationale for this criterion was established in the following way. A general criterion applicable to the four SIC groups and the regulatory alternatives involved was established on the basis of the increase in capital requirements that would cause the ratio of cash flow to current maturities of long-term debt to fall below 2:1. This ratio is viewed by the banking community as an indicator of the ability of cash flow to cover debts. As a general rule of thumb, a ratio of 2:1 is considered marginal. The circumstances of individual cases sometimes warrant that loans be made when the ratio is less than 2:1; nonetheless, the ratio of 2:1 is an indication of potential problems.

Table 7-70. ESTIMATED ASSETS FOR MODEL PLANTS[a]

Plant	Sales ($000)	Assets ($000)		
		SIC 2514	SIC 2522	SIC 2542
A	102,200	b	56,778	b
B	420,000	b	233,333	b
C	19,929	9,059	11,072	7,972
D	41,370	18,805	22,983	16,548
E	1,150	523	639	460
F	4,760	2,164	2,644	1,904
G	420,000	b	233,333	b
H	41,370	18,805	22,983	16,548
I	4,760	2,164	2,644	1,904
J	4,760	2,164	2,644	1.904

[a]Sales/total assets ratios used:

SIC 2514: 2.2

SIC 2522: 1.8

SIC 2542 2.5

[b]Plant is not associated with this SIC group.

Table 7-71. INCREMENTAL CAPITAL COSTS FOR NEW FACILITIES
($000)

		Increments relative to:	
Plant	Control Option	SIP[a]	Uncontrolled
A	Powder (spray)	240	240
	Waterborne	678	678
	70% High solids	0	0
	Incinerator & RACT coating	130	130
	65% High solids	0	0
B	Powder (spray)	417	417
	Waterborne	1,044	1,044
	70% High solids	0	0
	Incinerator & RACT coating	130	130
	65% High solids	0	0
C	Powder (spray)	83	83
	Waterborne	203	203
	70% High solids	0	0
	Incinerator & RACT coating	110	110
	65% High solids	0	0
D	Powder (spray)	84	84
	Waterborne	208	208
	70% High solids	0	0
	Incinerator & RACT coating	110	110
	65% High solids	0	0
E	Powder(spray)	29	29
	Waterborne	31	31
	70% High solids	0	0
	65% High solids	0	0
F	Powder(spray)	32	32
	Waterborne	67	67
	70% High solids	0	0
	65% High solids	0	0
G	Powder (fld.bed)	(110)	633
	Electrodeposition	2,416	3,159
	Incinerator & RACT coating	110	853
	Waterborne (convent.)	0	743

Table 7-71. INCREMENTAL CAPITAL COSTS FOR NEW FACILITIES
($000)
(continued)

Plant	Control Option	Increments relative to: SIP	Uncontrolled
H	Powder (fluidized bed)	(20)	127
	Electrodeposition	914	1,061
	Incinerator & RACT coating	110	257
	Waterborne (convent.)	0	147
I	Powder (fluidized bed)	(25)	34
	Electrodeposition	171	230
	Waterborne (convent.)	0	59
J	Waterborne	0	59

[a]Parentheses indicate decrease from baseline case.

Table 7-72. INCREMENTAL CAPITAL COSTS FOR MODIFIED/RECONSTRUCTED FACILITIES ($000)

Plant	Control Option	Increments relative to: SIP	Increments relative to: Uncontrolled
A	Powder (spray)	750	750
	Waterborne	707	707
	70% High solids	0	180
	Incinerator & RACT coating	130	310
	65% High solids	0	180
B	Powder (spray)	1,325	1,325
	Waterborne	1,110	1,110
	70% High solids	0	300
	Incinerator & RACT coating	130	430
	65% High solids	0	300
C	Powder (spray)	250	250
	Waterborne	215	215
	70% High solids	0	60
	Incinerator & RACT coating	110	170
	65% High solids	0	60
D	Powder (spray)	260	260
	Waterborne	222	222
	70% High solids	0	60
	Incinerator & RACT coating	110	170
	65% High solids	0	60
E	Powder(spray)	90	90
	Waterborne	57	57
	70% High solids	0	5
	65% High solids	0	5
F	Powder(spray)	100	100
	Waterborne	72	72
	70% High solids	0	5
	65% High solids	0	5
G	Powder (fld.bed)	1,040	1,040
	Electrodeposition	2,626	2,626
	Incinerator & RACT coating	130	873
	Waterborne (convent.)	0	743

Table 7-72. INCREMENTAL CAPITAL COSTS FOR MODIFIED/RECONSTRUCTED FACILITIES
($000)
(continued)

Plant	Control Option	Increments relative to: SIP	Uncontrolled
H	Powder (fluidized bed)	210	210
	Electrodeposition	904	904
	Incinerator & RACT coating	110	257
	Waterborne (convent.)	0	147
I	Powder (fluidized bed)	90	90
	Electrodeposition	211	211
	Waterborne (convent.)	0	59
J	Waterborne	0	59

Table 7-73. CAPITAL AVAILABILITY IMPACT FOR NEW FACILITIES

Plant	Control Option	% Impact relative to SIP baseline SIC 2514	SIC 2522	SIC 2542	% Impact relative to uncontrolled baseline SIC 2514	SIC 2522	SIC 2542
A	Powder (spray)	a	.42	a	a	.42	a
	Waterborne	a	1.19	a	a	1.19	a
	70% High solids	a	b	a	a	b	a
	Incinerator & RACT coating	a	.23	a	a	.23	a
	65% High solids	a	b	a	a	b	a
B	Powder (spray)	a	.18	a	a	.18	a
	Waterborne	a	.45	a	a	.45	a
	70% High solids	a	b	a	a	b	a
	Incinerator & RACT coating	a	.06	a	a	.06	a
	65% High solids	a	b	a	a	b	a
C	Powder (spray)	.92	.75	1.04	.92	.75	1.04
	Waterborne	2.24	1.83	2.55	2.24	1.83	2.55
	70% High solids	b	b	b	b	b	b
	Incinerator & RACT coating	1.21	.99	1.38	1.21	.99	1.38
	65% High solids	b	b	b	b	b	b
D	Powder (spray)	.45	.37	.51	.45	.37	.51
	Waterborne	1.11	.91	1.26	1.11	.91	1.26
	70% High solids	b	b	b	b	b	b
	Incinerator & RACT coating	.58	.48	.66	.58	.48	.66
	65% High solids	b	b	b	b	b	b
E	Powder(spray)	5.54	4.54	6.30	5.54	4.54	6.30
	Waterborne	5.93	4.85	6.74	5.93	4.85	6.74
	70% High solids	b	b	b	b	b	b
	65% High solids	b	b	b	b	b	b
F	Powder(spray)	1.48	1.21	1.68	1.48	1.21	1.68
	Waterborne	3.10	2.53	3.52	3.10	2.53	3.52
	70% High solids	b	b	b	b	b	b
	65% High solids	b	b	b	b	b	b
G	Powder (fld.bed)	a	c	a	a	.27	a
	Electrodeposition	a	1.04	a	a	1.35	a
	Incinerator & RACT coating	a	.05	a	a	.37	a
	Waterborne (convent.)	a	b	a	a	.32	a

(continued)

Table 7-73. CAPITAL AVAILABILITY IMPACT FOR NEW FACILITIES (continued)

Plant	Control Option	% Impact relative to SIP baseline SIC 2514	SIC 2522	SIC 2542	% Impact relative to uncontrolled baseline SIC 2514	SIC 2522	SIC 2542
H	Powder (fld. bed)				.68	.55	.77
	Electrodeposition	4.86	3.98	5.52	5.64	4.62	6.41
	Incinerator & RACT coating	.58	.48	.66	1.37	1.12	1.55
	Waterborne (convent.)				.78	.64	.89
I	Powder (fld. bed)				1.57	1.29	1.79
	Electrodeposition	7.90	6.47	8.98	10.63	8.70	12.08
	Waterborne (convent.)				2.73	2.23	3.10
J	Waterborne				2.73	2.23	3.10

[a] Plant is not associated with this SIC group.
[b] No impact involved - capital cost unchanged from baseline case.
[c] No impact involved - decrease in capital cost from baseline case.

Table 7-74. CAPITAL AVAILABILITY IMPACT FOR MODIFIED/RECONSTRUCTED FACILITIES

		% Impact relative to SIP baseline			% Impact relative to uncontrolled baseline		
Plant	Control Option	SIC 2514	SIC 2522	SIC 2542	SIC 2514	SIC 2522	SIC 2542
A	Powder (spray)	a	1.32	a	a	1.32	a
	Waterborne	a	1.25	a	a	1.25	a
	70% High solids	a	b	a	a	.32	a
	Incinerator & RACT coating	a	.23	a	a	.55	a
	65% High solids	a	b	a	a	.32	a
B	Powder (spray)	a	.57	a	a	.57	a
	Waterborne	a	.48	a	a	.48	a
	70% High solids	a	b	a	a	.13	a
	Incinerator & RACT coating	a	.06	a	a	.18	a
	65% High solids	a	b	a	a	.13	a
C	Powder (spray)	2.76	2.26	3.14	2.76	2.26	3.14
	Waterborne	2.37	1.94	2.70	2.37	1.94	2.70
	70% High solids		b	b	.66	.54	.76
	Incinerator & RACT coating	1.21	.99	1.38	1.88	1.54	2.13
	65% High solids	b	b	b	.66	.54	.76
D	Powder (spray)	1.38	1.13	1.57	1.38	1.13	1.57
	Waterborne	1.18	.97	1.34	1.18	.97	1.34
	70% High solids	b	b	b	.32	.26	.36
	Incinerator & RACT coating	.58	.48	.66	.90	.74	1.03
	65% High solids	b	b	b	.32	.26	.36
E	Powder(spray)	17.21	14.08	19.56	17.21	14.08	19.56
	Waterborne	10.90	8.92	12.39	10.90	8.92	12.39
	70% High solids	b	b	b	.96	.78	1.09
	65% High solids	b	b	b	.96	.78	1.09
F	Powder(spray)	4.62	3.78	5.25	4.62	3.78	5.25
	Waterborne	3.33	2.72	3.78	3.33	2.72	3.78
	70% High solids	b	b	b	.23	.19	.26
	65% High solids	b	b	b	.23	.19	.26
G	Powder (fld.bed)	a	.45	a	a	.45	a
	Electrodeposition	a	1.13	a	a	1.13	a
	Incinerator & RACT coating	a	.06	a	a	.37	a
	Waterborne (convent.)	a	b	a	a	.32	a

(continued)

Table 7-74. CAPITAL AVAILABILITY IMPACT FOR MODIFIED/RECONSTRUCTED FACILITIES (continued)

		% Impact relative to SIP baseline			% Impact relative to uncontrolled baseline		
Plant	Control Option	SIC 2514	SIC 2522	SIC 2542	SIC 2514	SIC 2522	SIC 2542
H	Powder (fld. bed)	1.12	.91	1.27	1.12	.91	1.27
	Electrodeposition	4.81	3.93	5.46	4.81	3.43	5.46
	Incinerator & RACT coating	.58	.48	.66	1.37	1.12	1.55
	Waterborne (convent.)	b	b	b	.78	.64	.89
I	Powder (fld. bed)	4.16	3.40	4.73	4.16	3.40	4.73
	Electrodeposition	9.75	7.98	11.08	9.75	7.98	11.08
	Waterborne (convent.)	b	b	b	2.73	2.23	3.10
J	Waterborne	b	b	b	2.73	2.23	3.10

[a]Plant is not associated with this SIC group.
[b]No impact involved - capital cost unchanged from baseline case.

Table 7-75. CASH FLOW TO CURRENT MATURITIES OF LONG-TERM DEBT ANALYSIS

Cash Flow From Model Plant of Table 7-69:

Net profits	.79
+ Depreciation	.51
= Net cash flow	1.30
÷ 2.2 (pre-control ratio of cash flow to current maturities of long-term debt[a]	.59
÷ 2.0 (ratio considered as marginal)	.65

$$\frac{.65 - .59}{.59} = 10\% \text{ increase}$$

[a]Source: Annual Statement Studies, Robert Morris Associates, Phila., PA.

For the metal office furniture component (SIC 2522) chosen earlier in the profit impact assessment as the least profitable of the four SIC groups involved in this analysis, the Robert Morris Associates data shows the ratio of cash flow to current maturities of long-term debt as 2.2:1. Table 7-75, which builds upon the discounted cash flow analysis presented in Table 7-69, shows that a 10 percent increase in the current maturities of long-term debt would reduce the ratio to 2:1. This percentage change in capital requirements was chosen as a level of potentially major impact.

A review of the data in Table 7-73 and 7-74 reveals that, in the case of shelving plants, Plant E is the only one subject to major impact. The impacts are associated with the waterborne options and if powder is applied at a film thickness of 6.35×10^{-3}cm (2.5 mil). For chairs, Plant I (small dip-coating plant) is subject to major impact under the electrodeposition option. Again, the presence of differential impact is apparent. For example, if Plant I is compared with its larger counterparts, Plant G and H, it can be seen that the magnitudes of the impacts drop off considerably with increasing plant size. For the new facility/uncontrolled baseline combination, the impact of the electrodeposition option on Plant I (under SIC 2542) is 12.08 percent. The corresponding impact for Plant H (medium) is 6.41 percent. (The largest dip-coating plant, Plant G, is only associated with SIC 2522). Thus, as far as the use of electrodeposition is concerned, Plant I would suffer a disadvantage relative to its larger competitor, Plant H.

7.4.4.5 Differential Impact Analysis. Based on the results obtained in the analyses of profit reduction and capital availability, another analysis was performed to assess differentials in impacts between the smallest and largest plants producing the same product for each of the control options. In virtually all cases, for both profit reduction and capital availability, the impact for the smallest plant is greater than the impact for the largest plant. In several cases, the differences in impacts are large. For example, in comparing Plant I (small dip-coating plant) with Plant G (large dip-coating plant) for the electrodeposition option, the following types of differences are found for the modified/reconstructed facilities - SIP baseline combination:

Profit reduction:

Plant I:	17.29 percent
Plant G:	1.88 percent
Difference	15.41 percent

Capital availability:

Plant I:	7.98 percent
Plant G:	1.13 percent
Difference	6.85 percent

These differences underscore the fact that Plant I is clearly disadvantaged relative to its larger dip-coating competitors. As pointed out earlier, Plant I is subject to major profit impacts for powder and electrodeposition, and major capital availability impacts for electrodeposition. Waterborne is the only control option available to Plant I which is not connected with some form of major impact.

7.4.5 Industry Compliance Costs

The preceding discussion has focused upon the impact of the NSPS regulations at the level of the individual plant. In this section, results from the plant-level analysis are utilized as a basis for assessing the potential incremental annualized cost which the metal furniture industry as a whole may have to bear.

In order to provide an estimate of the range over which industrywide compliance costs might vary, cost calculations were carried out for four of the various combinations of control options that might be employed. The combinations are shown in Table 7-76. For example, under Combination #1, 70 percent high solids would be used for all spray-coating operations (plant types A-F), waterborne for all dip-coating operations (plant types G, H, and I), and waterborne, again, for flow-coating operations (plant type J).

The estimates of the industrywide compliance costs associated with the four combinations of control options were based upon the projected numbers of new and replacement coating lines, as presented in Section 7.1.5.3. The projections in Section 7.1.5.3 call for the total number of new and replacement lines to reach 1,963 by the end of the 1980-85 period. This total is divided between 771 new facilities and 1,192 replacements of existing facilities.

Based on the discussion in Chapter 6, it was assumed that both the new and the replacement lines would be distributed on the basis of 85 percent being spray-coating lines, 10 percent being dip-coating lines, and 5 percent being flow-coating lines. The estimated numbers of lines in each coating-method category are as follows:

	New Lines	Replacement Lines
Spray	655	1,013
Dip	77	119
Flow	39	60
	771	1,192

For the numbers of new and replacement lines in the spray-and dip-coating categories, it was assumed that 25 percent of the lines would be accounted for by large plants, 50 percent by medium-sized plants, and the remaining 25 percent by small plants. For the flow-coating category, all of the lines are accounted for by one type of plant of small size (Plant J). This distribution is given in Table 7-77.

In order to facilitate calculations of cost for coating lines in the spray-coating category, it was necessary to select three plant types from among the six spray plants (Plants A-F), as being representative of large, medium, and small spray-coating operations. It will be recalled that within the spray-coating category, there are two model plants for each size classification (A & B, large; C & D, medium; and E & F, small). Cost data for the pairs of plant types were compared, and the differences were found to be small enough to permit the use of three plant types as the bases for the calculating compliance costs for the spray-coating category. The three plant types chosen were A, D, and E. For the dip-coating category, plant types G, H, and I were used as the bases for calculating compliance costs for large, medium, and small operations, respectively. For the flow-coating category, plant type J was used as the basis for cost calculations.

Table 7-76. REPRESENTATIVE COMBINATIONS OF CONTROL OPTIONS COVERING THE TEN TYPES OF MODEL PLANTS

Plant type	Application method	Size	Control options employed in combinations below			
			Combination #1	Combination #2	Combination #3	Combination #4
A	Spray	Large	70% High solids	Powder	Incinerator & RACT coating	70% High solids, powder, & waterborne[a]
B	Spray	Large	70% High solids	Powder	Incinerator & RACT coating	70% High solids, powder, & waterborne[a]
C	Spray	Medium	70% High solids	Powder	Incinerator & RACT coating	70% High solids, powder, & waterborne[a]
D	Spray	Medium	70% High solids	Powder	Incinerator & RACT coating	70% High solids, powder, & waterborne[a]
E	Spray	Small	70% High solids	Powder	Waterborne	70% High solids, powder, & waterborne[a]
F	Spray	Small	70% High solids	Powder	Waterborne	70% High solids, powder, & waterborne[a]
G	Dip	Large	Conventional waterborne	Electrodeposition	Conventional waterborne	Conventional waterborne
H	Dip	Medium	Conventional waterborne	Electrodeposition	Conventional waterborne	Conventional waterborne
I	Dip	Small	Conventional waterborne	Electrodeposition	Conventional waterborne	Conventional waterborne
J	Flow	Small	Waterborne	Waterborne	Waterborne	Waterborne

[a]The three control options are assumed to be equally represented.

Table 7-77. DISTRIBUTION
OF LINES IN COATING-METHOD CATEGORIES
BY SIZE OF PLANT INVOLVED

Coating method	Plant size	Number of lines in 1985 New[a]	Replacement[a]
Spray	Large	164	253
	Medium	328	507
	Small	164	253
Dip	Large	19	30
	Medium	39	60
	Small	19	30
Flow	Small	39	60

[a]Due to rounding error, numbers for new spray lines and replacement dip lines do not add up exactly to 655 and 119, respectively.

For each of the above plant types (i.e., A, D, E, G, H, I, and J), the amount of surface area coated annually per line was determined (based on data obtained from Chapter 5). These figures were then multiplied by the numbers of lines corresponding to the different coating method/plant size combinations (as shown in Table 7-77). The results of the calculations are given in Table 7-78.

The cost data used for extrapolation of the industrywide compliance costs are given in Tables 7-79 and 7-80, or Tables E-9 and E-10 (see Appendix E). The incremental costs presented in the tables are per thousand square meters coated. The data were obtained from Section 7.2. Only incremental costs relative to the SIP baseline are considered.

To obtain the total compliance costs for the four combinations of control options, the above costs were multiplied by the corresponding figures on surface area coated (as given in Table 7-78). The results are as follows:

	From Tables 7-78, 7-79 and 7-80	From Tables 7-78, E-9, and E-10 of Appendix E
Combination #1:	($14.7 million)	($18 million)
Combination #2:	$126 million	($1.7 million)
Combination #3:	$17.6 million	$17 million
Combination #4:	$54.8 million	$11 million

At $126 million, Combination #2 is by far the most costly of the four, and exceeds by $26 million the threshold for a Significant Action Analysis (as articulated in Executive Order 12044). However, this value ($126 million) is based on powder being applied at 6.35×10^{-3}cm (2.5 mil). This value changes to a savings of nearly $2 million (see Appendix E) if powder is applied at 3.81×10^{-3}cm (1.5 mil). Combination #1 would involve a savings of nearly $15 million.

The four combinations of control options were compared in terms of their cost effectiveness, using the emission estimates for the model plants presented in Chapter 5. For each of the coating method/plant size combinations examined, emissions at the SIP level were calculated and summed to

Table 7-78. SURFACE AREA
COATED PER YEAR BY PROJECTED
NEW AND REPLACEMENT LINES

Coating method	Plant size	Surface area coated per year ($m^2 \times 10^3$) New lines	Replacement lines
Spray	Large	109,333	168,667
	Medium	127,920	197,730
	Small	7,380	11,385
Dip	Large	7,600	12,000
	Medium	15,210	23,400
	Small	855	1,350
Flow	Small	1,755	2,700
		270,053	417,232

Industrywide total: 687,285,000 m^2

Table 7-79. INCREMENTAL ANNUALIZED CONTROL COST
PER THOUSAND SQUARE METERS COATED
NEW FACILITIES - SIP BASELINE
(in dollars)

Plant	70% High solids[c]	Conventional waterborne	Powder[d]	EDP	Incinerator & RACT coating
A	(21)	75	184	b	9
D	(29)	106	144	b	32
E	0	200	267	b	b
G	b	9	a	84	a
H	b	10	a	110	a
I	b	0	a	733	b
J	b	0	b	b	b

[a]Not considered for this plant under the four combinations of control options being examined.
[b]Control option does not apply to this plant.
[c]Parentheses indicate savings from baseline.
[d]These incremental annualized control costs are based on a film thickness of 6.35×10^{-3}cm (2.5 mil). However, the incremental annualized control costs are reduced significantly if powder is applied at a film thickness of 3.81×10^{-3}cm (1.5 mil). This data is presented in Appendix E.

Table 7-80. INCREMENTAL ANNUALIZED CONTROL COST
PER THOUSAND SQUARE METERS COATED
MODIFIED/RECONSTRUCTED FACILITIES - SIP BASELINE
(in dollars)

Plant	70% High solids[c]	Conventional waterborne	Powder[d]	EDP	Incinerator & RACT coating
A	(22)	76	205	b	8
D	(28)	110	185	b	31
E	0	267	489	b	b
G	b	9	a	94	a
H	b	10	a	169	a
I	b	0	a	889	b
J	b	0	b	b	b

[a]Not considered for this plant under the four combinations of control options being examined.
[b]Control option does not apply to this plant.
[c]Parentheses indicate savings from baseline.
[d]These incremental annualized control costs are based on a film thickness of 6.35×10^{-3}cm (2.5 mil). However, the incremental annualized control costs are reduced significantly if powder is applied at a film thickness of 3.81×10^{-3}cm (1.5 mil). This data is presented in Appendix E.

yield a total for the projected 1,963 new and replacement lines. Similarly, total emissions associated with each of the four combinations of control options were also calculated. The results are as follows:

Data Combination	Chapter 7 Total Emissions (kg/year)	Appendix E Data (kg/year)
SIP level	53,089,870	58,603,389
#1	33,104,807	36,647,286
#2	2,825,595	1,806,853
#3	36,647,988	39,648,887
#4	21,531,082	20,693,304

The reductions in emissions from the SIP level are: 19,985,063 kg/year for Combination #1; 50,264,275 kg/year for Combination #2; 16,441,882 kg/year for Combination #3; and 31,558,788 kg/year for Combination #4. When these figures are divided into the corresponding industrywide incremental annualized costs, the following incremental costs per kilogram of emission reduction are obtained:

	Chapter 7	Appendix E Data
Combination #1:	($ .74)	($.82)
Combination #2:	$2.52	($.03)
Combination #3:	$1.07	$.90
Combination #4:	$1.74	$.29

7.5 AGGREGATE ECONOMIC IMPACT ASSESSMENT

The purpose of this section is to analyze the macroeconomic and socio-economic effects of the proposed NSPS, and to determine whether they trigger the criteria for a Regulatory (Significant Action) Analysis. These criteria, as established by Executive Order 12044, are as follows:

- Additional annualized costs of compliance that, including capital charge (interest and depreciation), will total $100 million (i) within any one of the first five years of implementation (normally in the fifth year for NSPS), or (ii) if applicable, within any calendar year up to the date by which the law requires attainment of the relevant pollution standard.

- Total additional cost of production of any major industry product or service will exceed 5 percent of the selling price of the product.
- Net national energy consumption will increase by the equivalent of 25,000 barrels of oil per day.
- Additional annual demand will increase or annual supply will decrease by more than 3 percent for any of the following materials by the attainment date, if applicable, or within five years of implementation: plate steel, tubular steel, stainless steel, scrap steel, aluminum, copper, manganese, magnesium, zinc, ethylene, ethylene glycol, liquified petroleum gasses, ammonia, urea, plastics, synthetic rubber, or pulp.

7.5.1 Industry Structure and Concentration Effects

As shown in Section 7.4, for any given control option, the magnitude of impacts tends to vary inversely with the size of the plant; i.e., differential impact is present. Given a situation involving a full pass-through of costs, the resulting price increases would be smaller for large plants than for smaller plants. As pointed out in Section 7.4.2, the extent to which a firm can pass through incremental costs to the consumer is affected in part by the price elasticity of demand for the firm's product. If the demand for the firms's product is inelastic, a firm may be able to pass through incremental costs to the consumer. The extent to which this is possible, however, would depend upon intra-industry competitive factors. Locational considerations would be most important in this regard. If the demand for the firm's product tends to be elastic, the potential for cost pass-through is reduced. In this latter type of situation, the competitive disadvantage of small plants relative to large plants would tend to be accentuated. Over the long run, this increased disadvantage could lead to greater concentrations within the industry. Such a trend towards increased concentration would be encouraged more by some of the control options than by others.

7.5.2 Employment Effects

It is not anticipated that the proposed NSPS will have a major impact upon employment within the metal furniture industry. At most, the number of plants which would be forced to close as a result of the NSPS would be very small. Also, it is not expected that the standard would result in the curtailment of new construction in many cases.

7.5.3 Balance of Trade Effects

The proposed NPSP is not expected to have a measurable impact on the balance of trade. Exports account for only a very small share of the metal furniture industry's total value of shipments. Moreover, as pointed out in Section 7.1.4, imports are not an important factor in the metal furniture market.

7.5.4 Inflationary Impact

The potential inflationary impacts of the control options were determined as follows:

$$\frac{\text{Incremental Annualized Control Cost Per Shelf or Chair}}{\text{Retail List Price Per Shelf or Chair}} \times 100$$

The calculation yields the percentage by which retail list price would increase if the incremental control cost per shelf or chair were wholly passed on to the consumer. For shelves, a retail list price of $38.33 was used; for chairs, $52.50. (The derivation of these prices is discussed in Section 7.4.4.1.) Impacts for the shelving plants are presented in Table 7-81, and for the chair plants in Table 7-82. The incremental annualized control costs used in calculating the impacts were obtained from Tables 7-57 to 7-64.

In no case is there a potential increase of more than 5 percent (one of the criteria in Executive Order 12044 for determination of major economic impacts).

7.5.5 Energy Impact

Energy consumption estimates for each model plant control option combination are presented in Chapters 5 and 6 of this document. These estimates are given in terms of joules. Energy savings resulting from the use of less solvent are factored in the data.

For the purpose of this analysis, the estimates for each model plant were reduced to the amount of consumption per line per day. The number of days used in the calculation was 365. The data were then converted to incremental form relative to both SIP and uncontrolled baselines. In turn, these data, expressed in joules, were converted to equivalent barrels of crude oil by multiplying each amount by a factor of 1.63 (derived by assuming 1 BTU = 1055 joules, and 1 barrel = 5,800,000 BTU).

The results of this procedure are presented in Tables 7-83 and 7-84. In the case of the data calculated from the uncontrolled baseline, there are no situations involving incremental energy consumption. Energy savings are evidenced in all situations. With regard to the data calculated from the SIP baseline, the results are mixed. In the case of the high solids options (70 percent and 65 percent), there is no change in energy consumption from the baseline. For the conventional waterborne option, however, there are increments ranging from 0.08 to 0.15 barrel per day. For waterborne with electrodeposition, incremental consumption ranges from 0.10 to 0.21 barrel per day. The powder option involves energy savings in all cases. For thermal incineration with RACT coating, incremental consumption ranges from 0.03 barrel per day to 0.23 barrel per day.

With respect to energy consumption, Executive Order 12044 defines a major impact as one involving an increase in net energy consumption by the equivalent of 25,000 barrels of oil per day. To determine whether the NSPS would result in such an impact, a form of "worst case" analysis was performed. In the procedure described above, it was determined that the largest incremental consumption of energy would be equivalent to 0.23 barrel of crude oil per day. In Section 7.1, the total number of affected facilities (coating lines) was projected to reach 1,963 by the end of the 1980-85 period. If this figure is multiplied by 0.23, the result is an incremental consumption figure of 451 barrels per day. This is far below the 25,000-barrel threshold level, and, in reality, the figure would more likely be somewhat lower, and perhaps even negative. The conclusion is therefore that the NSPS will not have a major energy impact.

7.5.6 Industrywide Compliance Cost

The subject of industrywide incremental annualized control costs was presented in Section 7.4.5. Of the four combinations of control options discussed, Combination #2 (involving powder, electrodepostion, and waterborne)

Table 7-81. INFLATION IMPACT

SHELVING PLANTS[a]

Plant	Control Option	Inflation Impact % New Facilities SIP	New Facilities Uncontrolled	Modified/ Reconstructed facilities SIP	Modified/ Reconstructed facilities Uncontrolled
A	Powder (spray)[b]	.47	.44	.55	.50
	Waterborne	.18	.16	.21	.16
	70% High solids	c	c	c	c
	Incinerator & RACT coating	.03	c	.03	c
	65% High solids	c	c	c	c
C	Powder (spray)	.50	.47	.63	.57
	Waterborne	.21	.16	.21	.18
	70% High solids	c	c	c	c
	Incinerator & RACT coating	.08	.05	.08	.08
	65% High solids	c	c	c	c
E	Powder (spray)	.70	.52	1.28	1.10
	Waterborne	.52	.34	.70	.52
	70% High solids	c	c	c	c
	65% High solids	c	c	c	c

[a] Impacts calculated on the basis of a retail list price of $38.33 per shelf.
[b] The inflation impact changes significantly for the powder (spray) option based on data presented in Appendix E.
[c] No impact involved.

Table 7-82. INFLATION IMPACT

CHAIR PLANTS[a]

Plant	Control Option	Inflation Impact %			
		New Facilities		Modified/ Reconstructed facilities	
		SIP	Uncontrolled	SIP	Uncontrolled
B	Powder (spray)[b]	.10	.08	.11	.10
	Waterborne	.08	.06	.08	.06
	70% High solids	c	c	c	c
	Incinerator & RACT coating	.01	c	.01	d
	65% High solids	c	c	c	c
D	Powder (spray)[b]	.19	.17	.23	.21
	Waterborne	.13	.11	.13	.11
	70% High solids	c	c	c	c
	Incinerator & RACT coating	.04	.02	.04	.04
	65% High solids	c	c	c	c
F	Powder (spray)[b]	.13	.11	.30	.29
	Waterborne	.23	.19	.25	.23
	70% High solids	c	c	c	c
	65% High solids	c	c	c	c
G	Powder (fluidized bed)	.11	.13	.13	.13
	Electrodeposition	.06	.08	.06	.06
	Incinerator & RACT coating	.01	.02	.01	.03
	Waterborne (convent.)	.01	.02	.01	.03

Table 7-82. INFLATION IMPACT

CHAIR PLANTS[a]

(continued)

		Inflation Impact %			
		New Facilities		Modified/ Reconstructed facilities	
Plant	Control Option	SIP	Uncontrolled	SIP	Uncontrolled
H	Powder (fluidized bed)	.04	.10	.11	.11
	Electrodeposition	.13	.19	.21	.21
	Incinerator & RACT coating	.04	.08	.02	.08
	Waterborne (convent.)	.02	.06	.02	.04
I	Powder (fluidized bed)	.25	.40	.55	.53
	Electrodeposition	.46	.61	.55	.55
	Waterborne (convent.)	c	.13	c	.13
J	Waterborne	c	.13	c	.13

[a]Impacts calculated on the basis of a retail list price of $52.50 per chair.
[b]The inflation impact changes significantly for the powder (spray) option based on data presented in Appendix E.
[c]No impact involved.
[d]Less than .01%.

Table 7-83. INCREMENTAL ENERGY USE PER LINE PER DAY SIP BASELINE

Plant	High Solids[a]		Conventional waterborne		Waterborne with EDP		Powder[c]		Thermal incinerator and RACT coating	
	Joules[b]	Barrels	Joules[b]	Barrels	Joules[b]	Barrels	Joules[b]	Barrels	Joules[b]	Barrels
A	0	0	.09	.15	d	d	(.27)	(.44)	.10	16
B	0	0	.08	.13	d	d	(.27)	(.44)	.05	08
C	0	0	.09	.15	d	d	(.20)	(.33)	.07	11
D	0	0	.09	.15	d	d	(.20)	(.33)	.07	11
E	0	0	.05	.08	d	d	(.17)	(.28)	d	d
F	0	0	.05	.08	d	d	(.17)	(.28)	d	d
G	d	d	0	0	.11	.18	(.27)	(.44)	.02	.03
H	d	d	0	0	.06	.10	(.20)	(.33)	.14	.23
I	d	d	0	0	.13	.21	(.17)	(.28)	d	d
J	d	d	0	0	d	d	d	d	d	d

[a]Refers to both 65% and 70% high solids coatings.

[b]Units multiplied by 10^{10}.

[c]Parentheses indicate savings from baseline case.

[d]Control option does not apply to this plant.

Table 7-84. INCREMENTAL ENERGY USE PER LINE PER DAY UNCONTROLLED BASELINE

Plant	High Solids[a,c] Joules[b]	High Solids[a,c] Barrels	Conventional waterborne[c] Joules[b]	Conventional waterborne[c] Barrels	Waterborne with EDP[c] Joules[b]	Waterborne with EDP[c] Barrels	Powder[c] Joules[b]	Powder[c] Barrels	Thermal incinerator and RACT coating[c] Joules[b]	Thermal incinerator and RACT coating[c] Barrels
A	(.56)	(.91)	(.47)	(.77)	d	d	(.83)	(1.35)	(.45)	(.73)
B	(.56)	(.91)	(.47)	(.77)	d	d	(.83)	(1.35)	(.51)	(.83)
C	(.40)	(.65)	(.37)	(.60)	d	d	(.60)	(.98)	(.33)	(.54)
D	(.40)	(.65)	(.37)	(.60)	d	d	(.60)	(.98)	(.33)	(.54)
E	(.37)	(.60)	(.31)	(.51)	d	d	(.54)	(.88)	d	d
F	(.37)	(.60)	(.31)	(.51)	d	d	(.54)	(.88)	d	d
G	d	d	(.53)	(.86)	(.42)	(.68)	(.80)	(1.30)	(.52)	(.85)
H	d	d	(.39)	(.64)	(.33)	(.54)	(.59)	(.96)	(.25)	(.41)
I	d	d	(.33)	(.54)	(.21)	(.34)	(.50)	(.82)	d	d
J	d	d	(.33)	(.54)	d	d	d	d	d	d

[a]Refers to both 65% and 70% high solids coatings

[b]Units multiplied by 10^{10}.

[c]Parentheses indicate savings from baseline case.

[d]Control option does not apply to this plant.

would have a cost exceeding the $100 million threshold for a Significant Action Analysis. However, this is based on powder (spray) applied at a film thickness of 6.35×10^{-3}cm, (2.5 mil). Combination #2 could result in a savings of nearly $2 million if powder is applied at 3.81×10^{-3}cm (1.5 mil). Details of these costs are presented in Appendix E.

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APPENDIX A

A.1 LITERATURE REVIEW

The literature reviewed for this standard includes previous EPA in-house reports, EPA-funded contractor reports, published literature, and reports from industry and other private sources. Specifically, the review included the following:

Date	Literature Reviewed
August 11-20, 1975	Springborn Laboratories (SL) conducted an equipment survey to review coating equipment contacting manufacturers by telephone.
September 26, 1975	Office of Management and Budget approved the EPA questionnaire for distribution in the industrial finishing industry.
April 21-23, 1976	SL attended Chemical Coatings Conference in Cincinnati, Ohio.
August 23, 1977	SL conducted a telephone survey with resin suppliers discussing the present status of high solids coating for metal furniture.
August 25, 1977	SL conducted a telephone survey with resin suppliers discussing present status of powder coatings and waterborne coatings for metal furniture.
April 1978	SL submitted a draft copy of a Study to Support New Source Performance Standard for Surface Coating of Metal Furniture (EPA-450/3-78-008) to EPA.

November 25, 1978	TRW starts work on converting EPA-450/3-78-008 into a Background Information Document (BID).
January 15, 1979	TRW takes a trip to SL to collect data base used for writing the draft of EPA-450/3-79-008.
January-March 1979	TRW conducted a telephone survey of state and local agencies to obtain regulations and information covering the surface coating of metal furniture.
February 1979	TRW received an AEROS computer printout from EPA covering SIC codes 2514, 2522, 2531, and 2542.
March 1979	TRW received data contained in computer printout for metal furniture industries in Texas. Data obtained from Texas Air Control Board.
March-May 1979	TRW conducted a telephone survey of equipment vendors and paint suppliers for cost data.
May 1979	TRW received cost data for model plant coating lines from George Koch Sons, Inc.
May 1979	TRW received cost data for some of the model plant coating lines from Graco, Inc.
June 1979	TRW received data from Gordon E. Cole, GCA, concerning cure volatiles from powder coatings. Data also contained powder coating thicknesses that are achievable on an auto coating line.
January-June 1979	TRW reviewed and reduced collected data.
October 12, 1979	TRW received Sections 7.4 and 7.5 of the economics chapter from JACA.

A.2 EMISSION SOURCE TESTING

No performance testing was done during the project. This issue was decided early in the project. It was assumed that all of the VOC's in coatings are emitted, thereby allowing easy material balance calculations. Example calculations for VOC emissions are presented in Section 3.3 of the BID.

A.3 PLANT AND EQUIPMENT VENDOR VISITS

Plant trips were taken to observe different coating formulations being applied to metal furniture parts. Trips were taken to observe new types of equipment vendor application equipment being marketed that allow higher transfer efficiencies.

Date	Plant, Equipment Vendor, or Other Related Trips
August 18, 1975	SL visited Electrostatic Equipment Corp., to discuss the status of powder coatings and the ionized air coating process.
August 22, 1975	SL visited Nordson Corp. and Interrad Corp. to discuss the status of powder coatings and powder coating equipment.
January 14, 1976	SL visited Simmons Co., Munster, Indiana, to observe the electrostatic coating of metal drawers with high solids coatings.
February 3, 1976	SL visited Lyon Metal Products, Inc., Aurora, Illinois, to observe organic solvent base coating of metal furniture.
February 11, 1979	SL visited Virco Manufacturing Corp., Gardena, California, to observe powder coating of tubular furniture. Also, witnessed at this plant was the operation of a thermal incinerator on the bake oven.
February 24, 1976	SL visited Steelcase Company, Grand Rapids, Michigan, to observe powder coating of office metal furniture parts.
February 25, 1976	SL visited Goodman Brothers Manufacturing Company, Philadelphia, Pennsylvania, to observe powder coating of metal furniture hospital beds.

Date	Plant, Equipment Vendor, or Other Related Trips
February 25, 1976	SL visited Bunting Company, Philadelphia, Pennsylvania, to observe powder coating of outdoor metal furniture.
March 8, 1976	SL visited U.S. Furniture Industries, Highpoint, North Carolina, to observe powder coating of metal furniture.
March 9, 1979	SL visited Angel Steel Co., Plainwell, Michigan, to observe electrodeposition coating of metal furniture.
March 23, 1976	SL visited Herman Miller, Inc., Zeeland, Michigan, to observe powder coating of office metal furniture.
April 21-23, 1976	SL attended a Chemical Coatings Conference in Cincinnati, Ohio.
September 26, 1976	SL visited George Koch & Sons, Inc., Evansville, Indiana, to review available finishing technology.
	SL visited other facilities involved in surface coating. However, the above list were the only facilities that are involved in surface coating of metal furniture.
January 15, 1979	TRW visited SL, Enfield, Connecticut, to obtain the data base for EPA-450/3-78-006, Draft.
February 2, 1979	TRW visited EPA, Ohio, to obtain data for metal furniture facilities in Ohio.
February 2, 1979	TRW attended the South Coast Air Quality Management District meeting to obtain information covering proposed regulations for surface coating of metal furniture.

Date	Plant, Equipment Vendor, or Other Related Trips
March 26-27, 1979	TRW visited Steelcase, Inc., Grand Rapids, Michigan, to obtain information concerning coating lines, and various air pollution control techniques employed at the plant.
April 18, 1979	TRW visited Delwood Furniture Corp., Irondale, Alabama, to observe water-borne coating of metal furniture tables.
April 24-25, 1979	TRW visited Ransburg Electrostatic Equipment, Indianapolis, Indiana, to obtain information for high solids coatings and electrostatic spraying equipment.

A.4 MEETINGS WITH INDUSTRY

Date	Meeting
February 15, 1979	TRW attended meeting with Mr. E. W. Pete Drum of Ransburg Electrostatic Equipment to discuss electrostatic spraying equipment.
March 1979	TRW attended meeting with Mr. Wayne Travis of Graco, Inc. to discuss the costs of electrostatic spraying equipment.
January 30, 1980	Meeting with Ron Farrell, Dr. Alexander Ramig, and K. J. McInerney of Glidden Coatings and Resins to discuss powder coating costs and technical developments in the area of powder coatings.

A.5 REPORTS AND REVIEW PROCESS

Date	Report or Review Process
July 15, 1976	SL submitted first interim report on Air Pollution Control Engineering and Cost Study to EPA.
August 23, 1976	SL submitted second interim report on Air Pollution Control Engineering and Cost Study to EPA.

Date	Report or Review Process
May 19, 1977	SL attended a meeting with EPA, Research Triangle Park, North Carolina to discuss all surface coating projects.
June 14, 1977	SL received authorization from EPA to continue and complete the study to support a New Source Performance Standard (NSPS) for surface coating of metal furniture.
December 1977	EPA issued EPA-450/2-77-032 (OAQPS No. 1.2-086) Control of Volatile Organic Emissions from Existing Stationary Sources, Volume III: Surface Coating of Metal Furniture.
April 1978	EPA issued EPA-450/3-78-006, Study to Support New Source Performance Standards for Surface Coating of Metal Furniture.
April 5-6, 1978	SL and EPA attended a National Air Pollution Control Techniques Advisory Committee (NAPCTAC) meeting to support the proposed standard.
October 10, 1979	TRW began work on the project.
March 9, 1979	TRW finalized model plants and regulatory alternatives.
May 31, 1979	TRW attended initial meeting with EPA to obtain concurrence for selected model plants and regulatory alternatives.
June 18, 1979	TRW submitted to EPA a complete cost analysis.
July 31, 1979	TRW and EPA decide upon basis for a standard.
October 10, 1979	TRW received draft copies of Sections 7.4 and 7.5 from JACA Corporation.
October 31, 1979	TRW submitted to EPA draft copies of the Background Information Document (BID), and preamble and regulation for the EPA Working Group mailout.

Date	Report or Review Process
December 21, 1979	TRW submitted to EPA draft copies of the Background Information Document (BID), preamble and regulation for the EPA Steering Committee mailout.
January 11, 1980	TRW briefed the EPA Steering Committee on the proposed NSPS.
January 29, 1980	TRW submitted to EPA draft copies of the BID, preamble and regulation for the NAPCTAC mailout.
February 27, 1980	TRW gave a NAPCTAC presentation.

APPENDIX B

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements 39 FR 37419	Location Within the Background Information Document (BID)
1. Statutory basis for proposed standards	The statutory basis for the proposed standard is summarized in Chapter 1.
Relationship to other regulatory agency actions.	The various relationships between the proposed standard and other regulatory agency actions are summarized in Chapter 1, Section 1.2.
Industry affected by the proposed standards.	A discussion of the industries affected by the standard is presented in Chapter 2, Section 2.1. Also, details covering the "business/economic" nature of the industry is presented in Chapter 7, Section 7.1 (and subsections).
Specific processes affected by the standard.	The specific processes and facilities affected by the proposed standard are described in Chapter 2, Section 2.2. Model plants for these processes appear in Chapter 5, Section 5.1 (and subsections).
Availability of control technology	Information on the availability of control technology is given in Chapter 3. The regulatory alternatives selected from the control technologies are shown in Chapter 5, Section 5.2 (and subsections).
Existing regulations	A discussion of existing regulations on the industry to be affected by the standard is included in Chapter 2, Section 2.3.

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements 39 FR 37419	Location Within the Background Information Document (BID)
2. Alternatives to the proposed action	
Environmental Impacts	Environmental effects of not implementing the standard are discussed in Chapter 6.
Costs	The costs of alternative control techniques are discussed in Chapter 7, Sections 7.2, 7.3, and 7.4.
3. Environmental impact of proposed action	
Air Pollution	The air pollution impact of the proposed standard is discussed in Chapter 6, Section 6.1.
Water Pollution	The water pollution impact of the proposed standard is discussed in Chapter 6, Section 6.2.
Solid Waste Disposal	The solid waste disposal impact of the proposed standard is discussed in Chapter 6, Section 6.3.
Energy	The energy impact of the proposed standard is discussed in Chapter 6, Section 6.4.
4. Economic impact of proposed action	The economic impact of the proposed standard on costs is discussed in Chapter 7.

APPENDIX C
EMISSION SOURCE TEST DATA

No emission testing was done during this project. It is well documented in the technical literature that all of the organic volatile portion of coatings is emitted to the atmosphere. As a result, it is assumed for emission estimates that material balance calculations for volatile organic compounds (VOC) are acceptable.

APPENDIX D. EMISSION MEASUREMENT AND CONTINUOUS MONITORING

D.1 EMISSION MEASUREMENT METHODS

A. Emission Testing

No emission measurement tests were conducted by the Environmental Protection Agency (EPA) for this source category. The volatile organic compound (VOC) emissions from this coating industry are similar to the emissions from automobile and light duty truck surface coating operations as well as other surface coating operations. Several test methods can be used for measuring VOC emissions from surface coating operations.[1] These include:

1. Total Gaseous Non-Methane Organic (TGNMO) Analysis, i.e., oxidation/reduction of organics with Flame Ionization Detection.
2. Direct Flame Ionization Analysis (DFIA).
3. Gas Chromatographic Separation/Flame Ionization Detection (GC/FID).

Table D-1 lists advantages and disadvantages of these procedures.

For determination of VOC emissions, the need for identification and quantification of individual species is not necessary. Therefore, although useful in some cases, the GC/FID procedure was not considered as the best approach for measuring VOC emissions from surface coating operations. The other methods listed above yield a single result without identification of individual species present. The first two methods listed above were investigated during the study conducted for automobile and light duty truck surface coating operations. In the TGNMO method, the sample is manually collected in a sampling train consisting of a condensate trap and evacuated cylinder. The sampling train is returned to the laboratory where the entire organic contents of the condensate

Table D-1. ADVANTAGES AND DISADVANTAGES OF EACH EMISSION MEASUREMENT METHOD

Emission measurement method	Advantage	Disadvantage
1. Total Gaseous Nonmethane Organic (TGNMO)	A. Has been successfully employed in determining compliance by Los Angeles Air Pollution Control District.	A. Most costly.
	B. Is considered to be the most accurate of sampling methods for measuring total carbon from sources of unknown organics.	
2. Direct Flame Ionization Analysis (DFIA)	A. Has also been employed to determine compliance with state and local regulations.	A. Not as accurate as TGNMO for measuring unknown compounds.
	B. Costs less than TGNMO.	
3. Gas Chromatography/Flame Ionization Detector (GC/FID)	A. Identifies individual species.	A. Expensive and complex.

trap are oxidized to carbon dioxide, reduced to methane and quantitatively measured by a Flame Ionization Detector (FID). The non-methane organics collected in the tank (after chromatographic separation from carbon monoxide, carbon dioxide, and methane) are similarly oxidized to carbon dioxide, reduced to methane and quantitatively measured by a FID. The results are reported as total gaseous non-methane organics as carbon (ppm or mass basis). The advantage of this procedure is that because of the oxidation/reduction procedure, all organics in the sample are measured by the FID as methane; consequently, any variation in response to the FID to different organic species is eliminated.

The DFIA procedure involves directly measuring the effluent stream with a FID. VOC emission results are yielded in terms of the FID calibration gas (ppm or mass basis). Because FIDs have different response factors for various organic compounds, the accuracy of the results depends on the calibration gas chosen and the species of compounds in the effluent.

During the automotive coating study, a test was conducted on a gas-fired incinerator controlling the effluent from an automotive bake oven.[2] The results of this test indicated that the concentrations obtained from the DFIA technique were lower than the concentrations obtained by the TGNMO procedure; especially at the incinerator outlet.

B. Coatings Testing

Although no metal furniture coatings were tested, the recommended test procedure based on the results from automotive coatings would be Method 24, Determination of Volatile Organic Matter, Water Content, Density, Volume Solids, and Weight Solids of Surface Coatings.[3] This procedure uses ASTM methods to measure the coating density, the mass of volatile material per mass of coatings, the volume of solid material per volume of coatings, and the mass of water per mass of coating. The results from the different methods can be obtained to calculate the mass of volatile organic material per volume of coating solids as applied. The cost of analyzing a coating sample in triplicate using this procedure would be approximately $250.

Alternatively, the VOC content can be determined from the manufacturer's formulation data by calculation.

D.2 PERFORMANCE TEST METHODS

A. Emission Testing

Reference Method 25, Determination of Total Gaseous Nonmethane Organic Emissions as Carbon, is recommended as the performance test method for concentration measurement. This method is recommended as the reference test method because the problem of variation in response of a FID to different organic species is eliminated. This is accomplished by reducing all organic compounds to methane prior to measurement by the FID. Since the FID in the reference method measures all the non-methane organics as methane, all carbon atoms give an equal response. Therefore, Reference Method 25 is recommended as the performance test method for industrial surface coating operations since the effluent stream usually contains a mixture of various unknown organic species.

The recommended procedure for determining the mass of VOC (as carbon) in the incinerator system vents uses a combination of several standard methods. EPA Reference Method 1 is used to select the sampling site; Reference Method 2 measures the volumetric flow rate in the vent; and Methods 3 and 4 measure the molecular weight and moisture content to adjust the volumetric flow to dry standard conditions. The VOC concentration in the vent is measured by Reference Method 25. The results from these methods are combined to give the mass of VOC (as carbon) in the vent.

Three one-hour runs of Reference Method 25 are recommended for a complete test, with Reference Methods 2, 3, and 4 being performed at least twice during that period. Measurements at the inlet, outlet, and fugitive emission vents should be performed simultaneously. Although the actual testing time using Reference Method 25 is only 3 hours, the total time required for one complete performance test is estimated at 8 hours, with an estimated overall cost of $4,000, plus $2,000 for each fugitive vent measured. During the performance test, the process should be operating normally. Because this is a short-term test, the enforcement agency should consider the solvents and coatings being used and the products being produced to ensure representativeness.

B. Coating Analysis

Reference Method 24 is recommended as the reference method for measuring the volatile content of metal furniture coatings.

D.3 MONITORING SYSTEMS AND DEVICES

The purpose of monitoring is to ensure that the emission control system is being properly operated and maintained after the performance test. One can either directly monitor the regulated pollutant, or instead, monitor an operational parameter of the emission control system. The aim is to select a relatively inexpensive and simple method which will indicate that the facility is in continual compliance with the standard.

For solvent recovery systems, the recommended monitoring test is identical to the performance test. A solvent inventory record is maintained, and the control efficiency is calculated every month. Excluding reporting costs, this monitoring procedure should not incur any additional costs for the affected facility, because these process data are normally recorded anyway, and the liquid meters were already installed for the earlier performance test.

For incinerators, two monitoring approaches were considered: (1) directly monitoring the VOC content of the inlet, outlet, and fugitive vents so that the monitoring test would be similar to the performance test; and (2) monitoring the operating temperature of the incinerator as an indicator of compliance. The first alternative would require at least two continuous hydrocarbon monitors with recorders, (about $4,000 each), and frequent calibration and maintenance. Instead, it is recommended that a record be kept of the incinerator temperature. The temperature level for indication of compliance should be related to the average temperature measured during the performance test. The averaging time for the temperature for monitoring purposes should be related to the time period for the performance test, in this case 3 hours. Since a temperature monitor is usually included as a standard feature for incinerators, it is expected that this monitoring requirement will not incur additional costs for the plant. The cost of purchasing and installing an accurate temperature measurement device and recorder is estimated at $1,000.

REFERENCES FOR APPENDIX D

1. Guideline Series - Measurement of Volatile Organic Compounds. Emission Measurement Branch, Emission Standards and Engineering Division. EPA-450/2-78-041, OAQPS No. 1.2-115. EPA, Research Triangle Park, North Carolina. October 1978.

2. Emission Test Report: Ford Motor Company, Pico Riveria, California, ESED Report Number 78-ISC-1.

3. Determination of Volatile Organic Matter, Water Content, Density, Volume Solids, and Weight Solids of Surface Coatings. Draft, Emission Measurement Branch, Emission Standards and Engineering Division, EPA, Research Triangle Park, North Carolina.

APPENDIX E - REVISIONS TO ECONOMIC DATA

This appendix addresses issues concerning the technical content of the background information document (BID) for the surface coating of metal furniture. The following issues have been raised by industry representatives:

1. For all calculations the powder film thicknesses can range from 2.03 to 3.81 x 10^{-3} cm (0.8 to 1.5 mil) instead of 6.35 x 10^{-3} cm (2.5 mil).[1-6]

2. New cost data for powder coatings were submitted by industry.[1-6]

3. Other cost data and film thicknesses were submitted by industry for other low organic solvent coatings (e.g., high solids and waterborne).[1,3,6]

4. The impact of solid waste generated from different low solvent coatings was questioned by industry.[1]

5. The industry expressed concern that spray booth ventilation rates could decrease as solvent levels of RACT coatings are decreased.[7]

These are the major issues concerning the quality of the BID. Each issue is addressed separately in the following sections.

E.1 ADDITIONAL COSTS AND ECONOMIC ANALYSIS

E.1.1 Cost Analysis

This section covers Issues 1-3. Although Table E-1 is similar to Table 7-21 in the BID, the cost data contained in Table E-1 have been changed based upon data received from an industry representative.[1] The selected base year for cost calculations both in the BID and in this appendix is 1978. The film coating thicknesses have also been changed as shown below:[1]

Table E-1. MODEL PLANT ANNUAL CONTROL COST FACTORS

Operating	2000 h/yr
Electricity	$0.08/10^7 J ($0.03/KWh)
Natural gas	$1.89/10^9 J ($2.00/10^6 Btu)
Paint:	
Conventional solvent-borne (35% solids)	$1.85/liter ($7.00/gallon)
High solids (60% to 70% solids)	$2.80/liter ($10.75/gallon)
60/40 Waterborne	$1.98/liter ($7.50/gallon)
80/20 Waterborne	$2.10/liter ($8.00/gallon)
Powder	$3.53/kg ($1.60/lb)
Labor	$6.70/manhour
Capital recovery factor assumptions (Equipment life and interest rate):	
Coating line equipment	15 years 10% interest
Building	25 years at 10% interest
Add-on control equipment	10 years at 10% interest
Taxes, insurance, and G&A	4% of total installed cost
Maintenance labor	10% of direct labor
Maintenance material	1.5% of equipment cost
Overhead	80% of direct labor cost

Low organic solvent coatings	Film thickness, cm (mil)
Powder	3.81 x 10-3 (1.5)
High solids (60-70 percent solids)	3.05 x 10^{-3} (1.2)
Waterborne	Unchanged

In addition, high solids coatings are applied at transfer efficiencies as high or higher than are solvent-borne coatings. These transfer efficiencies are based on information obtained from an industry representative.[1]

As a result of the changes in film thickness and transfer efficiencies, the emission estimates for powder and high solids coatings are not the same for spray coating lines (Chapter 5). However, emission estimates for only three of the Model Plants (A, D and E) are shown in this appendix. This is because only three spray coating lines were employed in Chapter 7 to determine total fifth-year annualized costs. The emission estimates are shown in Table E-2.

Tables E-3 through E-10 show the results of these calculations for Model Plants A, D, E, G, H, and I. The costs only changed for Model Plants A, D and E.

E.1.2 Economic Analysis

The total fifth-year annualized costs for three regulatory alternatives are listed below:

Regulatory alternatives	Combination	Total annualized costs (savings), $ millions
II	1	(18)
IV	2	(1.7)
II	3	17
III	4	11

The regulatory alternatives and combinations are defined in Chapters 5 and 7, respectively, of the BID.

Based upon the analysis of the cost data, all of the low organic solvent coatings are competitive. The maximum inflationary impact, as discussed in Chapter 7, would still occur if Plant E applied powder

Table E-2. EMISSION ESTIMATES FOR MODEL PLANTS A, D AND E

Model plant	Control option	Emission estimate (kilograms)
A	Uncontrolled	195,362
	SIPs (60% solids)	84,148
	65% solids	67,966
	SIPs + incineration	58,904
	70% solids	54,095
	Waterborne	38,000
	Powder	1,981
D	Uncontrolled	49,814
	SIPs (60% solids)	21,458
	65% solids	17,144
	SIPs + incineration	15,001
	70% solids	13,715
	Waterborne	9,700
	Powder	386
E	Uncontrolled	2,197
	SIPs (60% solids)	947
	65% solids	767
	70% solids	606
	Waterborne	420
	Powder	22

Table E-3. CONTROL COSTS FOR MODEL PLANT A - LARGE SPRAY COATING FACILITY FOR FLAT METAL FURNITURE SURFACES

	Control options[a]						
	A-1	A-2	A-3	A-4	A-5	A-6	A-U
INSTALLED CAPITAL COSTS ($1000's)							
Line(s)	$1810	$2041	$1570	$1570	$1570	$1570	$1570
Add-on control equipment	----	----	----	130	----	----	----
Building	2063	2270	2063	2063	2063	2063	2063
Total capital costs	3873	4311	3633	3763	3633	3633	3633
Annualized capital costs	444	495	413	433	413	413	413
Insurance, taxes, and G&A	155	172	145	151	145	145	145
Total annualized capital costs	599	667	558	584	558	558	558
OPERATING COSTS ($1000's/yr)							
Direct labor	600	600	600	600	600	600	600
Maintenance labor	60	60	60	60	60	60	60
Overhead	480	480	480	480	480	480	480
Maintenance materials	27	31	24	26	24	24	24
Paint	775	760	610	711	656	711	671
Electricity	69	84	69	69	69	69	73
Natural gas	34	45	45	49	45	45	67
Total operating costs	2045	2060	1888	1995	1934	1989	1975
TOTAL ANNUALIZED COSTS ($1000's/yr)	2644	2727	2446	2579	2492	2547	2533
Cost (credit) per kilogram of emission reduction versus uncontrolled plant	0.6	1.2	(0.6)	0.3	(0.3)	0.1	N/A[b]
Cost (credit) per kilogram of emission reduction versus base case	1.2	3.9	(3.4)	1.3	(3.4)	N/A	N/A
Cost per area covered ($/1000 m^2)	661	682	612	645	623	637	633

[a]A-1 Powder
A-2 Waterborne
A-3 70 percent high solids
A-4 Incinerator on base case line(s)
A-5 65 percent high solids
A-6 Base case--typical SIP
A-U Uncontrolled plant.

[b]N/A Not applicable

Table E-4. CONTROL COSTS FOR MODEL PLANT D - MEDIUM-SIZED SPRAY COATING FACILITY FOR COMPLEX METAL FURNITURE SURFACES

	Control options[a]						
	D-1	D-2	D-3	D-4	D-5	D-6	D-U
INSTALLED CAPITAL COSTS ($1000's)							
Line(s)	$644	$728	$560	$560	$560	$560	$560
Add-on control equipment	----	----	----	110	----	----	----
Building	402	552	402	402	402	402	402
Total capital costs	1046	1170	962	1072	962	962	962
Annualized capital costs	125	140	114	131	114	114	114
Insurance, taxes, and G&A	42	47	38	43	38	38	38
Total annualized capital costs	167	187	152	174	152	152	152
OPERATING COSTS ($1000's/yr)							
Direct labor	150	150	150	150	150	150	150
Maintenance labor	15	15	15	15	15	15	15
Overhead	120	120	120	120	120	120	120
Maintenance materials	10	11	8	10	8	8	8
Paint	95	198	158	185	171	185	175
Electricity	9	10	9	9	9	9	9
Natural gas	8	11	11	12	11	11	16
Total operating costs	407	515	471	501	484	498	493
TOTAL ANNUALIZED COSTS ($1000/yr)	574	702	623	675	636	650	645
Cost (credit) per kilogram of emission reduction versus uncontrolled plant	(1.4)	1.4	(0.6)	0.9	(0.3)	0.2	N/A[b]
Cost (credit) per kilogram of emission reduction versus base case	(3.6)	4.4	(3.5)	3.9	(3.3)	N/A	N/A
Cost per area covered ($/1000 m^2)	736	900	799	865	815	833	827

[a]D-1 Powder
D-2 Waterborne
D-3 70 percent high solids
D-4 Incinerator on base case line(s)
D-5 65 percent high solids
D-6 Base case--typical SIP
D-U Uncontrolled plant

[b]N/A Not applicable

Table E-5. CONTROL COSTS FOR MODEL PLANT E - SMALL SPRAY COATING FACILITY FOR FLAT METAL FURNITURE SURFACES

	Control options[a]					
	E-1	E-2	E-3	E-4	E-5	E-U
INSTALLED CAPITAL COSTS ($1000's)						
Line(s)	$225	$225	$196	$196	$196	$196
Add-on control equipment	---	---	---	---	---	---
Building	23	25	23	23	23	23
Total capital costs	248	250	219	219	219	219
Annualized capital costs	32	32	28	28	28	28
Insurance, taxes, and G&A	10	11	9	9	9	9
Total annualized capital costs	42	43	37	37	37	37
OPERATING COSTS ($1000's/yr)						
Direct labor	40	40	40	40	40	40
Maintenance labor	4	4	4	4	4	4
Overhead	32	32	32	32	32	32
Maintenance materials	3	4	3	3	3	3
Paint	5	7	7	7	8	8
Electricity	4	5	4	4	4	4
Natural gas	4	5	5	5	5	7
Total operating costs	92	97	93	93	96	98
TOTAL ANNUALIZED COSTS ($1000's/yr)	134	140	130	130	133	135
Cost (credit) per kilogram of emission reduction versus uncontrolled plant	(0.5)	2.8	(3.1)	(3.5)	(1.6)	N/A[b]
Cost (credit) per kilogram of emission reduction versus base case	1.1	13.3	(8.8)	(16.7)	N/A	N/A
Cost per area covered ($/1000 m^2)	2978	3111	2889	2889	2956	3000

[a]E-1 Powder
E-2 Waterborne
E-3 70 percent high solids
E-4 65 percent high solids
E-5 Base case--typical SIP
E-U Uncontrolled plant

[b]N/A Not applicable

Table E-6. PLANT A - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF SIP LEVEL FACILITIES

	Control options[a]				
	A-1	A-2	A-3	A-4	A-5
INSTALLED CAPITAL COSTS ($1000's)					
Line(s)	$750	$500	0	0	0
Add-on control equipment	0	0	0	$130	0
Building	0	207	0	0	0
Total capital costs	750	707	0	130	0
Annualized capital costs	99	87	0	20	0
Insurance, taxes, and G&A	30	28	0	5	0
Total annualized capital costs	129	115	0	25	0
OPERATING COSTS (SAVINGS) ($1000's)					
Direct labor	0	0	0	0	0
Maintenance labor	0	0	0	0	0
Overhead	0	0	0	0	0
Maintenance materials	11	8	0	2	0
Paint	64	167	$(101)	0	$(55)
Electricity	0	15	0	0	0
Natural gas	(22)	0	0	5	0
Total operating costs	53	190	(101)	7	(55)
TOTAL ANNUALIZED COSTS (SAVINGS) ($1000's)	182	305	(101)	30	(55)
Cost (savings) per area covered ($/1000 m^2)	46	76	(25)	8	(14)

[a]A-1 Powder
A-2 Waterborne
A-3 70 percent high solids
A-4 Incinerator on base line(s)
A-5 65 percent high solids.

Table E-7. PLANT D - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF SIP LEVEL FACILITIES

	Control options[a]				
	D-1	D-2	D-3	D-4	D-5
INSTALLED CAPITAL COSTS ($1000's)					
Line(s)	$260	$182	0	0	0
Add-on control equipment	0	0	0	$110	0
Building	0	40	0	0	0
Total capital costs	260	222	0	110	0
Annualized capital costs	34	28	0	17	0
Insurance, taxes, and G&A	10	9	0	4	0
Total annualized capital costs	44	37	0	21	0
OPERATING COSTS (SAVINGS) ($1000's)					
Direct labor	0	0	0	0	0
Maintenance labor	0	0	0	0	0
Overhead	0	0	0	0	0
Maintenance materials	4	3	0	2	0
Paint	(90)	44	$(27)	0	$(14)
Electricity	0	2	0	0	0
Natural gas	(5)	0	0	1	0
Total operating costs	(91)	49	(27)	3	(14)
TOTAL ANNUALIZED COSTS (SAVINGS) ($1000's)	(47)	86	(27)	24	(14)
Cost (savings) per area covered ($/1000 m^2)	(60)	110	(35)	31	(18)

[a]D-1 Powder
D-2 Waterborne
D-3 70 percent high solids
D-4 Incinerator on base case line(s)
D-5 65 percent high solids.

Table E-8. PLANT E - CONTROL COSTS FOR MODIFICATION OR RECONSTRUCTION OF SIP LEVEL FACILITIES

	Control options[a]			
	E-1	E-2	E-3	E-4
INSTALLED CAPITAL COST ($1000's)				
Line(s)	$90	$55	0	0
Add-on control equipment	0	0	0	0
Building	0	2	0	0
Total capital costs	90	57	0	0
Annualized capital costs	11	7	0	0
Insurance, taxes, and G&A	4	2	0	0
Total annualized capital costs	15	9	0	0
OPERATING COSTS (SAVINGS) ($1000's)				
Direct labor	0	0	0	0
Maintenance labor	0	0	0	0
Overhead	0	0	0	0
Maintenance materials	1	1	0	0
Paint	(3)	1	$(1)	$(1)
Electricity	0	1	0	0
Natural gas	(2)	0	0	0
Total operating costs	(4)	3	(1)	(1)
TOTAL ANNUALIZED COSTS (SAVINGS) ($1000's)	11	12	(1)	(1)
Cost (savings) per area covered ($/1000 m^2)	244	267	(22)	(22)

[a]E-1 Powder
E-2 Waterborne
E-3 70 percent high solids
E-4 65 percent high solids.

Table E-9. INCREMENTAL ANNUALIZED CONTROL COST (SAVINGS) PER THOUSAND SQUARE METERS COATED AT NEW FACILITIES - SIP BASELINE ($1000's)

Plant	70% High solids[c]	Conventional waterborne	Powder	EDP	Incinerator & RACT coating
A	$(25)	$45	$24	b	$8
D	(34)	67	(97)	b	32
E	(67)	155	22	b	b
G	b	9	a	$84	a
H	b	10	a	110	a
I	b	0	a	733	b
J	b	0	b	b	b

[a]Not considered for this plant under the three combinations of control options being examined.

[b]Regulatory alternative does not apply to this plant.

[c]Parentheses indicate savings from baseline.

Table E-10. INCREMENTAL ANNUALIZED CONTROL COST PER THOUSAND SQUARE METERS COATED AT MODIFIED/RECONSTRUCTED FACILITIES - SIP BASELINE ($1000's)

Plant	70% High solids[c]	Conventional waterborne	Powder	EDP	Incinerator & RACT coating
A	$(25)	$76	46	b	$8
D	(35)	110	(60)	b	31
E	(22)	267	244	b	b
G	b	9	a	$94	a
H	b	10	a	169	a
I	b	0	a	889	b
J	b	0	b	b	b

[a] Not considered for this plant under the three combinations of control options being examined.

[b] Regulatory alternative does not apply to this plant.

[c] Parentheses indicate savings from baseline.

Table E-11. PROFIT IMPACT
MODEL PLANTS A, D AND E - NEW FACILITIES
SIP BASELINE

Plant	Control option	Incremental annualized control cost[a] ($000)	# Shelves coated (000)	Incremental annualized control cost per shelf coated[a] ($)	Profit margin impacts F.O.B. price per shelf ($)	$
A (shelves)	Powder (spray)	97	4000	.024	25.55	.09
	Waterborne	180	4000	.045	25.55	.18
	70% High solids	(101)	4000	(.02)	25.55	b
	Incinerator & RACT coating	32	4000	.008	25.55	.03
	65% High solids	(55)	4000	(.014)	25.55	b
D (chairs)	Powder (spray)	(76)	780	(.097)	35.00	b
	Waterborne	52	780	.067	35.00	.19
	70% High solids	(27)	780	(.035)	35.00	b
	Incinerator & RACT coating	25	780	.032	35.00	.09
	65% High solids	(14)	780	(.018)	35.00	b
E (shelves)	Powder (spray)	1	45	.022	25.55	.09
	Waterborne	7	45	.156	25.55	.61
	70% High solids	(3)	45	(.067)	25.55	b
	65% High solids	(3)	45	(.067)	25.55	b

[a]Parentheses indicated decrease from baseline case.
[b]No negative impact on profit margin.

Table E-12. PROFIT IMPACT
MODEL PLANTS A, D AND E - NEW FACILITIES
UNCONTROLLED BASELINE

Plant	Control option	Incremental annualized control cost[a] ($000)	# Shelves coated (000)	Incremental annualized control cost per shelf coated[a] ($)	Profit margin impact F.O.B. price per shelf ($)	Profit margin impact %
A (shelves)	Powder (spray)	111	4000	.028	25.55	.11
	Waterborne	194	4000	.049	25.55	.20
	70% High solids	(87)	4000	(.022)	25.55	b
	Incinerator & RACT coating	46	4000	.012	25.55	.05
	65% High solids	(41)	4000	(.010)	25.55	b
D (chairs)	Powder (spray)	(71)	780	(.091)	35.00	b
	Waterborne	57	780	.073	35.00	.21
	70% High solids	(22)	780	(.028)	35.00	b
	Incinerator & RACT coating	30	780	.038	35.00	.11
	65% High solids	(9)	780	(.012)	35.00	b
E (shelves)	Powder (spray)	(1)	45	(.022)	25.55	b
	Waterborne	5	45	.111	25.55	.43
	70% High solids	(5)	45	(.111)	25.55	b
	65% High solids	(5)	45	(.111)	25.55	b

[a]Parentheses indicate decrease from baseline case.
[b]No negative impact on profit margin.

Table E-13. PROFIT IMPACT
MODEL PLANTS A, D AND E - MODIFIED/RECONSTRUCTED FACILITIES
SIP BASELINE

Plant	Control option	Incremental annualized control cost[a] ($000)	# Shelves coated (000)	Incremental annualized control cost per shelf coated[a] ($)	Profit margin impact: F.O.B. price per shelf ($)	Profit margin impact: %
A (shelves)	Powder (spray)	182	4000	.046	25.55	.18
	Waterborne	305	4000	.08	25.55	.31
	70% High solids	(101)	4000	(.025)	25.55	b
	Incinerator & RACT coating	30	4000	.01	25.55	.04
	65% High solids	(55)	4000	(.014)	25.55	b
D (chairs)	Powder (spray)	(47)	780	(.060)	35.00	b
	Waterborne	86	780	.110	35.00	.32
	70% High solids	(27)	780	(.02)	35.00	b
	Incinerator & RACT coating	24	780	.031	35.00	.09
	65% High solids	(14)	780	(.018)	35.00	b
E (shelves)	Powder (spray)	11	45	.24	25.55	.96
	Waterborne	12	45	.27	25.55	1.06
	70% High solids	(1)	45	(.022)	25.55	b
	65% High solids	(1)	45	(.022)	25.55	b

[a]Parentheses indicate decrease from baseline case.
[b]No negative impact on profit margin.

Table E-14. PROFIT IMPAIRMENT

MODEL PLANTS A, D AND E - NEW FACILITIES

SIP AND UNCONTROLLED BASELINES

Plant	Control option	% Impairment at profit rates below					
		SIP baseline			Uncontrolled baseline		
		4.3%	4.8%	5.6%	4.3%	4.8%	5.6%
A (shelves)	Powder (spray)	a	1.88	a	a	2.29	a
	Waterborne	a	3.75	a	a	4.17	a
	70% high solids	a	b	a	a	b	a
	Incinerator & RACT coating	a	0.63	a	a	1.04	a
	65% high solids	a	b	a	a	b	a
D (chairs)	Powder (spray)	b	b	b	b	b	b
	Waterborne	4.42	3.96	3.39	4.88	4.38	3.75
	70% high solids	b	b	b	b	b	b
	Incinerator & RACT coating	2.09	1.88	1.61	2.56	2.29	1.96
	65% high solids	b	b	b	b	b	b
E (shelves)	Powder (spray)	2.09	1.88	1.61	b	b	b
	Waterborne	14.19	12.71	10.89	10.00	8.96	7.68
	70% high solids	b	b	b	b	b	b
	65% high solids	b	b	b	b	b	b

[a]Profit rate does not apply to this plant.

[b]No profit impairment involved. Incremental annualized cost for this control option is negative - i.e., there is a decrease in cost from the baseline case.

Table E-15. PROFIT IMPAIRMENT

MODEL PLANTS A, D AND E - MODIFIED/RECONSTRUCTED FACILITIES

SIP BASELINE

Plant	Control option	% Impairment at profit rates below SIP baseline		
		4.3%	4.8%	5.6%
A (shelves)	Powder (spray)	a	3.75	a
	Waterborne	a	6.46	a
	70% high solids	a	b	a
	Incinerator & RACT coating	a	0.83	a
	65% high solids	a	b	a
D (chairs)	Powder (spray)	b	b	b
	Waterborne	7.44	6.67	5.71
	70% high solids	b	b	b
	Incinerator & RACT coating	2.09	1.88	1.61
	65% high solids	b	b	b
E (shelves)	Powder (spray)	22.33	20.00	17.14
	Waterborne	24.65	22.08	18.93
	70% high solids	b	b	b
	65% high solids	b	b	b

[a] Profit rate does not apply to this plant.
[b] No profit impairment involved. Incremental annualized cost for this control option is negative - i.e., there is a decrease in cost from the baseline case.

Table E-16. INFLATION IMPACT

FOR MODEL PLANTS A, D AND E

Plant	Control option	Inflation Impact % New Facilities SIP	Inflation Impact % New Facilities Uncontrolled	Inflation Impact % Modified/ Reconstructed facilities SIP
A (shelves)	Powder (spray)	.06	.07	.12
	Waterborne	.12	.13	.21
	70% high solids	b	b	b
	Incinerator & RACT coating	.02	.03	.03
	65% high solids	b	b	b
D (chairs)	Powder (spray)	b	b	b
	Waterborne	.13	.14	.21
	70% high solids	b	b	b
	Incinerator & RACT coating	.06	.07	.06
	65% high solids	b	b	b
E (shelves)	Powder (spray)	.06	b	.63
	Waterborne	.41	.29	.70
	70% high solids	b	b	b
	65% high solids	b	b	b

[a]Impacts calculated on the basis of retail list price of $38.33 per shelf, and $52.50 per chair.
[b]No impacts involved.

coatings at a thickness of 6.35×10^{-3} cm (2.5 mil). The worst-case impact for Plant E is about 1.3 percent. However, if the coating thickness is changed to 3.81×10^{-3} cm (1.5 mil), the worst-case impact for Plant E is the waterborne control option. Under this control option, the wholesale price increases by about 0.70 percent. Tables E-11 through E-16 show additional information for profit impact, profit impairment, and inflation impact employing the different film thicknesses and transfer efficiency values. The only control option to change significantly is the powder option. In all cases for powder the impacts indicated significant improvement over Chapter 7 information.

E.2 SOLID WASTE DATA

This section covers Issue 4. Data reported in Table 6-7 of the BID have been questioned by an industry representative. However, the variability of the data presented in Table 6-7 is due to the assumed transfer efficiencies for solvent-borne, high solids, and waterborne coatings and to the powder utilization efficiencies and film thickness. Regardless of how the transfer efficiencies are changed, the conclusion of the solid waste impact reported in Chapter 6 remains unchanged.

E.3 SPRAY BOOTH VENTILATION RATES

Another industry representative has questioned calculated application exhaust flow rates in areas that apply high solids and waterborne coatings, stating that these flow rates are fixed by OSHA regulations.[7] However, as shown in the following excerpt, this OSHA regulation allows a range of flow rates, and the second part of the regulation allows reduction of flow rates because of quantity of "solids and nonflammables contained in the finish":

> "(6) Velocity and air flow requirements.
>
> (i) Except where a spray booth has an adequate air replacement system, the velocity of air into all openings of a spray booth shall be not less than that specified in Table G-10 for the operating conditions specified. An adequate air replacement system is one which introduces replacement air upstream or above the object being sprayed and is so designed that the velocity of air in the booth cross section is not less than that specified in Table G-10 when measured upstream or above the object being sprayed.

Table G-10—Minimum Maintained Velocities Into Spray Booths

Operating conditions for objects completely inside booth	Cross draft, f.p.m.	Air flow velocities, f.p.m.	
		Design	Range
Electrostatic and automatic airless operating contained in booth without operator.	Negligible.........	50 large booth... 100 small booth...	50-250 75-125
Air-operated guns, manual or automatic	Up to 50..........	100 large booth... 150 small booth...	75-125 125-175
Air-operated guns, manual or automatic	Up to 100.........	150 large booth... 200 small booth...	125-175 150-250

Notes:

(1) Attention is invited to the fact that the effectiveness of the spray booth is dependent upon the relationship of the depth of the booth to its height and width.

(2) Crossdrafts can be eliminated through proper design and such design should be sought. Crossdrafts in excess of 100 fpm (feet per minute) should not be permitted.

(3) Excessive air pressures result in loss of both efficiency and material waste in addition to creating a backlash that may carry overspray and fumes into adjacent work areas.

(4) Booths should be designed with velocities shown in the column headed "Design". However, booths operating with velocities shown in the column headed "Range" are in compliance with this standard.

(ii) In addition to the requirements in subdivision (i) of this subparagraph the total air volume exhausted through a spray booth shall be such as to dilute solvent vapor to at least 25 percent of the lower explosive limit of the solvent being sprayed. An example of the method of calculating this volume is given below . . . ."Note that the quantity of solvent will be diminished by the quantity of solids and nonflammables contained in the finish.

"To determine the volume of air in cubic feet necessary to dilute the vapor from 1 gallon of solvent to 25 percent of the lower explosive limit, apply the following formula:

$$\text{Dilution volume required per gallon of solvent} = \frac{4(100\text{-LEL})(\text{cubic feet of vapor per gallon})}{\text{LEL}}$$

Using toluene as the solvent.

(1) LEL of toluene . . . is 1.4 percent.

(2) Cubic feet of vapor per gallon . . . is 30.4 cubic feet per gallon.

(3) Dilution volume required =

$$\frac{4\ (100-1.4)\ 30.4}{1.4} = 8{,}564 \text{ cubic feet.''}$$

The reduced exhaust flow rates from the coating application area are also supported by coating line designers contacted during the development of the BID.

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16. ABSTRACT

Standards of performance to control emissions of volatile organic compounds (VOC) from new, modified, and reconstructed metal furniture surface coating facilities are being proposed under Section 111 of the Clean Air Act. This document contains information on the background and authority, regulatory alternatives considered, and environmental and economic impacts of the regulatory alternatives.

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