II. CHARACTERISTICS OF THE PAINT AND ALLIED COATING PRODUCTS INDUSTRY

A. Overview

Paint and allied coating products constitute a general class of materials whose primary functions are the protection and decoration of surfaces. Coatings are also used for fire retardation, color coding, electrical insulation, and temperature control [1]. In the most narrow sense, "paint" refers only to pigmented products such as interior (wall), exterior (house), masonry, and traffic coatings; terms for other coatings include enamel, undercoater, primer, sealer, varnish, lacquer, stain, and industrial finishes. Historically, however, the term "paint" has sufficed as the common description for coating materials consisting of a covering material (pigment), a film-forming material (usually an oil or resin), and viscosity modifiers (thinners and solvents). The terms "organic surface coating," "paint and coating," or "chemical coating" are increasingly being used to describe a variety of products that are used for the protection or decoration of surfaces. Related to the various types of surface coatings are allied products such as putties and paint and varnish removers. The major types and end uses of paint and coating products are shown in Table II-1.

The manufacture of most coatings basically involves the incorporation of pigment particles in a film-forming matrix, thinning and adjusting the resultant product, and dispensing it into containers of various sizes for shipment and sale. The manufacture of varnishes, which contain no pigments, is a different type of batch process which involves mixing ingredients and "cooking" them in a reactor vessel or kettle. Definitions of various terms used in the coatings industry are listed in the Glossary (Appendix A).

Thousands of different raw materials [2] are used in the manufacture of approximately 20,000 different coating products [3-5]. The need for so many raw materials and products results from the great diversity of surfaces requiring treatment. There are numerous small manufacturers because paint-making is still largely a batch process that does not readily lend itself to automation or continuous flow processing [2]. Few firms sell nationwide because of high shipping costs, the difficulty of maintaining production schedules, and other distribution problems.

1. Industry Trends

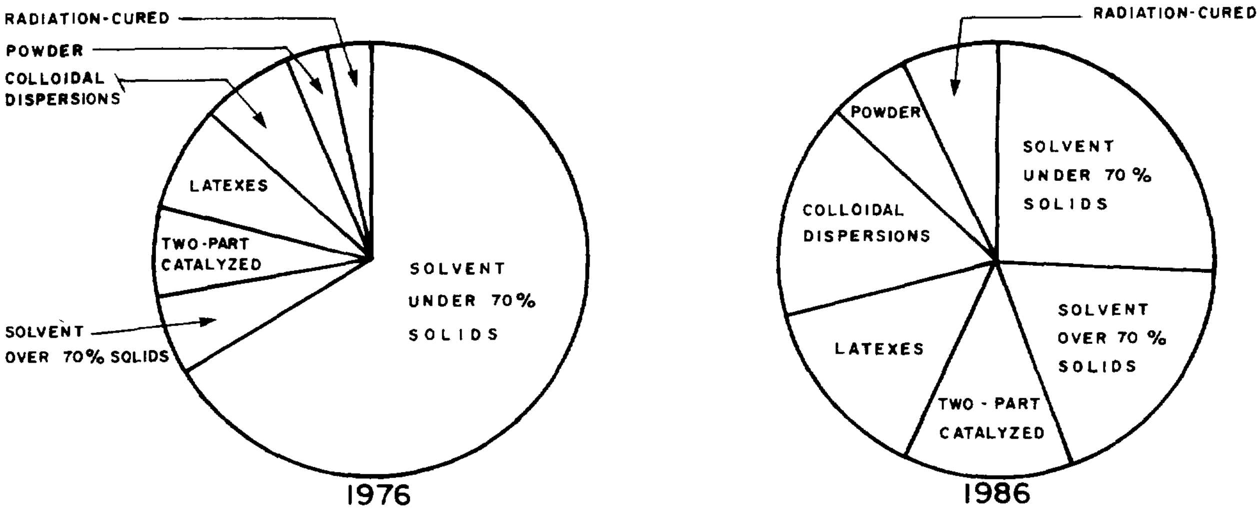
Growth in the total production of the U.S. paint and allied coating products industry has been about 2% annually since 1967 and is expected to continue at this rate through 1990 [6]. In 1981, over 900 companies produced architectural coatings, approximately 250 companies made product coatings for original equipment manufacturers, and approximately 250 companies made special purpose coatings [6]. The largest companies are active in all coatings categories; whereas, the smaller companies may specialize in only one segment of the industry [6].

TABLE II-1. TYPICAL END USES FOR THE MAJOR CATEGORIES OF PAINTS AND COATINGS [6]

Category	End Uses
Architectural Coatings	Exterior house and trim paints (including flat house paints and enamels) Exterior masonry paints Undercoaters, primers, and sealers Interior wall, ceiling, and trim paints (including flat wall paints, and gloss and semigloss enamels) Varnishes Stains
Product Coatings for Original Equipment Manufacturers	Automobile, truck, and bus finishes Wood furniture and fixture finishes Metal furniture and fixture finishes Finishes for railroad equipment Aircraft and missile coatings Appliance finishes Marine finishes Electrical and electronic insulation coatings Machinery and equipment finishes Prefinished metal (coil coatings) Prefinished wood and composition boards Container and closure coatings Paper and paperboard coatings Plastic and film coatings Pipe coatings
Special Purpose Coatings	Specially formulated high-performance maintenance finishes Automobile, truck, and bus refinish coatings Marine refinish coatings Other refinish coatings Traffic paints Metallic finishes Aerosol paints

Air pollution regulations limiting the amount of volatile organic compounds that can be used in coatings and the rapid rise in solvent prices are responsible for the trend in the coatings industry to replace conventional low-solids, volatile organic solvent-based coatings with high-solids (i.e., over 70%) or low solvent or water-based formulations such as radiation-curable coatings, powder coatings, two-part catalyzed systems, and nonaqueous dispersions [1,2,6]. However, it is believed that conventional organic solvent-based coatings will still have a large share of the market at least until 1990 [6-8]. Figure II-1 shows the relative market share in 1976 and an estimate for 1986 for the primary types of coatings.

FIGURE II-1. MARKET SHARES OF VARIOUS PAINT AND COATING SYSTEMS IN 1976 AND ESTIMATES FOR 1986 [8]



In addition to the air pollution emission potential of various coating systems, a factor in their selection is the amount of energy required for application and for engineering controls to reduce occupational exposure. Because of relatively high energy efficiencies, the use of high-solids and radiation-curable coatings is expected to increase [7,8].

2. Extent of Exposure

According to the 1978 Annual Survey of Manufacturers [9], the paint and allied coating products industry in the United States employed about 61,500 workers in 1,700 individual plants. About 60% of the paint facilities had fewer than 20 workers, and only about 3% of the facilities (i.e., about 50) had more than 250 workers [9]. According to NIOSH data generated in 1983 [10], there were about 68,000 workers in 1,800 individual plants. The Department of Labor estimated that there were 60,600 workers in Paints, Varnishes, Lacquers, Enamels, and Allied Coating Products manufacturing (SIC code 2851) in 1982 [11].

3. Product Classifications

In 1979, the Federal government revised its reporting system for categorizing paints and coatings classifying them as either (1) architectural coatings (paints), (2) product finishes for original equipment manufacturers, or (3) special purpose coatings [9]. The typical end uses for each of the three major categories of paints and coatings are shown in Table II-1.

"Architectural coatings" are generally classified as stock type or shelf goods that are formulated for normal environmental conditions and general applications on new and existing residential, commercial, institutional, and industrial structures [6]. Approximately 70% of all architectural coatings are water-based and most are applied by brush or roll [1].

"Product coatings for original equipment manufacturers" are formulated specifically to meet conditions of application and product requirements [6]. These coatings include paints, lacquers, and powders and are applied during the manufacturing process to the surfaces of products made from metal, wood, or plastic. About 60-65% of these coatings have been solvent-based, but in recent years applications for water-based, high-solids, powder coatings, and two-part catalyzed systems have been increasing [9].

"Special purpose coatings" may be stock-type or shelf goods, but they are formulated specifically for refinishing and specialty applications or for environmental conditions such as extreme temperatures or corrosive-chemical atmospheres [6]. These coating types include high-performance industrial maintenance paints, automotive and machinery refinishes, and traffic paints and can be either solvent- or water-based [9].

4. Job Classifications

A scheme for the classification and description of jobs in this industry has been developed by Discher et al. [12]. A revised version of this classification is presented in Table II-2. A similar description of job classifications in the varnish manufacturing process is shown in Table II-3. In many smaller plants, one worker might perform a number of different jobs rather than just one particular task.

TABLE II-2. JOB CLASSIFICATIONS IN THE MANUFACTURE OF PAINT AND ALLIED COATING PRODUCTS

Classification	Description
Raw materials handlers	Transport and store raw materials in the plant.
Prebatch assemblers	Weigh and assemble raw materials (usually dry) for the mixer, primarily in the raw materials storage and mixing areas.
Mixers (including mill operators)	Load mixing tanks or mills. Responsible for quality control checks for dispersion. May be responsible for cleaning the mills.
Tinters (including thinners, shaders, and body adjusters)	Responsible for the dispersed paint quality. Add solvents, driers, preservatives, and tinting paste. Responsible for quality control for color, viscosity, etc.
Fillers	Fill paint containers. Set up the filling line (if mechanized).
Tank and tub cleaners	Clean portable tanks and tubs.
Laboratory personnel	Test raw materials. Responsible for finished product testing and for research and development.
Others	Includes packagers, maintenance personnel, shippers, and loading personnel in the warehouse.

Adapted from Discher et al. [12]

TABLE II-3. JOB CLASSIFICATIONS IN THE MANUFACTURE OF VARNISHES

Classification	Description
Reactor operators	Load reactors with raw materials. Adjust and maintain reaction conditions.
Varnish cookers	Cook varnish and maintain reaction conditions (applies only to open-kettle process).
Filter press operators	Filter and reduce the varnish and clean the presses.
Fillers	Fill varnish containers.
Laboratory personnel	Test raw materials. Responsible for finished product testing and for research and development.
Others	Includes packagers, maintenance personnel, shippers, and loading personnel in the warehouse.

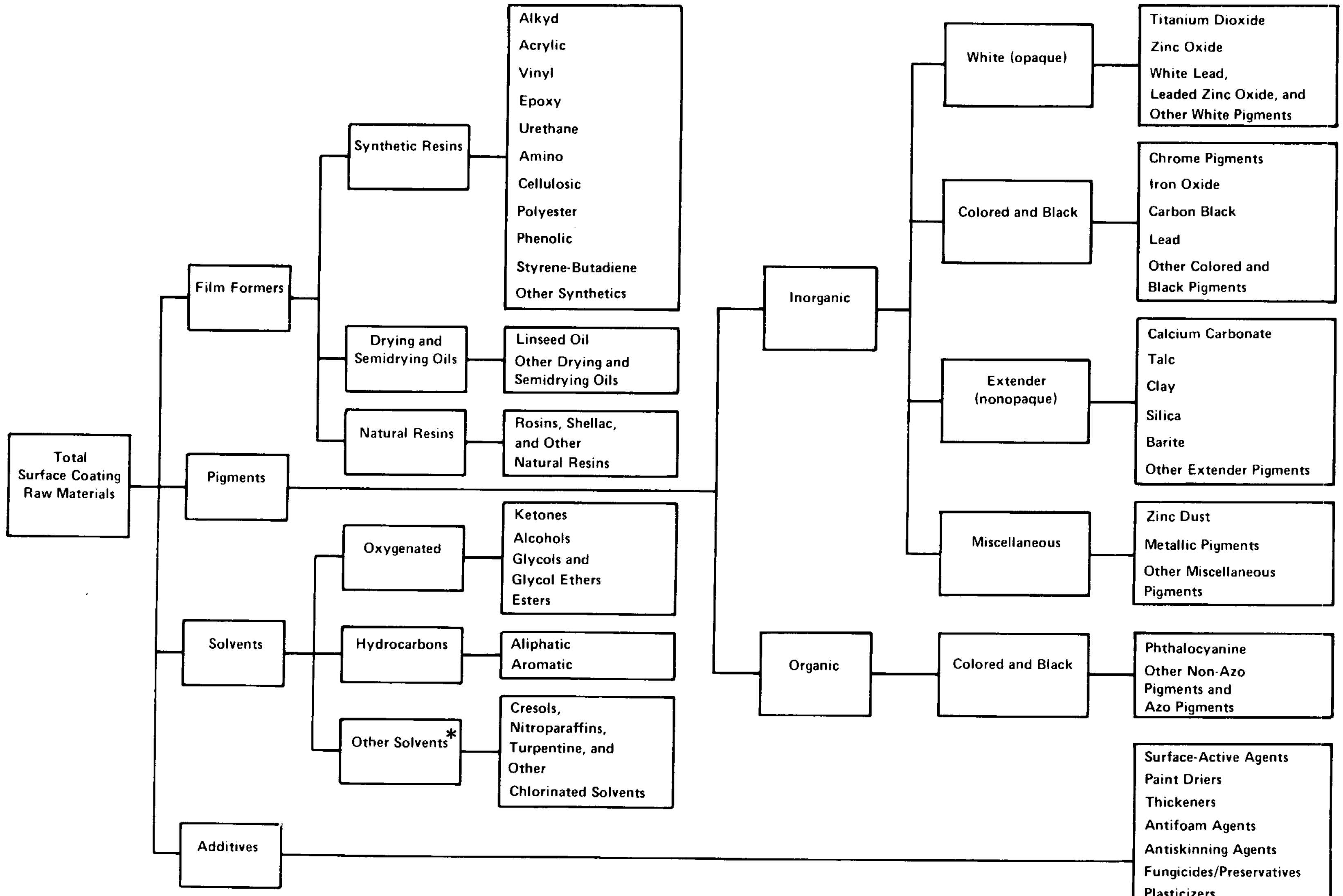
Adapted from Discher et al. [12]

B. Raw Materials

Liquid paint is a suspension of pigment particles in a mixture of film-former and volatile solvent. The solvent, which reduces viscosity to allow easy application, and the film-former hold the pigment in the dried film and cause it to adhere to the coated surface. The pigment confers hiding and coloring power as well as durability to the dried film. Various additives are used to obtain particular characteristics. Although drying is usually accomplished through evaporation of the solvent, drying may also be by polymerization of the film-former through oxidation (e.g., with oils and alkyds), by coalescence (e.g., with latexes), or by chemical reactivity (e.g., with epoxy resins) [13].

In 1980, an estimated 9.5 billion pounds of raw materials (excluding water) were used in the manufacture of paint and allied coating products [6]. The four general categories of raw materials used (film-formers, pigments, solvents, and additives) are identified in Figure II-2.

FIGURE II-2. RAW MATERIALS USED IN THE MANUFACTURE OF COATINGS
(Adapted from Chemical Economics Handbook [1])



* Categories designated by the term "other" are generally of small volume and heterogeneous composition.

1. Film-Formers

Film-formers are the nonvolatile binders or vehicle portions of coatings. They may be classified as one of three different chemical types: synthetic resins, drying and semidrying oils, and natural resins. Synthetic resins account for over 94% of all film-formers and include alkyds, acrylics, vinyls, epoxies, urethanes, aminos, cellulosics, polyesters, phenolics, styrene-butadienes, and others [1]. Linseed oil is the primary drying oil utilized as a film-former. Natural resin film-formers constituted less than 1% of all film-formers consumed in 1977, in contrast to about 50% prior to World War II [1]. Some of these natural resins include rosins and shellac.

2. Pigments

Pigments are incorporated into coatings to impart color, opacity, and properties such as durability, corrosion inhibition, and mildew control or to be a filler or extender [1]. They are finely powdered solids that are essentially insoluble in the medium in which they are dispersed. Almost all of the pigments utilized in the U.S. (99%) are inorganic [1,6] with titanium dioxide accounting for about one-third of total pigments used [6]. Pigments are generally classified as white (opaque) pigments, colored and black pigments, extenders (non-opaque), and miscellaneous (mainly metallic powders).

Extenders are white pigments that have a low refractive index and have little hiding or coloring ability by themselves in solvent-based coatings but have a strong influence on costs and the performance of most pigmented coatings in which they are used. Extender pigments are used to control gloss, texture, suspension, viscosity, and other physical characteristics of coatings [2,14]. In water-based coatings, however, extender pigments contribute to opacity and hiding ability. Extenders include talc, china clay (aluminum silicate), silica, asbestos, diatomaceous earth, calcium silicate, magnesium carbonate, and mica [2,14].

Generally, pigments are available as dry powders that are shipped in bags or in cardboard or fiber drums. Pigments are also shipped as aqueous slurries and pastes or as pellets.

3. Solvents

The primary function of solvents in paints and coatings is to dissolve or suspend film-formers, thereby providing a consistency suitable for application. Solvents also influence the rate of setting, the drying time, the flow properties, and the flammability of coatings [1]. Water-based paints consist of a dispersion of film-formers within an aqueous medium. Generally, organic solvents are classified as hydrocarbon solvents, oxygenated solvents, and "other." The latter category includes furans, nitroparaffins, chlorinated solvents, and terpenes.

a. Hydrocarbon Solvents

Among the organic solvents, hydrocarbon solvents rank first by volume of use (56%) in paint and allied coatings [1]. They are less expensive than many other types of organic solvents and have many uses. An organic solvent-based coating material that contains no hydrocarbon solvent is unusual. Hydrocarbon solvents used in the paint industry are classified as either aliphatic naphthas or aromatics. Aliphatic naphtha solvents such as mineral spirits or Varnish Makers' and Painters' (VM&P) naphtha are predominantly paraffins, with a smaller but appreciable content of cycloparaffins (naphthenes such as cyclopentane and cyclohexane). These solvents may also contain as much as 20-30% aromatics [2]. Mineral spirits constitute about three-fourths of all hydrocarbon solvents used in the paint and allied coating products industry overall. The aromatic hydrocarbon solvents such as toluene, xylene, high flash solvent naphthas, and aromatic naphthas predominantly exhibit higher solvency than aliphatic solvents.

b. Oxygenated Solvents

Oxygenated solvents are so designated because of the presence of oxygen which contributes polarity (a difference in the electric charge on various portions of the materials). This polarity is the fundamental difference between oxygenated and hydrocarbon solvents, which are essentially nonpolar. Because of their polarity, many oxygenated solvents are water-soluble and are better solvents for the more polar film-formers such as shellac, cellulose esters, amino-formaldehydes, vinyls, acrylics, epoxies, polyurethanes, and silicones [15]. Oxygenated solvents account for about 42% of the organic solvents used in the paint and allied coatings industry [1] and include glycols, glycol ethers, glycol ether esters, water-miscible alcohols such as methanol, ethanol, butanol, and isopropanol, acetate esters, and ketones such as acetone, methyl ethyl ketone (MEK), and methyl isobutyl ketone (MIBK) [6]. Since they are more expensive than the hydrocarbon solvents, a mixture of oxygenated and hydrocarbon solvents is used in most paint formulations [15].

c. "Other Solvents"

Other solvents, which account for only 1% of the organic solvents used, include furans such as tetrahydrofuran and tetrahydrofurfural alcohol, nitroparaffins such as 2-nitropropane, chlorinated solvents such as methylene chloride, and terpenes such as turpentine, dipentene, and pine oil [2,15].

4. Additives

Many substances that contribute to the ease of manufacture, the stability of the paint in the package, the ease of application, or the quality or appearance of the applied film are used in relatively small quantities in paint formulations. These substances are referred to under the broad term "additives." Each additive rarely exceeds 1% of the total formulation, and the total amount of all additives seldom exceeds 5% of the paint product [16]. The major classes of additives are plasticizers, surface-active agents, flow modifiers, driers, anti-skinning agents, biocides, and "other."

a. Plasticizers

A plasticizer is a substance added to a coating material to keep the finished film flexible and to avoid undesirable effects such as cracking or checking, without appreciable sacrifice of such desirable effects as film strength, continuity, and resistance to attack by chemicals [17]. True plasticizers are permanent and relatively nonvolatile components of coating films. Plasticizers account for about one-third of the additives consumed in coatings [1]. Over 500 different plasticizers are available [2].

b. Surface-Active Agents

Surface-active agents or "surfactants" are added to aqueous coatings (such as latexes) and comprise over 20% of the additives used in paints [1]. There are four general groups: anionic surfactants, used primarily to promote pigment dispersion by providing better wetting of the particles; nonionic surfactants, used to stabilize total dispersed systems; antifoam agents, used to prevent, reduce, or eliminate foam formation during coatings manufacture and application; and emulsifiers, which are materials used to stabilize mixtures of immiscible liquids such as oil and water by reducing interfacial tensions between liquids [16,17].

c. Flow Modifiers

Flow modifiers such as thickening (bodying) agents affect the viscosity of coatings. Thickening agents are used to provide desired paint consistency, prevent pigment settling, and assist in applying films of adequate and uniform thickness [16].

d. Driers

Driers promote or accelerate the drying, curing, or hardening of oxidizable coatings [16]. Driers should be clearly differentiated from curing agents that chemically react or condense with the coating material to become an integral part of the final polymer composition [16].

e. **Anti-skinning Agents**

Skinning refers to the drying of a coating, but at the wrong time and in the wrong place (e.g., while it is still packaged). Oxidative polymerization of the film-formers at the air-liquid interface can lead to the formation of a solid or gelatinous skin on the surface. Anti-skinning agents are volatile antioxidants which prevent oxidation of the paint in the package and volatilize while the coating is drying.

f. **Biocides**

Fungicides and preservatives are used to control the growth of fungi and other microorganisms. Microorganisms cause spoilage or deterioration and premature failure of paint and other coatings. Bacteria and fungi can use coatings, particularly water-based coatings, as food sources [2,16]. Biocides are used as mildewcides in exterior house paints, as antifoulants in marine paints, as preservatives and stains for wood used primarily as furniture, and as in-can preservatives in latex architectural coatings [9]. Zinc oxide, which is also a white pigment, is commonly used to confer mildew resistance to paints [13].

Due to environmental concerns, the use of phenylmercury salts as a biocide is declining [9]. Other traditional biocides such as creosote, pentachlorophenol, and coal tar products which are used in wood stains, preservatives, and coatings are also coming under regulatory scrutiny [9]. Replacements for these biocides include copper naphthenate, tributyltin oxide, zinc naphthenate, N-(trichloromethylthio)phthalimide, and cuprous oxide [9].

g. **"Other" Additives**

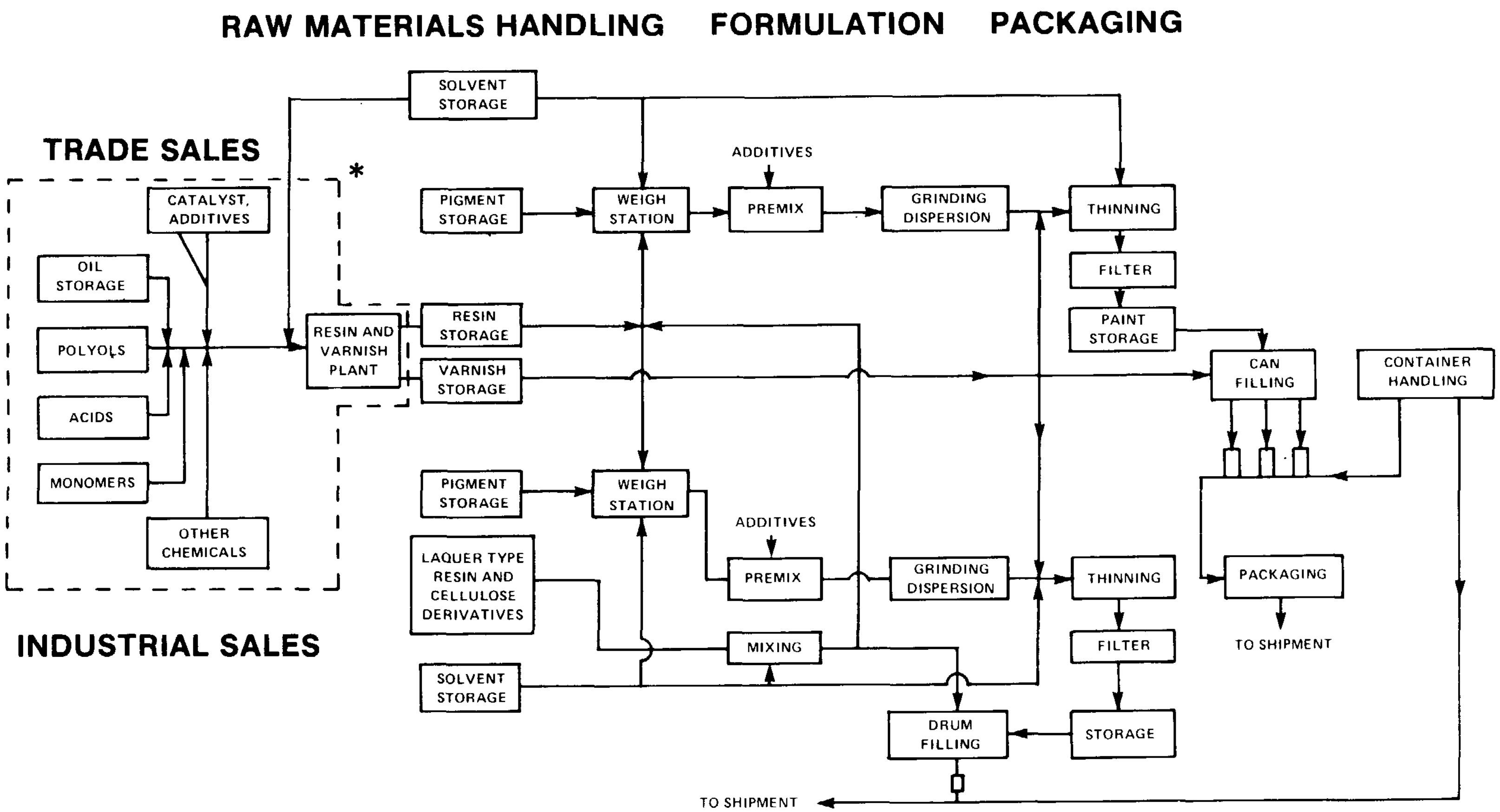
Many other substances are added to coatings in small amounts. These include coalescing agents, wet edge extenders, freeze-thaw and heat stabilizers, odorants, flame retardants, anti-livering agents, ultraviolet (UV) light absorbers, and agents that promote mar resistance [1].

C. Manufacturing and Related Operations

The manufacture of paint and allied coating products involves the assembling of materials, mixing, dispersing, thinning and adjusting, filling, and warehousing. Other related activities include materials handling, laboratory work, and shipping. The flow of materials in a typical paint manufacturing plant is shown in Figure II-3.

The manufacture of paint and allied coating products is essentially a series of unit operations (physical procedures) involving little or no chemical

FIGURE II-3. MATERIALS FLOW SHEET FOR THE MANUFACTURE OF PAINTS [19]



* Many plants purchase rather than manufacture their resins and varnishes.

reactions. Production is begun by mixing the pigment, film-former, and solvent (organic solvent or water). This is followed by the dispersion operation, which is a manipulation of the mixture to achieve pigment particle separation, wetting, and stabilization. The performance of the finished product depends on the maintenance of uniform interparticle distances in the dried film [2].

A variety of equipment is used to effect dispersion. The trend currently is to use equipment in which the paint formulation can be continuously mixed and dispersed, followed by thinning in the same unit [2]. After dispersion, the resultant material is tested for viscosity, color, and other physical properties while being adjusted or thinned. After passing this inspection, the batch is strained and loaded into containers.

The manufacture of varnishes is one of the most complex processes in a coatings plant, primarily because of the large variety of different raw materials, products, and cooking formulae used [18,19]. Varnishes are classified on the basis of the resins used. Oleoresinous varnishes are solutions of both oils and resins; whereas, spirit varnishes such as shellac are formed by dissolving a resin in a solvent. Varnish manufacture essentially consists of heating or cooking materials in a reactor vessel or kettle and then thinning and filtering the final product [18].

1. Paints

a. Materials Handling

Materials handling occurs primarily at both ends of the production process. Raw materials are available as liquids, solids, powders, pastes, and slurries.

b. Dispersion

The assembly of raw materials is followed by the mixing of pigments with film-formers, solvents, and additives and the dispersion of the pigment particles in the liquid matrix. Dispersion consists of a deagglomeration or separation of aggregates of individual particles, the wetting of particles with solvent and film-former, and uniformly distributing particles in the liquid phase. Types of dispersion equipment include high-speed shaft-impeller dispersers, dough mixers, and a variety of mills such as roller, stone, pebble, media, stator-rotor, attritor, Uniroll, resonant, vibratory, and Kady® [12]. After the dispersion operation, it may be necessary to clean the mills and tanks before a new batch is introduced. Tank and mill cleaning can involve hand and power tools as well as caustic cleaners and solvents.

c. **Thinning, Tinting, and Shading**

Thinning operations involve the further addition of a film-former or solvent to the batch following the mixing and dispersion operations. These operations may be performed in stationary tanks or in portable change cans. Tinting and shading operations involve adding color to white bases or adjusting the color of solid color bases that have been formulated as complete products. After these operations, the quality of the paint must be checked by sample collection and laboratory analysis.

d. **Filling Operations and Finished Product Handling**

After the desired paint quality is achieved, the paint is strained or filtered to remove foreign material. Fabric or metal screen filters, vibrating or variable-speed centrifugal clarifiers, vibrating screens, and cartridge filters can be used. After filtering, the coating is either manually or machine-filled into cans that are subsequently sealed, labeled, packed, and stored or shipped.

2. Lacquers

Lacquers differ from most other coatings in that the film dries or hardens entirely by evaporation. Therefore, it is impractical to manufacture lacquers in the customary manner because volatilization of the solvents results in deposits of a dry, solid film on processing equipment [12]. Thus, production is carried out in enclosed equipment such as tanks or mixers to reduce solvent loss, ensure ease of cleanup, and provide fire safety. However, lacquer is produced in the same general manner as paint.

3. Varnishes

All varnishes (i.e., oleoresinous and spirit) are solutions of film-formers in organic solvents. The manufacture of oleoresinous varnishes involves a cooking stage to render the oil and resin more compatible, to develop high molecular weight molecules or polymers, and to obtain solubility in the thinner or solvent. The manufacture of spirit varnishes usually involves cold cutting the resin with the solvent; however, mild heat may be used occasionally [18].

Varnish is cooked in portable kettles or in large reactors, although kettles are now used only to a limited extent and primarily by smaller manufacturers [19]. Large closed reactors with capacities of 1,000 to 8,000 gallons are more common [18].

a. Operation of Kettles

In facilities where portable kettles are still used, resin and oil or resin alone is added to the kettle and then heated to about 600°F (316°C). Natural resins must be heated prior to adding the oils to make the resin more compatible with the oils. All materials are poured in over the top of the kettle (150-375 gallon capacity). During the cooking phase, the kettles are covered with retractable hoods with exhaust pipes that may be fitted with solvent condensers. After the materials are cooked, the kettles are moved to rooms where the kettles are cooled quickly, often by water spray, and thinner and driers are added [19].

b. Operation of Reactor Vessels

Varnish production is different when reactor vessels are used instead of kettles. Most reactors range in size from 500 to 8,000 gallons [18,19]. Reactors are designed to give exact process control and usually can handle a variety of different varnishes, operate over a wide range of temperatures, and be cleaned easily. Varnish reactor vessels are similar to batch reactor equipment used in the chemical process industry. The vessels are fitted with agitators, manholes, sight-glasses, lines to charge liquid reactants, condensers, temperature measuring devices, sampling devices, discharge lines, and heat sources.

c. Filtering

Filtration of the thinned resin is the final step before the varnish is packaged. This is normally done while the resin is still hot. The filter press is the most commonly used filtering device [20].

4. Powder Coatings

Powder coatings are solventless systems based on the melting and subsequent fusion of resin and other additive particles onto surfaces of heated objects. Powder coatings, which may be either thermosetting or thermoplastic, are made from various types of resins such as epoxies, polyethylene, polyesters, polyvinyl chloride, and acrylics.

Three methods have been used to manufacture powder coatings: dry blending, extrusion melt-mixing, and a combination of the two. Dry blending of powder coating ingredients is usually accomplished by placing all components (powdered resin, pigments, additives, and powdered curing agents) into a cooled pebble mill with high density porcelain grinding media.

The extrusion melt-mixing method involves premixing the dry components to ensure homogeneity and to reduce particle size. The mix is placed in a specially-designed extruder where it is heated until molten. The molten material is then deposited on a cooling belt, and when it has cooled to a friable state, it is transferred to a coarse granulator. The granulated material is then passed through a fine grinder and particle size classifier and packaged. Figure II-4 shows a typical layout for the manufacture of powder coatings by the extrusion melt-mixing method.

5. Radiation-Curable Coatings

Radiation-curable coatings are composed of liquid components which polymerize to a hard surface when exposed to radiation. These coatings are manufactured in the same general manner and with the same general equipment as solvent-containing coatings. However, radiation-curable coatings do not contain solvents and are usually manufactured in enclosed equipment to prevent occupational exposure to volatile and reactive monomers, particularly acrylics.

6. Stains

The primary function of a stain is to furnish color [2]. Raw and polymerized linseed oils are often used as the film-former for exterior stains; the pigment content is very low to ensure a degree of transparency and to avoid undesirable film build-up [2]. Lightfast pigments such as iron oxide, titanium dioxide, and carbon black are used to color exterior stains [2]. A wider range of pigments is used with interior stains. The film-formers for interior stains are usually very low-solids alkyd resin solutions. Generally, the manufacture of stain is similar to that of paint.

7. Allied Coating Products

Many of the allied or sundry products of the coatings industry are manufactured in the same plants as paint, with few variations in the processes previously discussed in this section.

a. Putties

The manufacture of putties involves the dispersion of calcium sulfate in oils and adjustment with small amounts of solvent in a dough-type mixer or in a mixer known as a putty chaser [21]. The viscous putty is usually put into containers directly from the dispersion stage.

FIGURE II-4. FLOW CHART FOR THE MANUFACTURE OF POWDER COATINGS BY THE EXTRUSION MELT-MIXING METHOD [22]
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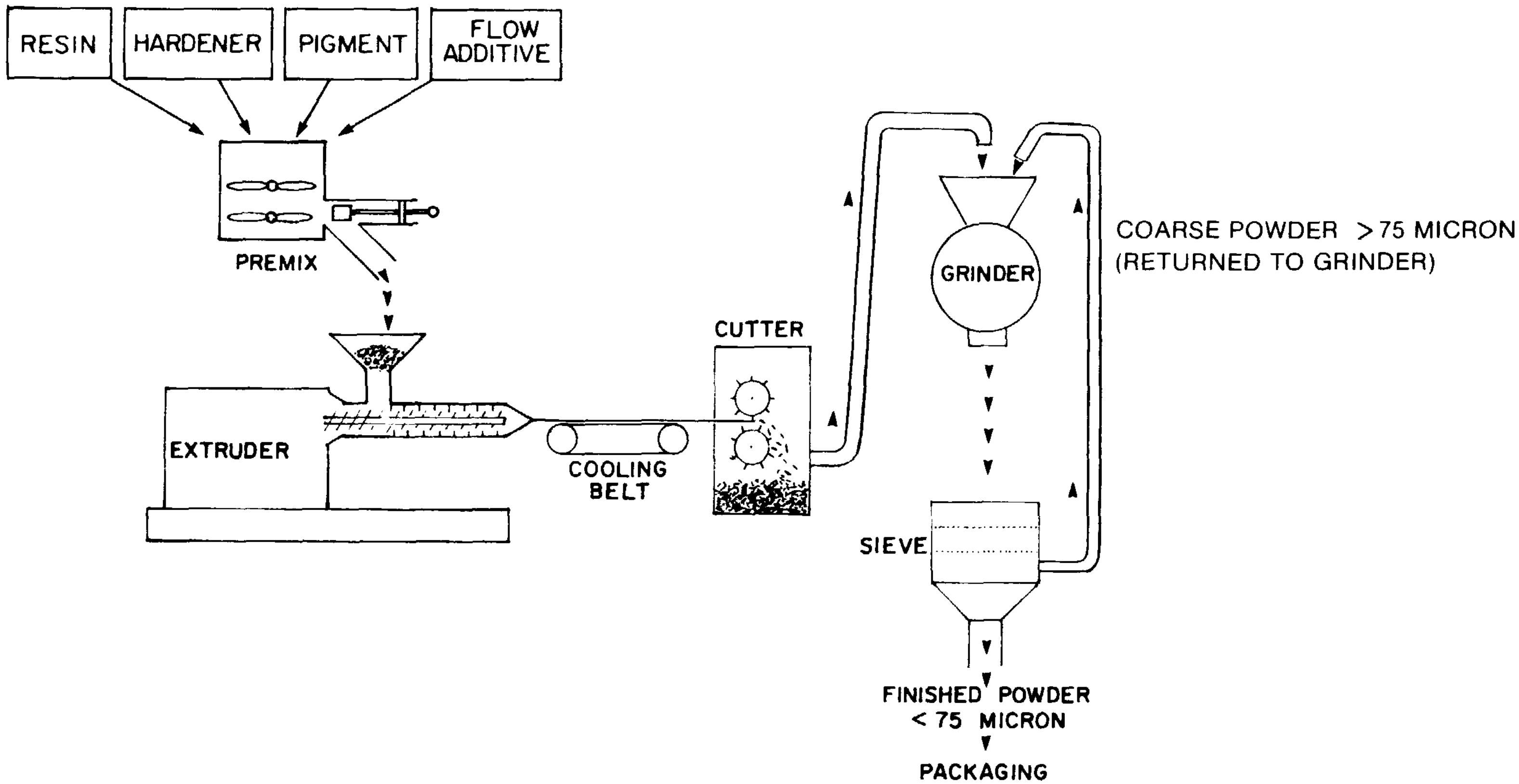

b. Paint and Varnish Removers

The production of paint and varnish removers involves the mixing of a solvent (usually methylene chloride, acetone, methyl ethyl ketone, toluene, or xylene) with activators, thickeners, evaporation retarders, and penetrants [23]. Alcohols are used to strip shellac, and mixtures of alcohols and acetates are used to remove lacquers [23].

8. Laboratory Functions

Analytical and developmental laboratory functions are integral to the manufacture of coatings. Four functional types of laboratories are found in coatings manufacture: analytical, quality control, formulation or product development, and research and development [24]. Many companies combine the various laboratory functions in one space; whereas, others separate each function. Analytical laboratories receive samples of incoming raw materials to be tested for conformity with purchase specifications. Other analytical laboratory functions include the analysis of competing products and "bad batches" of paint. Quality control laboratories test the product before it is packaged for various physical characteristics such as weight per gallon, viscosity, color, and drying time. In the formulation or product development laboratory, existing products are refined. This differs from the research and development laboratory which is involved with basic research and the development of completely new classes of products.