Lecture #35

ERDM

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material adapted from lecture of Prof. John K. Gershenson

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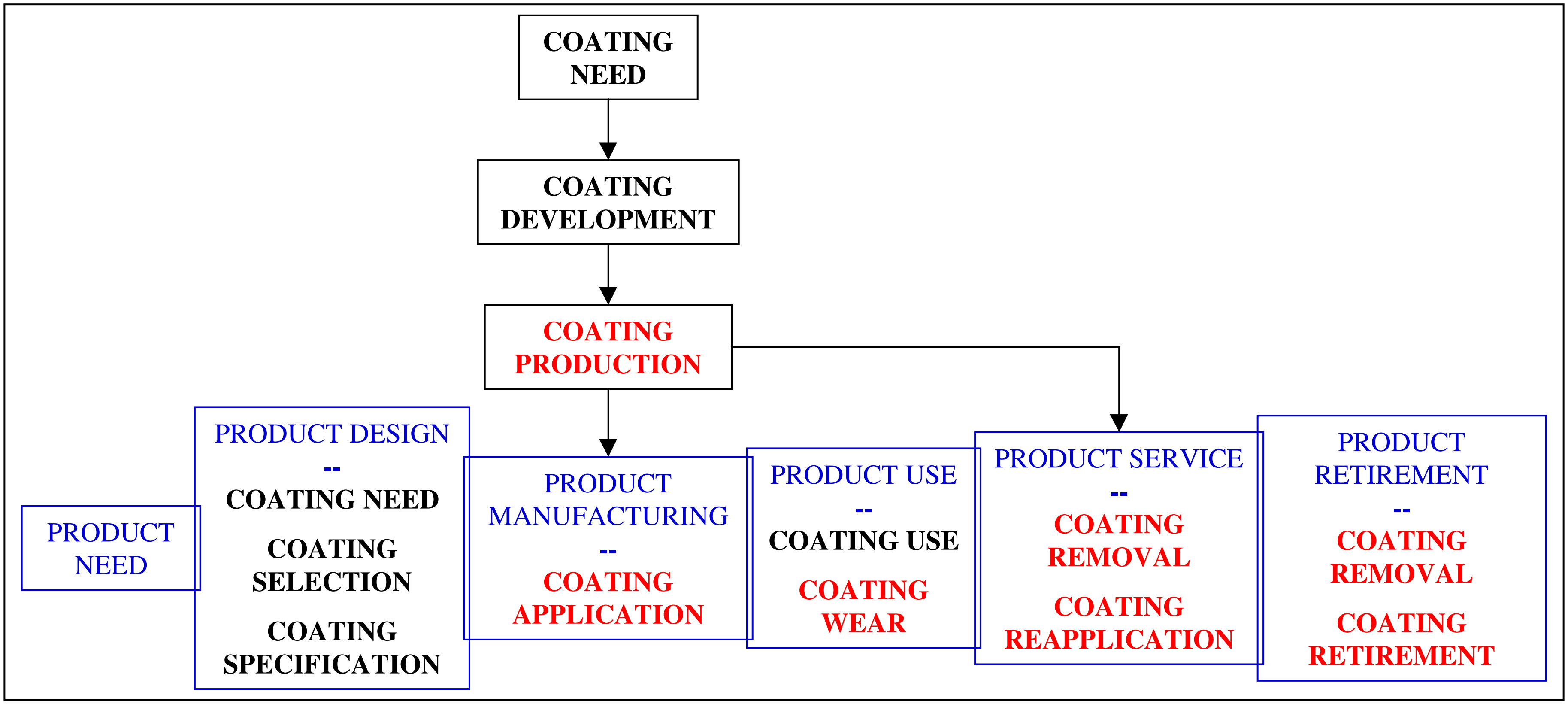
Coating Selection

- Coatings
- Coatings Life-cycle
- Coatings Environmental Problems / Regulations
- Pollution Prevention – P2
- Designers' Needs
- Coating Selection

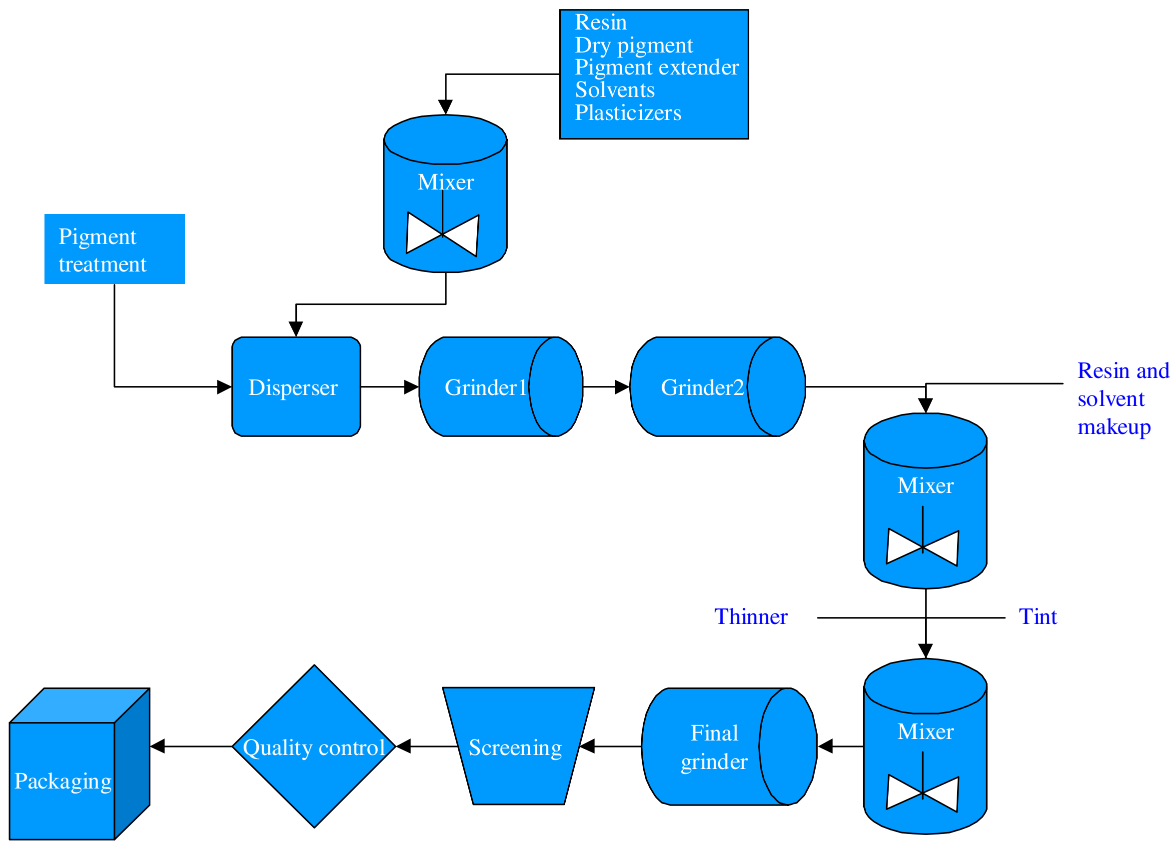
Coatings

- Total U.S. paint and coatings sales reached $15.9 billion in 1995
- Applied to a surface, forms a solid continuous film
- Major components of coatings are solvents, binders, pigments, and additives (extenders, plasticizers, etc.)
  - Resins provide the coatings with film continuity and adhesiveness.
  - Solvents dissolve or disperse the binder components to modify the viscosity of coatings.
  - Pigments provide color and impart glossiness, opacity, and durability to the finish. Pigments also protect the substrate against corrosion and microbial attack.
  - Extender pigments and additives are used to improve coating performance and coverage, enhance durability, and reduce material costs.
- Three basic functions provided by coatings: decoration, protection, and identification
  - Decoration: Finish has become a strong indication of quality to the customer.
  - Protection: against corrosion, chemicals, temperature, wear, fire, weather, electrical, bacterial/fungal, water, aging, radar, etc.
  - Identification: applying coating on the product to make it easier to identify, obtain better distribution of light or greater illumination of an object
- Coatings classified into three types, water borne coating, solvent borne coating, and powder coating
- Applications: metal containers, automotive, machinery, metal furniture, traffic paint, etc.

Coating Life-cycle

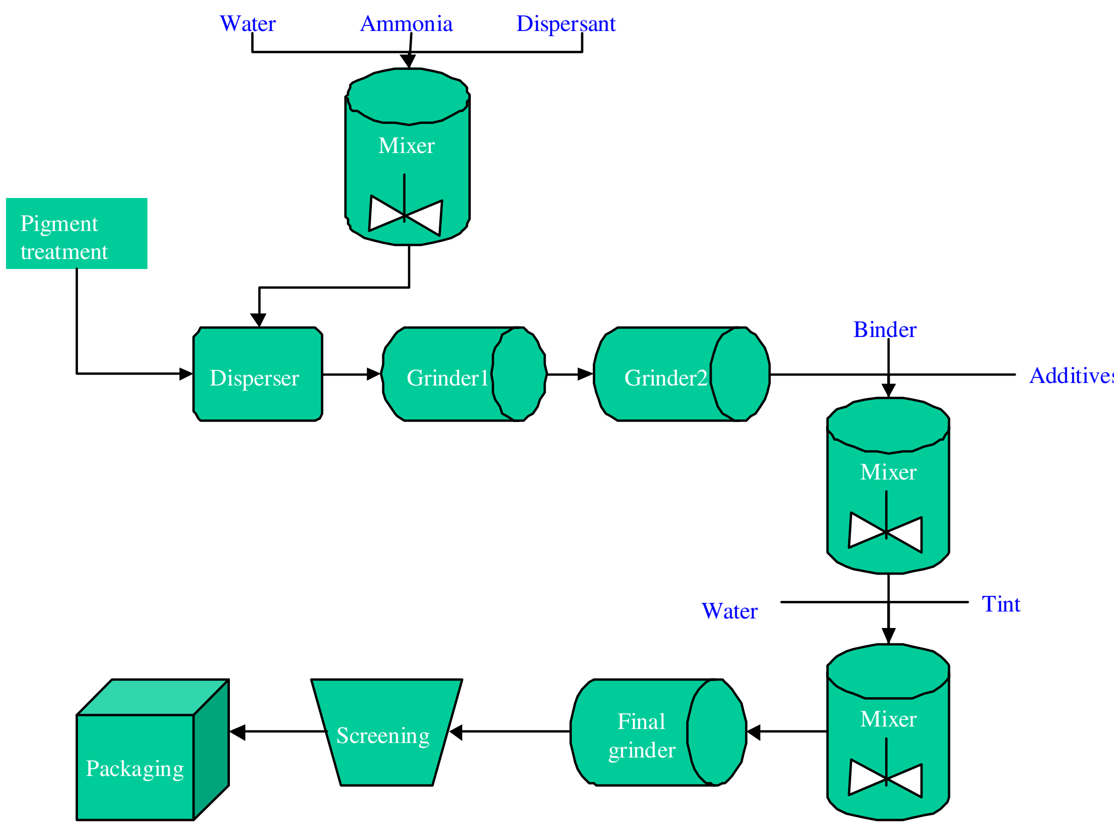


Coating Production



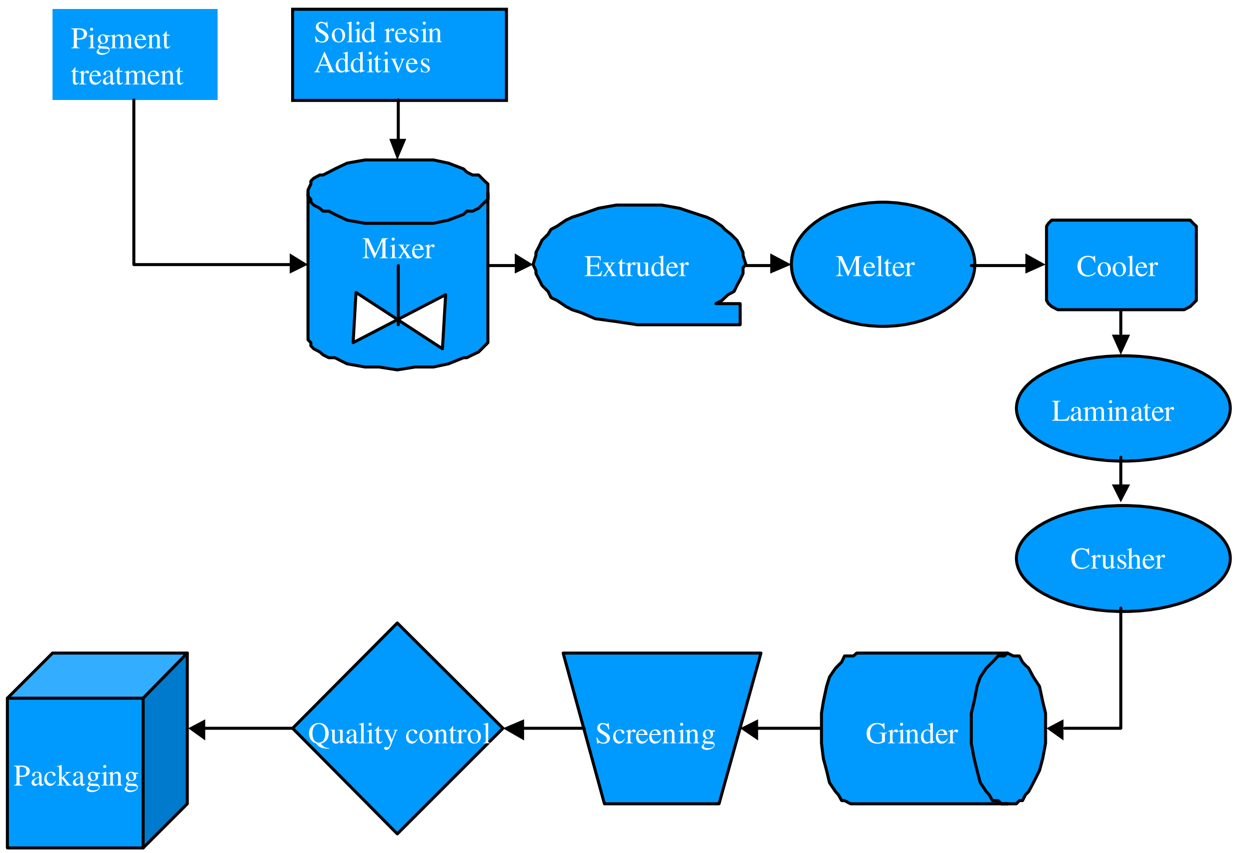
solvent borne coatings

Coating Production



water borne coatings

Coating Production

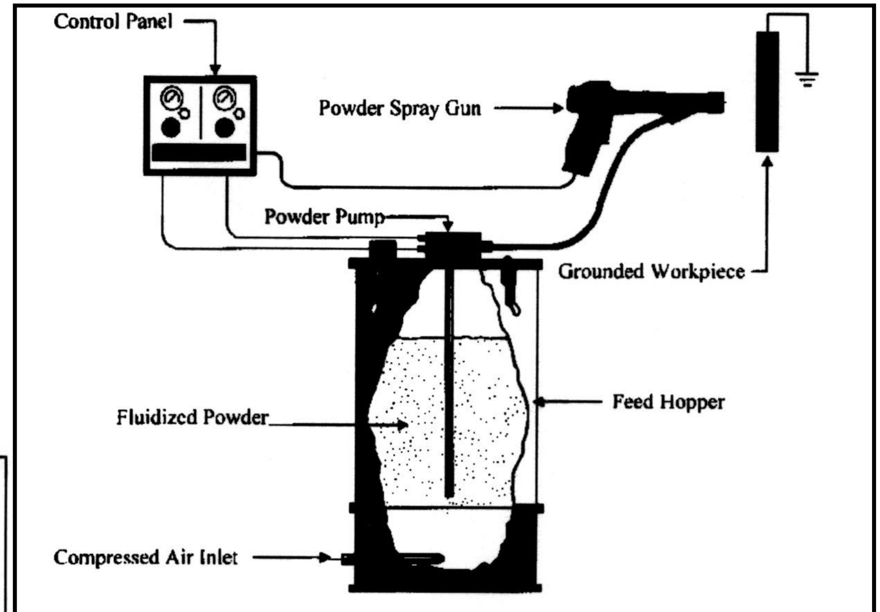


powder coatings

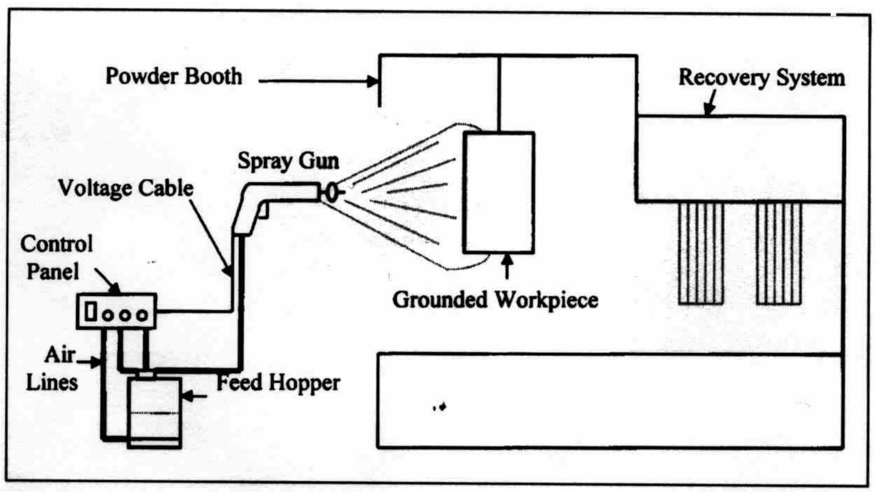
Coating Application

- Solvent borne coating
  - Spray
    - Air-assisted airless
    - Airless
    - Air spray
    - Flame spray
  - Electrostatics
    - Electrostatic spray
    - Rotary atomization
  - Curtain coating
  - Roll coating
- Powder coating
  - Electrostatics
    - Electrostatic spray
    - Electrostatic fluidized bed
  - Fluidized bed
  - Powder flocking
  - Flame spray
- Water-borne coating
  - Spray
    - Air-assisted airless
    - Airless
    - Air spray
    - Flame spray
  - Electrostatics
    - Electrostatic spray
    - Rotary atomization
  - Dip
  - Dip spin
  - Flow
  - Curtain coating
  - Roll coating

Coating Application



Powder Coating Application



Electrostatic Spray Application

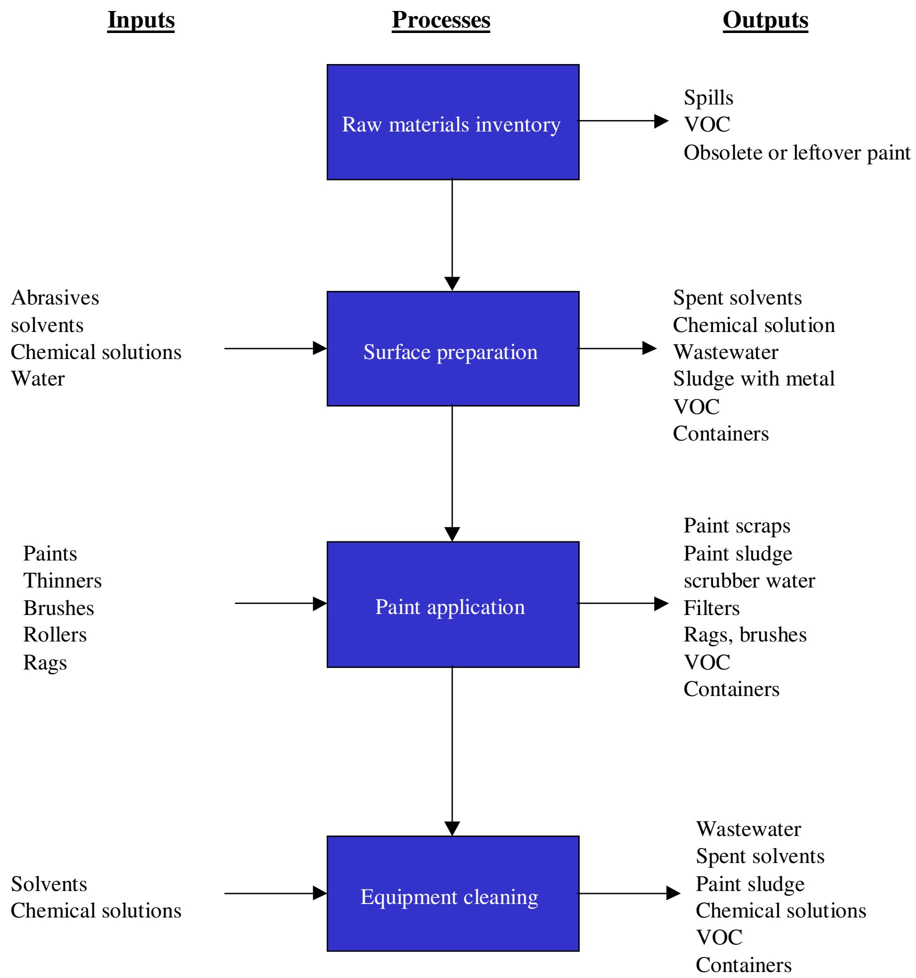
Coating Wear

- Coating shavings – solid waste
- Potential for air borne and water borne emissions
- Product disposal is a very large problem as well but not one we are discussing today since it really falls under product design for retirement

Coating Removal

- **Remove oil and grease**
  - Solvent clean
  - Steam clean
  - Emulsion clean
  - Alkali clean
- **Remove loose coatings**
  - Hand clean
  - Power tool clean
  - Scrub with solution
  - Lightly abrasive blast
- **Remove tightly bonded coatings**
  - High-temperature clean
  - Abrasive blast
  - Liquid clean

Environmental Problems



Environmental Problems and Regulations

- Air Emissions
- Wastewater Discharges
- Solid Waste
- Hazardous Waste

Air Emissions

- **Raw materials contain VOCs, which react in the presence of sunlight to create photochemical ozone or smog. They are emitted into the air during transfer, blending, settling, or any other time the material is exposed to air. Many VOCs have been listed as hazardous air pollutants (HAPs), which are regulated under air pollution programs. HAPs (or air toxics) are chemicals that cause serious health and environmental hazards. The products used for cleaning equipment also typically contain VOC and HAP chemicals.**

- **Pigment dust that may be generated during the manufacturing process, known as particulate matter emissions (or PM10 emissions), can also have an adverse effect on air quality and workplace health. This particulate matter, which can contain HAPs, heavy metals, and other solids, is emitted into the air during transfer and blending of the materials, and is mostly associated with fugitive dust and baghouse emissions.**

Air Emissions

- Regulations limit emissions from particular types of coating operations, such as those coating metal furniture, miscellaneous metal parts, plastic parts, and large appliances. Coating facilities affected by these regulations may need to obtain permits, control and monitor air emissions, and submit reports.
- Governed by the Clean Air Act and its amendments
  - Also New Source Performance Standards (NSPS), National Emission Standards for Hazardous Air Pollutants (NESHAP), Control Technique Guidelines (CTGs), Alternative Control Techniques (ACTs)

Wastewater Discharges

- Process wastewater is frequently generated from cleaning, phosphating, and other surface preparation steps associated with coating operations. Most contamination of waterways occurs either from storm water run-off or process (cleaning/cooling) wastewater discharge. Storm water is affected mainly from storing raw materials and hazardous wastes outside. Process wastewater and other controlled discharges of cleaning and process wastewater often are contaminated with solvents and heavy metals. Also, many paint booths generate wastewater.

- If your coating operation discharges process wastewater to a sewer, then you have specific responsibilities that are defined in the Clean Water Act and its associated regulations. Some coating facilities must comply with Categorical Pretreatment Standards. All coating facilities must comply with the General Pretreatment Regulations.
  - The three most commonly applicable Federal effluent guidelines for coating operations are: Coil Coating Categorical Standards (40 CFR 465), Electroplating Categorical Standards (40 CFR Part 433), and Metal Finishing Categorical Standards (40 CFR Part 433).

Solid Waste

- Paints and coatings manufacturers generate solid waste in a number of ways. Examples include used containers, spent filters, dried paints, pallets, and packaging materials. The solid waste can be in the form of solids, liquids, or sludges. These materials, if not determined to be a dangerous waste, are subject to solid waste regulations, since the improper disposal of wastes can result in pollution of groundwater, surface water, and air.

Hazardous Waste

- **Paint and coatings manufacturers generate a number of wastes from their processes. The raw materials required in the manufacturing process contain VOCs and heavy metals, as do many of the by-products of the process, such as off-specification paint that is unusable, or material from the cleanup of spills and equipment. If the presence of VOCs and heavy metals exceeds allowable levels for solid waste, as determined by regulatory standards, the paint and coatings manufacturer is required to handle the waste as a hazardous or dangerous waste.**

Hazardous Waste

- The Resource Conservation and Recovery Act or RCRA ("rick-rah") is the central law that gave EPA the authority to control hazardous waste from the "cradle-to-grave." This includes the generation, transportation, treatment, storage, and disposal of hazardous waste. RCRA also set forth a framework for the management of non-hazardous wastes.
- Hazardous waste can be one of two types:
  - Listed waste - appears on one of four lists published in the Code of Federal Regulations (40 CFR Part 261). Currently, more than 400 wastes are listed. Wastes are listed as hazardous because they are known to be harmful to human health and the environment when not managed properly or because they are "acutely hazardous wastes."
  - Characteristic wastes - demonstrates one or more of the following characteristics: catches fire under certain conditions (ignitable waste - paints and certain degreasers and solvents), corrodes metals or has a very high or low pH (corrosive waste - acid or alkaline cleaning baths, and battery acid), unstable and explodes or produces toxic fumes, gases, and vapors when mixed with water or under other conditions such as heat or pressure (reactive waste - certain cyanides or sulfide-bearing wastes), harmful or fatal when ingested or absorbed, or it leaches toxic chemicals into the soil or ground water when disposed of on land (toxic waste - lead contaminated waste, spent stripping solutions, or sludges).

Pollution Prevention: P2

- **Wastes generated are usually managed in one of four ways: on-site reuse, on-site recycling, off-site recycling, and off-site treatment/ disposal.**
  - **On-site reuse involves the reuse of waste as a feedstock or wash material for producing other batches of paint. Cleaning waste is generally either collected and used in the next compatible batch of paint as part of the formulation, or collected and reused for cleaning until spent. A simple method commonly used to extend the life of this solution is to allow the solids to settle and decant the liquid cleaning solution. Also included in reuse is the sale or in-house use of off-specification paint as utility paint.**
  - **On-site recycling is primarily the reclaiming of solvent by distillation. A material is "reclaimed" if it is processed to recover a useful product or if it is regenerated. Reclaimed solvent directly replaces virgin solvent for its intended use. The distillation residuals are sent offsite for treatment and disposal.**
  - **Off-site facilities provide recycle, treatment and disposal services. These facilities reclaim as much solvent as possible. This reclaimed solvent is returned to the manufacturer and is used as virgin solvent would be used. The residuals from this treatment operation are blended with other waste and used as a fuel. This waste-derived fuel is sent for incineration in a cement kiln.**

Pollution Prevention: P2

- **Spray coating operations currently release pollutant gases (volatile organic solvent) into the environment, with resultant potential health problems for production workers and the community as a whole. About one billion pounds of organic solvents, from liquid coating operations, are currently being released into the environment by chemical process and manufacturing industries each year. Government legislation has made the control of these pollutants an industrial priority and has mandated drastic reductions in VOC content. New formulations produced to meet these requirements have far more complicated rheological and film formation behavior, and generally exhibit reduced performance and are more prone to defects such as sagging (drip marks), blisters, and "orange-peel." Development of such new coating products and processes that are economically competitive, use minimal amounts of material, produce final defect-free coatings in actual on-line operations, without adverse environmental impact, is a formidable scientific and engineering challenge.**

P2 Resources

- **Organic Coating Replacements (EPA/625/R-94/006). This guide gives information in choosing cleaner technologies for further analysis and in-plant testing. It is intended for facilities in all segments of the paints and coatings industry including applicators of architectural coatings, finish coatings for parts and assemblies, and maintenance coatings.**
- **Pollution Prevention in the Paints and Coatings Industry EPA/625/R-96/003. The paints and coatings industry represents a significant source of multimedia pollution through the use of solvent-based process materials and the extensive amounts of wastewater generated by the operations. This manual presents practices for minimizing the generation of pollution in this industry.**
- **Organic Coating Removal EPA/625/R-93/015. This guide describes cleaner technologies that can be used to reduce waste in coating removal operations.**
- **CTSA and CAGE.**

CTSA – Cleaner Technologies Substitution Assessment

- EPA document provides a framework to guide designers through the data collection and analysis process in the early stages of product/process design, incorporating environmental fate and effects, human health hazards, process safety, risk, market competition, and energy and resource conservation issues into final alternative selection.
- Applied using a functional step approach to identify specific steps within an overall process for which alternatives can be chosen to meet the same functional performance criteria. The method also has a connection to specific chemical properties for each feasible alternative that drive the alternative's overall environmental and societal impacts (human and environmental hazards and energy and resource utilization).
- The physical, chemical, and biological properties of these process chemical components are then used to map human and environmental hazards and energy and resource utilization characteristics of each process alternative. Within this CTSA methodology, guidelines are provided for the quantification of relative environmental and societal impacts of chemical components using chemical and process-specific information to evaluate the trade-offs to an individual and to society among risk, and energy and resource conservation considerations. These guidelines are designed to provide semi-quantitative measures of risk and environmental impact so that trade-offs among feasible process alternatives can be made to minimize the risk to workers, surrounding populations (human and ecological), or consumers through use of substitutes and improved workplace practices.

CTSA

- Comprehensive in its treatment of DfE issues, but quite complex.
- Not efficient (simple and rapidly useable), and would be difficult to have it widely used within the design engineering community.
- Simply making available more information on a new topic does nothing to encourage product and process design engineers to design improved products. There are already too many requirements to trade-off in an ever shortening design cycle. What is needed is a way of facilitating the environmental impacts of various design choices with a minimal burden on design engineers. It is proposed that components of the CTSA approach be used to generate a more efficient coating selection process using the process methodology described herein.
- While this project proposes to utilize an existing methodology (CTSA) to describe environmental and societal impacts of alternative coatings, the incorporation of this impact descriptor methodology within a coating design context is unique, and represents a fundamental contribution to engineering science.

CAGE – Coating Alternatives Guide

- The Coatings Guide™ contains several tools to help users identify low-VOC/hazardous air pollutant coatings that may serve as drop-in replacements for existing coating operations
  - Cost Tool, Expert System, Coating Alternatives Information, Application Equipment Information, Regulatory Matters, Coatings by Industry Sector
- Lacking environmental and societal impact burdens, over the life-cycle of the coating
- Similar shortcomings to CTSA

Selection of Industrial Coatings Based on Environmental Impact

- Product and process engineers need tools to weigh environmental and societal impacts versus cost for selection decisions early in the design process when information and time are scarce
- Source of industrial pollution is not a factory/ process/product but the design of that factory/ process/product
- Fundamental bridge between design, environment, and auditing; all operate with a single schedule of environmental and societal impact

Designers' Needs

- ***"… the need for scientifically sound, user friendly tools and methodologies to assist in making decisions on complex risk management problems [has become] increasingly important. These tools and methodologies can be of invaluable assistance for identifying and evaluating technologies and approaches that are less polluting when compared to each other, or to more traditional end-of-the-pipe treatment. For pollution prevention to play a key role both now and in the future, tools and methodologies must be developed that are more quantitative in nature.*" (U.S. Environmental Protection Agency Pollution Prevention Research Strategy Report , 1998)**
- **Missing are tools and methodologies that aid in the development of concepts into environmentally sound products**
- **More than just DfE or CTSA**

Motivation

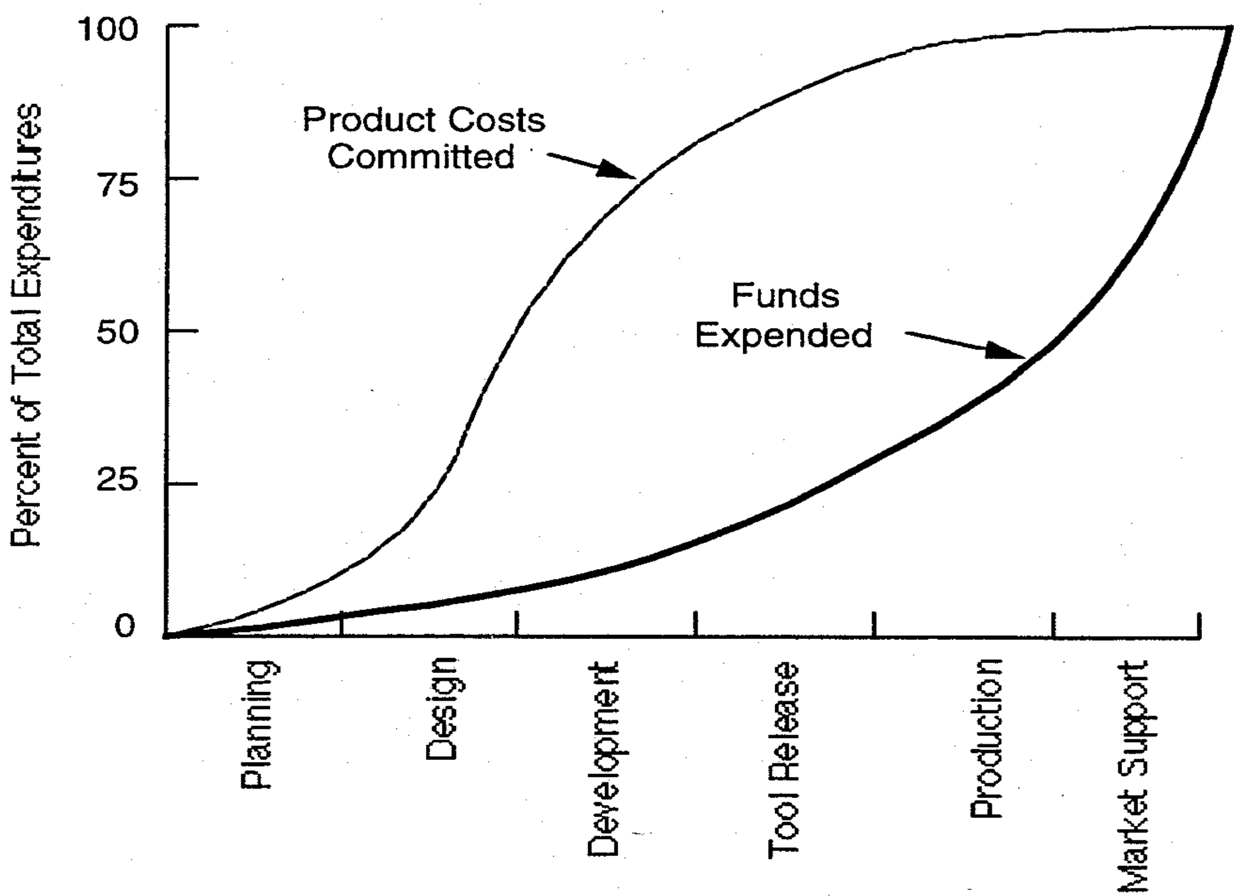
- How do the effects of hazardous agents encountered in industrial processes and products map onto existing taxonomies of land, air, and water resources?
- How does the inclusion of environmental factors in the design of products and production systems affect the effectiveness and efficiency of the design process?
- What measures may be developed for environmental factors?

Objective

- Develop a tool to permit incorporation of impact measures in engineering decisions by relating environmental and societal characteristics to key performance variables

- For a particular industrial coatings selection problem (corrosion resistant coatings, UV resistant coatings, etc.), each coating type under consideration (solvent-borne coating, powder coating, etc.) would have an associated relationship between the selection problem's key performance variables (corrosion protection, hardness, etc.) and each environmental and societal impact characteristic (aquatic toxicity, energy utilization, etc.)

Economics of Decisions



Coating Selection Issues

- **Primary function**
  - Why to consider this first is based on this consideration: first, it is relevant to performance measures tightly. In addition, if a coating cannot meet the function requirement, it will fail quickly and lead bad effect on that substrate. Even the cheapest coating materials are wastefully expensive if it fails to perform its service function. As mentioned before, coating functions classified into three basic functions, identification, decoration, and protection.
- **Service environment**
  - The service environments will produce the secondary function requirements. For example, the primary requirement for a coating is to provide corrosion resistance and its service environment is in a high temperature environment also, then this coating must have heat resistance too.
- **Nature of substrate**
  - The nature of substrate will have great effect on the function of coating thus to performance measures. Therefore, while seeking a coating having properties that will enable it to withstand the primary requirements and the rigors of the service environment to which it will be exposed, we must consider the nature of the substrate. For example, a coating capable of giving excellent performance in acid environment when applied on a metal surface may fail badly in that same environment if applied on wood, partly because of the poorer dimensional stability and greater coating elasticity requirements of wood surface. It is evident, therefore, that the choice of choosing the suitable coating must take into account the chemical and physical nature and the surface topography of the substrate, smoothness, porosity, alkalinity, adhesion ability, reactivity, etc.

Coating Selection Issues

- **Surface layer location**
  - As mentioned before, the surface layer locations are classified into three types: topcoat, intermediate coat, and primer. Based on the surface layer location, the function requirement for the coating applied on the substrate will be different. For example, primer is applied as the first coat of paint on the substrate to be painted and its chief function is to provide a satisfactory between the finish coats and substrate. Although the primary function requirement is corrosion resistance, the intermediate coat and topcoat will be applied on the primer. Therefore the primer will not be exposed into service environment directly, the requirement of corrosion resistance for primer is lowered, but it must provide satisfactory bond.
- **Types of coating**
  - It is obvious that we should consider coating types. For different types of coatings could provide the same function, we could narrow down our search range by indicating the types. Following Figure 20 is an example of coating selection taxonomy and describes the coating selection process graphically. It selects the suitable coating according to the above five steps. First, in the selection process of function, the basic function is protection, then the sub-functions are chosen step by step as following: corrosion resistance, wet corrosion resistance, and aqueous solution resistance. Second, in the selection process of environment, the environments are chosen step by step as following: acidic environment, non-alkaline environment, sulfuric environment, saline environment, dry environment, UV-exposure environment, hot environment, pressure greater than 10 psi, impact, and bacteria. Third, the substrate and properties of substrate surface are chosen: metal, painted, porous, smooth, low adhesive, and reactive. Fourth, the surface layer are chosen, intermediate coat. Finally, water borne coating are chosen.

Performance Variables

- Bleeding resistance
- Relative hiding power
- Rusting resistance
- Checking resistance
- Cracking resistance
- Erosion resistance
- Blistering resistance
- Flaking resistance
- Water resistance
- Wear resistance
- Solvent resistance
- Temperature-change resistance
- Fire retardance
- Indentation hardness
- Elasticity
- Alkaline resistance
- Water vapor transmission
- Permanganate time
- Package stability
- Heating loss rate
- Print resistance
- Relative tinting strength
- Adhesion
- Freeze-thaw stability
- High temperature resistance
- Scrub resistance
- Light stability
- Fuel resistance
- Block resistance
- Impact resistance
- Chipping resistance
- Acid and mortar resistance
- Mold resistance
- Washability
- Chemical resistance
- Abrasion resistance
- Radiation resistance
- Chalking resistance
- Sag resistance
- Mar resistance
- Biofouling resistance
- Rub abrasion mar resistance
- Aging resistance
- Detergent resistance

More on Coatings

- See Dr. John Gershenson