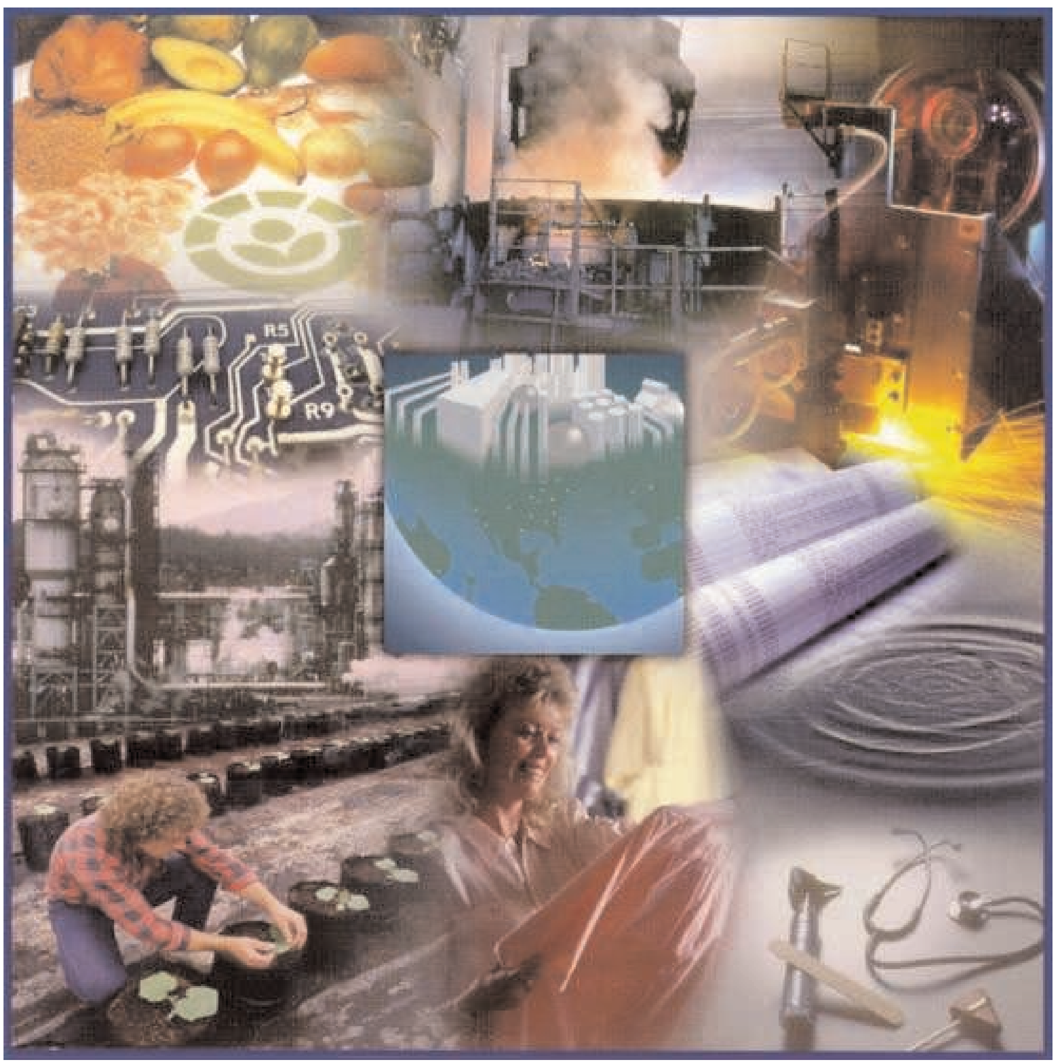
UV Curable Coatings—Marketing Kit

Technical Report



UV Curable Coatings—
Marketing Kit

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Final Report, June 2000

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REPORT SUMMARY

Ultra violet (UV) curable coatings are being successfully applied to electric motors, metal shafts, cell phones, printing, plastic packaging, and wood laminates. Demand is expected to expand to an even greater number of end products as issues related to environmental well-being, finish quality, cost reductions, and manufacturing efficiencies drive this market. This UV Curable Coatings—Marketing Kit is designed to help utility sales and marketing personnel present UV curable coating opportunities to customers who currently coat metal, wood, or plastic components. The kit is designed for utility personnel who have limited knowledge of UV coatings technology.

Background

UV curable coatings can be applied to nearly all manufacturing operations involving coatings, inks, adhesives, and sealants. Recent developments in the coatings industry are limiting environmental emissions such as volatile organic compounds (VOCs), thus forcing coatings companies to eliminate or minimize releases from traditional solvent-based processes. Not only do UV curable coatings provide an environmental solution, with emissions reductions approaching 100%, but they also require a lower temperature cure that makes it possible to coat heat-sensitive materials such as plastic and wood. Metal that is in proximity to heat-sensitive materials, such as insulation or gaskets, is also a strong candidate for UV curable coatings. Other benefits of incorporating UV technology in coatings systems include higher quality surface finish, faster cure times, improved process efficiency through combined manufacturing steps, more precise control of the coating process, greater energy efficiency in the overall finishing process, higher reliability and safety, and lower labor and maintenance costs. While the cost of UV curable coatings is coming down as the market expands, prices are still at a premium when compared with traditional coatings. Demand continues to grow, however, because there are many other issues to consider when evaluating whether a UV curable system is right for a particular coatings application. The challenge lies in identifying which industries are the prime candidates for conversion to UV curable coatings and then employing a sales approach maximized for success.

Objective

To provide electric utility sales and marketing personnel with background information about the advantages of UV curable coatings, so they are comfortable presenting these electrotechnology opportunities to their coatings customers.

Approach

This marketing kit is assembled from information available in nine books, eight EPRI reports, and 29 Standard Industrial Classification (SIC) codes. The marketing kit is primarily a

concentration of information previously presented to member utilities, revised now to meet the needs of utility sales staff.

Results

This UV coatings marketing kit provides

- An overview of the U.S. coatings industry
- A method of identifying where UV technology can best be applied in coating processes
- A complete review of the sales process, including an overview of major considerations in specifying and purchasing coating systems
- Suggestions for overcoming objections involving the cost of UV powder, price and availability of electricity, equipment expense, operator training, and even fear of new technology
- A reference section on coating technologies
- A vendor list of major suppliers of UV coating equipment
- A glossary of coating terms

EPRI Perspective

EPRI is dedicated to helping utilities advance the use of electrotechnologies. This kit is intended to help electric utility representatives market electrotechnologies to the coatings industry. EPRI suggests that the greatest opportunities lie in finding firms that are coating temperature-sensitive parts, seeking to minimize environmental emissions, upgrading to higher performance specifications, increasing production output, or replacing older equipment. This kit provides the information necessary to formulate an overall marketing plan for targeting UV curable coating opportunities within a service territory.

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Keywords

Ultraviolet coatings
Temperature sensitivity
Finishing process
Low temperature coating cure
Energy efficiency

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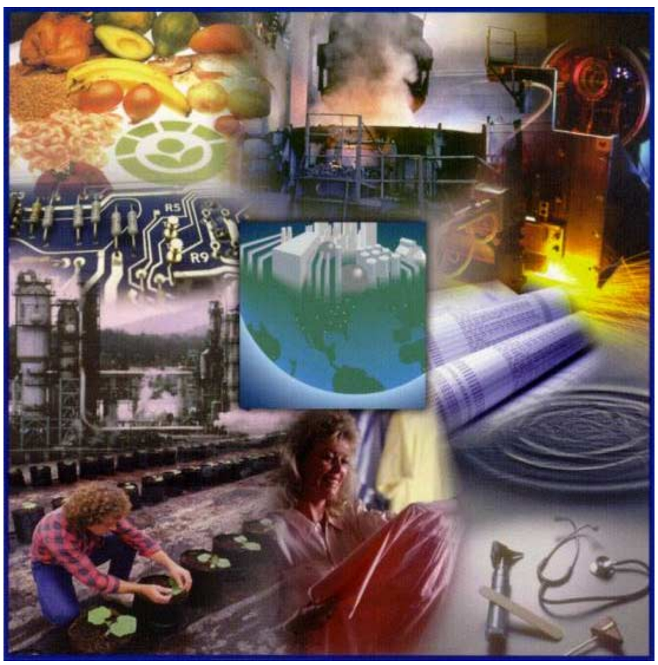


Coatings technologies are a major consumer of energy and a significant user of electricity. The industry is extremely diverse, both in the types of customers who apply coatings and the various systems in use.

This section provides an overview of the U.S. coating industry and its potential use of UV curing. It includes an analysis by commercial and captive coating, and a summary description of the types of industries that are candidates for UV systems.

1
INTRODUCTION

How to Use This Kit

This publication is organized to aid the reader in a progressive analysis of prospects for UV opportunities in coatings applications. It is designed for utility personnel who have a limited knowledge of the coatings industry.

Once a particular application for a UV coating is defined, the reader is directed to follow the text through a series of inquiries that focus on that particular application. If the reader is not focusing on a specific UV coating application and is reviewing this document in order to generally become familiar with the technology, and its myriad applications, then it is best to follow the text in the sequence presented.

The kit is divided into seven major sections, briefly described below:

Introduction – provides and overview of the U.S. coating industry, including a description of the types of coating operations and the differences in motivation between the various segments.

Technology Description –introduces the reader to UV coating technology.

Identifying Opportunities – provides a comprehensive method of identifying situations where UV technology might be used in coatings operations. Beginning with a general discussion of which types of customers would be most open to UV technology, it ends by presenting checklists specific to evaluating UV equipment purchasing decisions. Along the way, it identifies SIC codes which would likely contain coatings applications that have potential to be converted to UV technology.

The Sales Process – gives an overview of the major considerations in specifying and purchasing coating systems. It provides a series of questionnaires and checklists that will be useful to anyone involved in purchasing a coating system.

References – includes useful list of books, periodicals, industry associations, and EPRI CMF publications of interest to anyone involved in coatings. An internet web address is provided for each item listed in the section.

Vendor List – contains contact information for several major suppliers in the UV coatings industry.

Appendix – UV coating is a complex subject with "industry" terminology that must be understood to help identify UV opportunities. A glossary of common coatings terms is provided.

Coating Basics

In 1970, almost all industrial coatings were applied using low solids suspended in organic solvents. To develop good properties, high-molecular-weight polymers were dissolved in solvents and applied at a solids density of about 25% or less. However, at that time, a revolution was taking place in the coatings industry due to ecological and health concerns, an OPEC-caused energy shortage, and a push to improve manufacturing processes. Increasing solvent costs were also an important economic factor at the time.

Powder coatings, high-solids coatings, waterborne coatings and radiation-curable coatings were developed to address these issues. The coatings industry was forced to change due to these external factors. Crosslinking assumed a new importance as a way to develop properties from small bits of polymers known as oligomers. All the new technologies found a place, but with the exception of radiation-curable (ultraviolet and electron beam) coatings, most required that a polymer be first made and fabricated to fit the technology and then the cure mechanism applied.

Radiation curing uses liquid, monomeric materials that are 100% solids in nature and that dry almost instantly to form hard coatings when exposed to radiation from ultraviolet (UV) light or electron beams (EB).

Today, UV technology is widely used and probably touches everyone's life in some fashion. Consider that almost every cereal box, every yogurt container and every compact disk is printed with a UV-curable ink/coating. The two halves of DVD-system disks are adhered to each other with a UV-curable adhesive. This is quite a feat, since the product must be optically clear and uniform when cured and cause no bending or warping of the composite disk. All cellular phones contain components that have been cured with radiation technology. Other end uses include adhesives and coatings for wood, optical fiber, printed circuit boards, flex circuitry, cans (for example, the exterior of Coors beverage cans), automobiles, labels, packaging materials, and lottery tickets.

The U.S. Coating Industry

Coatings comprise such a diverse range of products, well beyond the scope of the UV curable coatings niche highlighted in this report. The coatings market is a $20 billion industry and is expected to grow 3.5% through 2004. Most growth opportunities in the industry are in powder, electrocoat and radiation cure technologies, sectors that are anticipated to grow 9% for the 1997-2004 period. Environmental regulations and the country's economic direction will have the greatest impact on the paint and coatings market.

Industry figures are available for the UltraViolet/Electron Beam (UV/EB) coatings market from a widely recognized survey administered by Ken Lawson of DSM Coating Resins. This survey analyzed data from 99 industry members and 65 organizations, and reported that the UV/EB market grew just over 10% during 1999. Total sales volume of UV/EB formulations has grown from about 45,000 metric tons (100 million pounds) in 1995 to about 70,000 metric tons (154 million pounds) in 1999. The UV component of the radiation cure market represents approximately 90% of the total UV/EB market volume. The average annual market growth for these products is expected to be 8% to 10% in the foreseeable future, with several of Lawson's respondents expecting growth of 11% to greater than 30% per year.

Industry Importance to the Utility Industry

The opportunities for electrotechnologies within the coatings industry are significant. Chief among the factors contributing to these opportunities is the drive for efficiencies in every area of production. Increased competition is forcing companies to rethink antiquated, inefficient processes such as those found in abundance within coating operations. Energy efficiencies of 15% to 40% found in fossil fired technologies are being replaced by electrotechnologies with efficiencies in the 60 to 90% range. Customers are increasingly looking to reduce overall system costs instead of focusing solely on fuel costs.

A window of opportunity exists with customers’ expectations of more favorable electric rates in the era of deregulation. Electrotechnologies, such as UV curable coatings systems, offer significant growth potential within the coatings industry. The industry trends toward higher line speeds, safety, environmental friendliness, higher quality, and higher energy efficiency all favor UV technology.

Though the UV market is experiencing solid growth, many sales opportunities are lost due to insufficient analysis and an aversion to change from traditional techniques. Considerable opportunities exist for UV in the coatings market as customers upgrade older equipment, and look more openly to electrotechnologies in a deregulated electric utility industry.

Although many coaters serve the automotive sector in the Midwest, there are smaller concentrations of coaters within other manufacturing industries that are dispersed throughout the country. There is justification for utilities all across the country to have an interest in the coatings industry.

General Economy

The most dominant influence on the coatings industry is the general status of the overall economy. Similar to most other industries, when the economy is unstable or in a recessionary lull, expansion and capital equipment purchase plans are put on hold. Capital equipment dollars may not be available and any major sales effort is likely to fail. However, valuable groundwork can be laid, outlining the advantages of UV curable coatings systems and planning for future opportunities. During periods of economic growth and well being, capital dollars are available and expansion plans are being implemented. Timing is critical. If one is too late in the planning process, it becomes extremely difficult to influence the decision to go with one coating system over another.

The emerging telecommunications and electronics sector have combined with the resurgence of the automotive sector to have a positive effect on the UV curable coatings industry. These industries are continuously developing new materials and manufacturing processes in an effort to improve quality, performance, energy efficiency, and reduce environmental impact. Sometimes the materials or the coatings themselves require lower curing temperatures. In other instances, the process of combining manufacturing steps requires lower curing temperatures so as not to damage heat sensitive materials. UV curable materials offer many advantages over traditional coatings, and are finding increasing applications in a variety of products.

Environmental Issues

Purchasing decisions based on environmental impact are becoming increasingly common. Several pending air quality proposals, if enacted, will have a significant influence on the cost of using solvents and also on the cost of operating gas fired convection systems. The Clean Air Act of 1996 requires the reduction of solvent use by regulating volatile organic compound (VOC) emissions. Some sources suggest that the number of non-attainment zones could increase by as much as three to four times the current number. Additionally, the cost of compliance with these proposed emissions standards will have a significant impact on the bottom line of these coating facilities.

Internal plant environmental conditions for improved employee safety and comfort have also moved to the forefront. Long term trends point to greater costs borne by manufacturers, particularly those in higher risk environments like those found in coating shops. The enforcement of OSHA regulations and other cited statutory requirements are leading to higher fines and litigation costs. These trends create significant opportunities for electric utilities. Critical work place quality issues such as safety and point-of-use emissions (air, noise, and water) are better served by environmentally friendly processes such as those demonstrated by UV curable coating systems.

Commercial and Captive Coaters

Commercial coaters are specialized establishments engaged primarily in the coating of metal, wood and plastic materials for the trade. They are also called contract coaters or job shops. They support manufacturers in primary metals, metals fabrication, machinery, and transportation sectors where improved mechanical properties are required. Commercial coaters are usually identified under SIC 3479 (Metal coating and Allied Services), though there are a variety of other industries (e.g., engraving) within this same SIC code. A typical commercial coater employs an average of 30 people, has 5 to 10 coating lines at a given location, and is capable of coating a wide variety of incoming parts.

Captive coaters use in-house coating and finishing processes as a part of their own manufacturing process. They can be identified by knowing the types of products they produce, and understanding which of these require coatings. Examples of captive coaters are plastics companies and manufacturers of wood products, automotive and aerospace companies, publishing and printing companies, electronics manufacturers, telecommunications companies, and a variety of other companies within the manufactuirng sector. There are significantly more captive coaters compared to commercial coaters.

For the purposes of this report, our primary interest lies with the captive coater. Not only do they occupy over 90% of the market, they also are more likely to invest in new electrotechnologies for reasons explained later in this report.

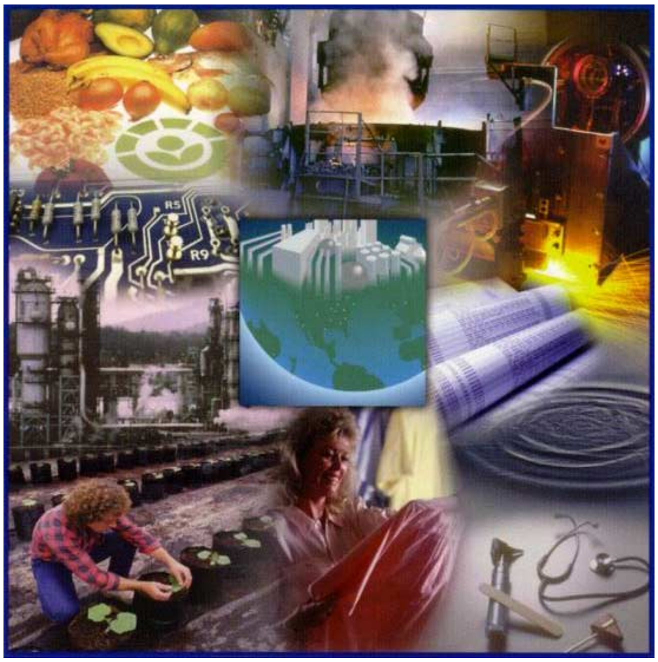
Trends

Industry sales and revenue trends are tracked by various industry associations and companies including Radtech International, a trade association representing the Ultraviolet and Electron Beam (UV/EB) coating industry. These two technologies are often combined under the category "radiation-curable coatings". Recent Radtech sales figures show a 10% growth rate in 1999 and forecast double digit increases for the next several years as performance and environmental issues continue to weigh heavily on purchase decisions within the coatings industry.

Technology trends are also affecting the coatings industry, and are having a very positive impact on growth opportunities for UV curable coatings. The proliferation of plastic parts in electronics applications are requiring more sophisticated coating processes. The explosive growth of cellular phones and DVD technology are two examples that have had a significant impact on the grwoth of UV curable coatings. Opportunities arise when the customer is demanding faster line speeds, lower cure temperatures, greater process control, higher energy efficiency, or systems that minimize environmental emissions.

The coatings industry is a regional business. Rarely are parts shipped great distances to be coated. Manufacturing companies with captive coating operations continue to streamline their processes, moving to in-line as opposed to off-site coating operations, to increase their manufacturing efficiencies. In those cases where this cannot be accomplished, parts are outsourced to commercial coaters. The trend toward outsourcing in some industries such as the automotive industry is further complicated by labor issues. However, the net effect of outsourcing is to move the coating business from the captive segment to the commercial coatings shop.

TECHNOLOGY DESCRIPTION



UV curing is an emerging technology in the coating industry with a sharp growth curve in recent years. The need for higher performance coatings, process speed, process control, lower temperature curing and reduced environmental emissions are becoming increasingly important in equipment selection. This section details the advantages of UV curing over traditional coating equipment, and discusses the considerations that are taken into account for various coating applications.

2
TECHNOLOGY DESCRIPTION

Coating and Curing Technology Overviews

Coatings

Coatings are a form of surface finish. Coating materials are applied to the surface of an object as thin films or layers to change the appearance of the surface or impart functional properties. Some people define **coatings** to mean substances applied primarily for protection and define **paints** to mean liquid substances applied for visual or esthetic reasons. Many people include **inks** in the category of coatings, and some include materials such as stiffeners (e.g., starch for clothing), adhesives, and metallic coatings (e.g. zinc or chrome). So, while the term "coating" often is not defined in a strictly precise sense, its general meaning is rather clear. Coating types include paints, varnishes, lacquers, enamels, plastics, metals, inks, toners and all other such materials applied as films to a surface. In this document, we will devote our attention to organic paints, coatings and printing inks because they represent the most significant opportunities for UV. The application sections of the overview discuss both coatings in general and printing inks and varnishes specifically.

The surface material of the workpiece to which a coating is applied is called the **substrate** and can be metal, plastic, wood, particle board, cloth, glass, ceramic, paper, paperboard, minerals, or other materials. Substrates can be smooth or rough, rigid or pliable, absorbent or non-absorbent, and flat or multidimensional. Variations in their shape can be regular or irregular.

Coatings always consist of a substance that is left as a film on the surface of the workpiece. They may contain tiny solid particles that impart color or sheen, and/or other substances that act as solvents, carriers, binders or participate in necessary chemical reactions. Before application, coatings may be in the form of a solid, powder, liquid, or paste. About 80% of the coatings used by industry are liquid. **Liquid coatings** may be a solution of the coating material in an organic solvent or an emulsion of the coating material and water. Water based coatings provide a definite advantage over coating/solvent solutions with respect to environmental concerns, but they are not commercially available for all applications and thus hold a smaller market share. In recent years, **powder coatings** are gaining popularity and are increasingly replacing liquid coatings.

Why Coatings are Used

Manufacturers apply coatings to change a product's appearance or to give desired physical or chemical characteristics to its surface. Coatings can protect from weather, abrasion, friction, impact, and corrosion. They also can provide electrical, acoustic, and thermal insulation. Sometimes coatings are used to compensate for using lower grade manufacturing materials since they can cover surface defects and other flaws.

Coating Selection

Coatings may be chosen according to the type of substrate, the physical or chemical properties desired and the appearance desired. Selection criteria also include the workpeice shape and size, cleanliness and temperature and relative thermal expansion with respect to the coating. For each application, there are many physical, aesthetic, and economic factors that must be considered in selecting the proper coating.

Types of Coatings - General

Coatings often are divided into broad categories describing their use and the materials from which they are made. The use categories are architectural and industrial, the material makeup categories are organic and inorganic, and the purpose categories are decorative and functional. While these categories are of no particular consequence, they are commonly used and should be understood.

- **Architectural Coatings -** Architectural coatings are paints, varnishes, and other coatings used to protect or decorate the materials used in constructing buildings. House paint is the quintessential architectural coating.
- **Industrial Coatings -** Industrial coatings are enamels, lacquers, and other coatings used to protect or decorate the materials used in the manufacture of goods. Automobile coating is an example of an industrial coating.
- **Organic and Inorganic Coatings -** Broadly speaking, organic coatings are materials manufactured from polymers or natural resins, while inorganic coatings are made of metals and minerals. Porcelain enamel and anodizing are examples of inorganic coatings. Strictly speaking, organic substances are the compounds of carbon, other than its oxides, carbonates, and cyanides. Inorganic substances are everything else.
- **Decorative Coatings -** Decorative coatings are those that are applied primarily for purposes of aesthetics. In such coatings, color, tone, reflectivity, gloss, and overall appearance are of prime importance. Decorative coatings are usually thin films of thermoset polymers.
- **Functional Coatings -** Functional coatings are those that are applied primarily in order to protect a surface from physical or chemical damage, or to reduce thermal or electrical conduction. Functional coatings are usually thick films of thermoplastic polymers.

Types of Coatings – Specific

Coatings also have more common names and some of these follow:

- **Paint** - A generic term for opaque liquids or pastes that contain pigments and other materials dispersed in a carrier fluid such as an oil or water that are applied to a surface to provide a coating that adheres to the surface and imparts color and/or protection.
- **Varnish** - Transparent or translucent solution of hard natural tree resins (gums) dissolved in an alcohol or oil, such as turpentine. Varnishes also include solutions of synthetic resins formulated to resemble those produced in nature by sandarac trees or other plants, including hemp and cashew. Varnishes are applied to a surface as a liquid and form a hard, glossy, transparent or translucent film over the substrate, usually wood or paintings.
- **Overprint Varnishes** - Overprint varnishes are coatings that are used to protect or alter the appearance of the underlying images or substrates. Magazines, brochures and packaging labels are some examples of printed materials that are coated. As with inks, the coatings can be solvent-borne, water-borne, or radiation-cured materials that contain neither solvent nor water.
- **Shellac** - A soft, water-insoluble resin produced by insects and deposited on trees (this contributes to confusion between shellac and varnish). Shellac is dissolved in spirits (denatured alcohol), acetone, or other volatile organic solvent and is used as a fast-drying, solid and transparent coating for woods. It is sometimes called a spirit varnish, but this is not correct. Phonograph records were once made of compressed shellac.
- **Enamel** - An opaque, oil-based, thermosetting coating that contains pigments. The resins are usually synthetic alkyds, polyesters or thermosetting acrylics. Enamels are applied to a surface as a liquid and form a hard, smooth, glossy, opaque film over the substrate. The substrate can be any relatively rigid material. Enamels dry and then cure to a thermoset state. Sometimes enamels are cured with heat.
- **Lacquer** - A coating based on nitrocellulose or other natural or synthetic cellulose derivative resins or thermoplastic acrylics, dissolved in a volatile solvent. They are applied to a surface as a liquid and form a bright glossy film over the substrate, which may be plastic, metal, fingernails, paper (in ink), textiles, or leather (producing patent leather). Lacquers have a high luster, polish easily, can be opaque or transparent, clear or colored. Most lacquers do not cross-link and can be redisolved with solvents.
- **Pigment** - Small solid particles that are insoluble in the medium that carries them, and whose chemical and physical properties impart color, opacity, reflectivity or other properties related to light. Pigments can be organic or inorganic substances that are dispersed through the coating to produce an opaque or translucent film.
- **Dye** - A compound that is soluble in the medium that carries it, and whose chemical properties impart color. Dyes are usually organic substances that attach themselves chemically to the substrate.
- **Ink** - A pigment dispersed, or dyes dissolved in a liquid, paste, or powder carrier. Inks are applied to substrates of almost any material, where they adhere and impart hue or tone for purposes of decoration or communication. Inks are used to deposit various types of images on a substrate. The images can be in the form alpha/numeric characters (words), pictures, lines, dots or patterns. The substrate can be paper, fabric, plastic, metal, wood or any other material to which the application of images is desired. The type of ink used depends upon the

nature of the substrate, the printing method, the drying or curing process, the type of finish desired, and the color(s). The inks can be solvent-borne, water-borne or radiation-cured materials that contain neither solvent nor water.

- **Toner** - A very fine black powder selectively deposited on paper by electrostatic attraction and fused there by heat. Used in printing processes to form more or less permanent characters, symbols, lines, shapes, or other graphic images. Toners are usually applied as a powder, but may be suspended in a liquid.
- **Powder Coating** - Resins that are combined with pigments, curing agents (cross-linkers) and other additives. Powder coatings are very similar to liquid paints, but the resins are solid polymers rather than liquid. Also, powder coatings do not contain solvents or other liquids. The raw materials are thoroughly melt-mixed with extruders, formed into flakes, and then ground to a very fine powder of consistent particle size range.

Application of Coatings

Substrate (or Part) Preparation

Before receiving a coating, the substrate usually must be cleaned thoroughly, often using water or organic solvents, acids, chemical cleaners or abrasives. The surface is then rinsed and dried. In some cases, the surface must also be treated with phosphates, chromates and/or other chemicals in order to make the surface more receptive for the coating and/or to prevent corrosion. Surfaces also may need to be smoothed before the coating application, and in some cases heated.

Processes Used to Apply Coatings

Mechanical, chemical and **thermal** processes are used to apply coatings. Brushing, extruding, calendering, dipping, spraying, and mechanical plating are the most common mechanical application techniques. Chemical application techniques include electrolytic deposition or electroplating, and chemical conversion processes such as anodizing. Thermal techniques for applying coatings are flame or plasma spraying, and plating with vaporized metals, or "sputtering". Some of the more common applications follow:

- **Spray gun application** is the most widespread technique for applying coatings. In a simple system the coating material is atomized by the spraying equipment and applied to the workpiece. With electrostatic spray application, the coating material is atomized and given a negative charge as it passes through the head of the spray gun. The workpeice is electrically grounded and the negatively charged powder particles cling to the positively charged surface of the workpiece. Because the electrostatic forces attract the coating less material is lost to over-spray. Electrostatic application is necessary for applying powder coatings unless the part is pre-heated.
- **Electrostatic discs or bell-shaped atomizers** that rotate at high speeds are used to apply industrial coatings. The liquid or powder coating is dispersed over the surface of the disc or bell, which is electrically energized to impart a negative charge to the coating material. The tremendous centrifugal force that is generated by the high-speed rotation of the disc or bell

drives the coating from the rotating surface and causes the liquid paint droplets, or powder coating material, to atomize. Electrostatic forces then cause the coating material to be attracted to the grounded workpiece. Electrostatic bells are used extensively in the automotive industry.

- In the **fluidized bed** method of applying powder coatings, a preheated workpiece is suspended in a tank containing a cloud of powder coating particles created by upward airflow. Upon contact, the powder melts and adheres to the surface of the workpiece. The part is then placed in an oven where the powder fuses further and, in the case of thermosets, cross-links. Usually, however, this technique is used to apply thick thermoplastic functional coatings and not thermoset coatings.
- The **electrostatic fluidized bed** method is similar to the fluidized bed process, but the part may or may not be preheated. The part and the powder are given opposite charges and, thus, are mutually attracted. The powder coating adheres to the conductive substrate which is then sent on to an oven for curing.
- **Coil coating** or **roll coating** is the process of applying and permanently bonding a coating to one or both sides of a coil of steel, aluminum, or other material. Such coatings are usually applied as liquids, but plastic films also may be attached by lamination using heat and pressure to effect the bond with the substrate. With a liquid coating, a rotating roll is immersed in a reservoir that contains the paint. The roll picks up the paint and transfers it to a second roll, which then applies it to the surface of the coil. The second roll, or applicator, is equipped with a “doctor blade” to control the coating thickness. The coil then passes through a baking oven where the paint is then dried and cured. Coil coating is used for high-speed applications with lines commonly operated at speeds of 500 – 1000 feet (152.4 – 304.8 meters) per minute.

Powder Coating Application

When applying powder coatings, a combination of processes is often used. The powder is applied to the surface of the object to be coated with an electrostatic spray gun or by pre-heating the object and immersing it in a fluidized bed containing the powder. When applied via electrostatic spray methods, the powder adheres lightly to the substrate until heated. Upon heating, the powder flow and levels, develops adhesion to the substrate, and becomes a paint-like film. There are both thermoplastic and thermosetting powder coatings.

Drying and Curing of Coatings

In a manufacturing facility, the equipment and processes for preparing the substrate followed by applying, drying and curing the coating is called the **finishing line**. At a simple level, a typical finishing line would include equipment for washing and drying the part and for applying and curing the coating. Finishing lines are a complex array of sophisticated, finely tuned equipment. It is important to know as much as possible about an entire finishing line, before making recommendations for process improvements. It is not rational to change one component of the finishing line without carefully considering the entire line because other components are tightly coupled with the finishing line.

Once a coating is applied, several process steps occur before a part is ready for its intended use. Basically the steps are flow and leveling, drying and curing. This section of the technology description deals with this latter part of the finishing line.

Flow and Leveling

When a coating, or paint, is applied to a substrate it must first flow to “wet-out” the entire surface. This assures that complete coverage of the substrate occurs and mechanical and/or chemical adhesion is achieved. In the case of smooth finishes (as opposed to textured finishes) the coating must then level to reduce the “orange-peel” effect. With most liquid coatings, a substantial portion of the flow and leveling process takes place prior to entering the curing oven. However, with powder coatings, it is necessary to melt the powder particles to achieve flow and leveling, thus the entire flow and leveling process occurs in the curing oven.

Drying

After a liquid coating is applied to a workpiece, the water, organic solvent, or other liquids must be removed. That process may occur by natural evaporation, or may be accelerated by adding heat and forced air. The heat gives the liquid more energy to evaporate, while the forced air carries away the vapors, making room for more. Such removal of liquid is called “drying”.

A rapid drying process is known as **flash off**. In this process, air and heat are rapidly applied to the coated part to drive off water and others liquids from the coating. It may take place in a portion of the curing oven designed specifically for that purpose.

Curing

Curing is a set of chemical and physical processes that coating materials must undergo after drying. The coating must attach itself to the substrate physically (adhesion) or chemically (cohesion) and must cohere to itself. It may also need to undergo chemical reactions such as “polymerization” (formation of plastic). These processes are known collectively as curing. Depending upon the chemistry of the coating material, curing can take place at room temperature, at elevated temperatures, or by free radical reaction. Most of the industrial coatings used today are thermally cured and the curing time is an essential process variable. With thermally curable coatings, adding heat can accelerate the curing process, but care has to be taken not to overheat the coating. It should be noted that curing and drying are different steps in the coating process although these terms are sometimes mistakenly interchanged.

Curing agents are chemicals added to polymer based coatings to help control the formation of polymer chains from monomers and the cross-linking between adjacent polymer chains. Chemicals added to prevent premature polymerization during storage are called **inhibitors** or **stabilizers**. Another common type of curing agent is a class of chemical materials called **catalysts** or **initiators** that are added to cause the start of polymerization. Most of us are familiar with household adhesives (epoxies) that require mixing a catalyst or “hardener’ with a resin to form the desired adhesive polymer. Curing agents are added to resins to speed up the processes of chain formation and cross-linking after they are initiated. These curing agents are called **accelerators** or **promoters**.

Gelling/Gel Formation

Gel formation is an intermediate step in the curing process of thermosetting coatings. When polymerization is initiated, the polymer chains continue growing, branching, and inter-linking, until essentially one large molecule is formed. At this point in the curing process, sufficient cross-linking is attained to prevent further flow and leveling of the polymer. That state is called "gelling" in the language of polymers and coatings.

Results of Improper Curing

If the finishing line processes are not carried out properly, the end result is coating defects. Most of these are readily spotted in the final product. Some typical defects are as follows:

- **Spotting** - Discoloration that appears on the surface due to contamination.
- **Chalking** - The progressive conversion of the coating to a dull powder from the surface toward the substrate.
- **Bleeding** - Seeping of color from a sub-coat through the topcoat.
- **Blistering** - The appearance of bubbles in the topcoat, usually due to improper surface preparation or excessive thickness of the film.
- **Flaking or peeling** - The separation of a coating from its substrate, usually due to dirt, grease, water, or other surface contaminant.
- **Alligatoring** - A kind of flaking where the center part of the flake remains attached to the substrate.
- **Blushing** - A whitish haze that appears on coatings when they are cured in the presence of excessive moisture.
- **Chipping** - The removal of very small areas of the coating by objects striking the cured surface.
- **Cracking** - The formation of cracks such that the coating resembles dried mud. Cracking is usually the result of improper surface preparation, excessive thickness, or insufficient flash and dry times.
- **Checking** - The formation of very fine parallel cracks. Checking, like cracking, is usually the result of improper surface preparation, excessive thickness, or insufficient flash and dry times.
- **Orange peel** - An uneven coating finish that resembles the outer surface of an orange. It can be caused by improper flashing or drying, and by improper curing.

Coating Curing Processes

Ultraviolet (UV) Radiation

Ultraviolet radiation, or UV light, is the part of the electromagnetic spectrum that lies between 10 and 400 nanometers in wavelength as shown in Figure 2-1. It is light we cannot see and has higher energy, shorter wavelengths, and a higher frequency than visible light. Ultraviolet radiation is emitted by, and absorbed by, the valence electrons of atoms. When an electron in an outer atomic orbital encounters a photon with the right level of energy, the electron will absorb the photon and move from its normal “relaxed” state to an “excited” state. If the photon has enough energy, the electron will leave the atom entirely and become a free electron, or free radical. When UV light strikes an object, the electron may be reflected, transmitted, or absorbed. As with visible light, reflectors can be used to direct and focus UV light.

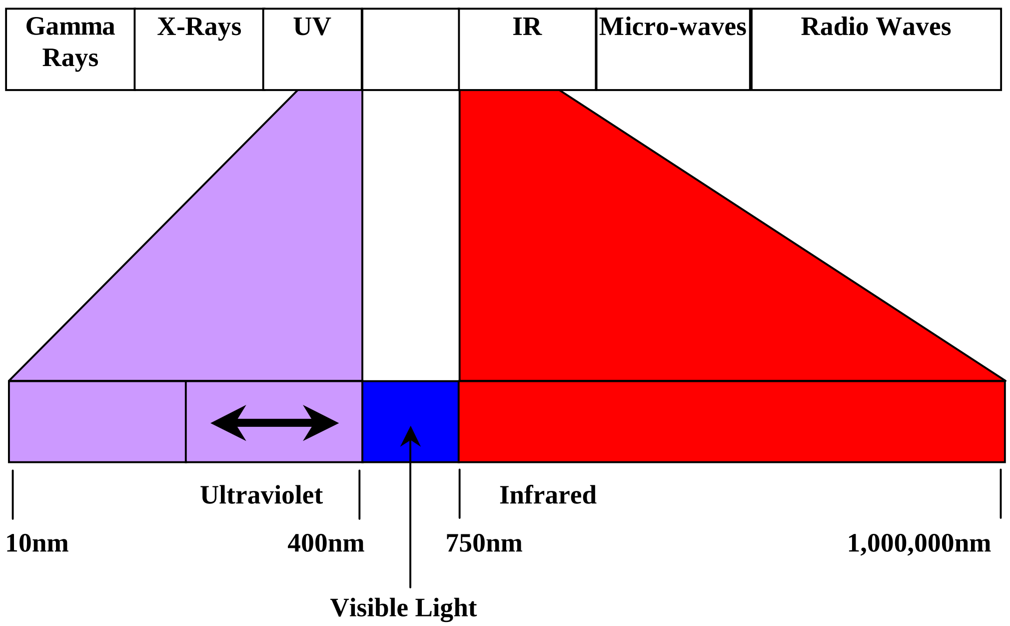


Figure 2-1
UV Range in Electromagnetic Spectrum

Our sun is the largest emitter of UV light we encounter, but for industrial applications man-made emitters are used. The most common industrial UV source is the medium-pressure mercury vapor lamp. An electrode arc or microwave energy is used to excite the mercury, which causes the UV emission.

UV Curing Process

UV curable coatings contain a catalyst called a photo-initiator. The photo-initiators generally react to wavelengths of between 200 and 400 nanometers. It absorbs UV light and starts a photochemical reaction that employs the use of free electrons, or free radicals, and causes an almost instantaneous cross-linking of the resins. UV curable coatings are formulated with unsaturated resins that are capable of free radical reaction. Unsaturated resins have fewer hydrogen atoms or equivalent groups than saturated resins and will combine directly with hydrogen, chlorine, oxygen, or various other substances to form long chain polymers. Only the photo-initiator and exposure to ultraviolet light are required to start and complete the reaction. Thermal processing is not necessary to cross-link the resins used in liquid UV-curable coatings. However, some heat is necessary with UV-curable powder coatings in order to melt, flow, and level the particles of powder before curing.

The reduction or elimination of heat, which reduces energy consumption, makes UV curing very attractive for many applications. However, because UV light travels in straight paths, a line-of-sight is needed to all parts of the substrate being coated. This is difficult to achieve in complex shapes, so UV curing is not a panacea for all coatings applications. The following is a summary of the advantages and disadvantages of UV curing:

Advantages of UV-Curable Coatings

- **Much faster than thermal processes** - UV coatings cure in a matter of seconds, rather than minutes or hours.
- **Faster start-ups and shut-downs and lower energy consumption** - UV lamps turn on and off almost instantaneously. There is virtually no energy or time lost waiting for the oven to come up to temperature in order to start or resume production, and stand-by modes are not necessary.
- **Improved productivity** - Because UV coatings cure in a matter of seconds, higher line speeds are possible.
- **Less contamination –** lower reject rates - No air movement to exhaust byproducts of combustion is necessary in UV curing systems. This reduces the chance of air-borne contamination of the coating.
- **Less thermal, noise, and air pollution** - Since only minimal heat is necessary to cure the coating, there is less thermal pollution of the workplace and less noise pollution from fans, burner regulators, and valves.
- **Reduces or eliminates VOC emissions and solid waste disposal** - Many UV coatings are 100% solids and contain no solvents; thus VOC emissions can be eliminated. Also, in many cases, over-sprayed coating can be recovered for use, thus reducing solid waste disposal.
- **Less space required** - Due to the speed of cure, UV systems require less floor space. Typically UV systems take only 5% or less of the space needed for convection ovens.
- **Superior finishes** - UV curable coatings can offer improved performance and better visual properties than their thermally cured counterparts.
- **Can be used on temperature-sensitive substrates** - Substrates such as wood and plastic, and fully assembled products that may contain gaskets and/or fluids, can be safely coated with UV curable coatings. Also large parts, such as castings, that require enormous amounts of energy just to get the substrate to the curing temperature of the coating material, are ideal

candidates for UV curing. Table 2-1 shows the lower curing temperatures of UV compared to conventional liquid and powder coating.

Table 2-1
UV Curable Coatings – Energy Requirement Comparison

Coating System Type	Curing Energy (kJM^2)	Typical Curing Temperature
Liquid Paint	1.00	300^{o}F (149^{o}C)
Powder Coating	0.50	375^{o}F (191^{o}C)
UV Liquid Paint	0.15	-
UV Powder Coating	0.35	225^{o}F (107^{o}C)

- **Safety** - The absence or reduced amount of solvents in UV curable coatings, along with the fact that heat is not necessary for curing, reduces the health and fire hazards associated with highly volatile materials.

Disadvantages of UV-Curable Coatings

- **Material Cost –** The cost of UV powders, though declining, is still at a significant premium compared to conventional coatings.
- **Requires line-of-sight** - Because ultraviolet rays travel in a straight line, some geometrically complex parts may be difficult to cure with UV. Recessed areas and areas of the part that lie at 90° angles to the emitters will pose difficulties. However, the use of reflector cases to re-direct the radiation to hidden areas of the part may overcome some of these problems. Some complex parts may simply be impossible to cure with UV light.
- **Part placement may cause “shadowing”** - Parts typically placed close together may result in blockage of the UV light from adjacent surfaces. Even when reflectors are used, it may be necessary to increase the spacing of parts in order to allow the UV light to be directed to all coated surfaces.
- **Set- ups can be complex and time consuming** - If parts of various sizes and geometrical configurations are being processed, it may be necessary to re-configure the UV lamps when the product-mix changes.
- **Some colors are difficult to cure with UV** - Not all colors react the same way to ultraviolet light. Some colors readily absorb UV light, while others, such as opaque colors, may reflect more of the light than they absorb.
- **Repair of coating defects is difficult** - Spot repair is almost impossible with UV coatings and it may be necessary to re-coat the entire part if there are defects in the coatings. However, with most thermoset coatings, this is almost always the case regardless of the curing method used. The exception is lacquers, which can readily be spot-repaired and rubbed-out, if necessary.

- **Safety -** UV light can be dangerous and can pose a health risk to humans when proper precautions are not heeded. Of particular concern is possible damage to eyes or skin from high-energy UV sources and prolonged exposure to UV radiation (the same phenomena as overexposure to the sun).

Thermal Curing

Thermal curing is simply curing by exposing the coated part to heat and typically involves a time-temperature relationship related to the part characteristics (size, material, etc.) and the coating used. About 90% of the industrial coatings used in the United States are thermally cured using either convection heating or radiant heating.

Convection Heating

Gas convection is the most common type of oven in the United States for industrial process heating. In these ovens, natural gas is burned in the oven to provide heat. Most gas convection ovens are **direct-fired** ovens, which means that the hot combustion gases come into direct contact with the product. Convection heating requires mass movement of large volumes of hot gas to achieve heat transfer to the part. The atmosphere in these ovens contains carbon dioxide, carbon monoxide, nitrogen oxides, water vapor, and solvent vapors. The air may also contain unburned fuel and carbon particles. In **indirect-fired** ovens, combustion takes place in a special chamber and heat exchangers are used to heat the air that comes into contact with the product. These ovens can provide a much better finish than the direct-fired type, but they are less efficient than direct-fired ovens.

Infrared Radiant (IR) Heating

Both electric based and gas combustion based systems are available for IR heating. IR offers increased energy efficiency and, therefore, its use for curing of coatings is increasing in North America. As with visible light and UV light, IR follows a straight path, and can be reflected and focused toward the object to be heated. When the object absorbs the IR, the temperature of the object rises. In the case of a coated part, the coating absorbs the infrared energy and starts to heat. When the required temperature is attained, the coating gels and cures.

Electric IR emitters used in industry are similar to the heat sources used in many home appliances and can produce IR in the short, medium or long wave ranges. Toasters (medium wave), electric ovens (long wave), quartz space heaters (short wave), electric barbecue grills (long wave), and heat lamps (short wave) are familiar examples. Like their household counterparts, industrial electric ovens use Cal-rods, quartz tubes, or tungsten filaments as IR emitters. The type of emitter used depends upon the IR wavelength that is desired. The factor that determines whether long, medium, or short wave IR is produced is the temperature of the emitter. Cal-rods are limited to about 1400° F (760^{o}C) and are usually found in long wave electric IR ovens. Quartz tubes can attain temperatures up to 2200° F (1204^{o}C) and are used when medium wave IR is needed. Tungsten filaments IR emitters operate at 2500° F - 4500° F (1371^{o}C – 2482^{o}C) and are used for producing short wave IR.

There are two main types of gas IR burners: **impingement** and **surface**. With impingement burners, gas flames directly contact a ceramic block and transfer heat to the ceramic by convection and radiation. The ceramic then radiates heat to the product. The ceramic radiators may reach temperatures of 2000^{o} F (1093^{o}C). Surface IR burners typically use ceramic also. The ceramic may be of the **ported** type or a ceramic **foam.** In either case, gas is released through tiny perforations on the surface of the ceramic and burns at the surface of the material. The ceramic then radiates heat to the product. Surface radiators sometimes operate at lower temperatures, around 1600^{o}F (871^{o}C). Due to the operating temperatures achievable with gas IR systems, they can only produce long and medium wave IR.

Another type of gas burner used for IR ovens is the **gas catalytic IR** burner. In these ovens a catalyst, usually platinum, is used to aid in combustion. The catalyst lowers the activation energy of the gas and aids in more efficient combustion. It increases the percentage of gas that actually burns, but does not affect the amount of heat produced by the combustion.

Another variation of the gas IR oven is frequently found in the automobile industry. " **Black-wall**" ovens, in which dark colored ceramic or steel panels are heated from behind by gas combustion, are used as the first stage, or flash-off zone, of convection ovens. The heated panels radiate heat toward the part, usually an automobile body. Little or no air movement is required and, as such, the risk of air-borne contamination of the uncured coating is reduced. Black-wall ovens are often incorrectly considered to be convection ovens, but are actually a type of long-wave gas IR oven.

Thermal curing in many cases offers advantages over UV curing. Some of the advantages are obvious technical considerations, while others may be economic factors. However, misperceptions and a general lack of knowledge of UV curing processes have limited the growth of UV curing for many applications. The key is in knowing whether the application is conducive to radiation curing or whether thermal curing is the best alternative. The following are some of the advantages and disadvantages of thermal curing:

Advantages of Thermal Curing

- **Product and Coating Flexibility -** Coatings can be thermally cured on geometrically complex parts as well as simple parts. Convection heating works well on large parts and small parts, on metal, wood, and some plastic substrates, and on thick substrates as well as thin materials. Parts of various sizes, shapes, and substrates may be intermingled in convection ovens and cured alongside each other. Radiant, or infrared heating, can offer shorter curing times, faster line speeds, and energy efficiency when compared to convection heating, and IR ovens require less space than convection ovens. However, infrared energy will only heat objects that are within its line-of-sight. Thus, uniform curing of complex geometrical shapes can present problems as it does with UV curing. In addition to product flexibility, thermal processing can be used to cure virtually all the different types of coatings commonly used by industry. For many applications, including many geometrically complex parts, a comprehensive analysis will show that UV curing is superior to thermal curing.
- **Simplicity and Forgiveness -** Convection ovens are relatively simple to operate when compared to most radiation curing systems. However, they are actually more subsystems

involved. Convection ovens require many mechanical devices such as burner regulators, valves, fans, and other controls. Also, the air currents associated with convection heating are very complex. Convection ovens need to be balanced regularly to maintain proper heat distribution and ensure adequate exhaust of emissions such as volatile organic compounds (VOCs) and/or products of combustion. Electric IR ovens are typically much simpler to operate and maintain than convection ovens. In addition, convection ovens are generally very forgiving since the heat transfer rates are so low. For example, if a part is left in a convection oven a bit too long, there may be no harmful effects to the coating. This is because the part will never exceed the temperature of the oven atmosphere and most coatings can withstand considerable over-baking without damage (up to twice the required curing time). However, if the same part was exposed to twice the amount of infrared energy (up to twice the curing temperature), the coating might be severely damaged.

- **Psychological Comfort Level** - From the floor operator to senior management, virtually everyone is familiar with the operation of gas convection ovens. They are the traditional workhorse of all industrial process heating in the US and operate on the same principles as household heating units. For this reason, they are accepted as a safe, reliable technology. Electric IR ovens, because of their simplicity of operation and the incorporation of safety devices, have made inroads in many drying and curing applications and are being well accepted by industry.

Disadvantages of Thermal Curing

- **Longer cycles and more floor space** - Thermal curing requires much longer cycles than UV curing. Consequently, thermal curing ovens usually occupy considerably more floor space than UV curing chambers.
- **Contaminating air in oven** - The necessary air movement in convection ovens carries dust and air-borne contaminants to the product finish. IR ovens require less air movement, but some exhaust is still needed to remove the moisture and by-products of the curing reaction from the oven atmosphere.
- **Variable quality** - Convection ovens often have hot and cold spots, which can affect product quality.
- **Thermal, acoustic, and air pollution** - Gas convection ovens can pollute the work environment with heat that spills out of the entrance and exit silhouettes, noise from fans and pumps, and fumes from the combustion of gas and evaporation of solvents.
- **Energy and productivity losses** - Convection ovens typically heat the entire mass of the product, which then requires long cooling-off periods before further handling of the parts is possible. More selective heating is possible with IR, but heating of the part is still necessary in order to cure the coating, thus cool-off time is still required before the parts can be handled. Convection ovens take a significant amount of time to heat-up and cool-down, and must often be turned on well ahead of the start of production and left running through breaks and unscheduled production shutdowns. In addition, the high thermal inertia in a convection oven causes them to be slow in responding to changes. IR ovens respond much faster (especially electric IR) and less energy is wasted, but a stand-by mode (idle), which consumes energy, is typically required for gas IR systems.

- **Inefficiency** - Gas ovens produce combustion products that must be carried away (along with large quantities of heat). These can result in energy losses to the local environment and may result in additional expenses for air handling and treatment systems.
- **Safety** - Any process that generates high temperatures carries with it the potential for fires. Gas ovens are inherently more dangerous than electric ovens due to a risk of explosion, but even in electric process heating, the risk of fire exists.

Application of Printing Inks and Varnishes

Processes used to Apply Inks and Varnishes

There are several methods used to apply inks. The most common methods are lithography, flexography, letterpress, gravure, screen, and plateless printing (ink-jet). With the exception of letterpress and ink-jet, varnishes are applied with the same methods used to apply the inks. With many items, such as magazine covers and brochures, the entire surface of the substrate is over-coated with the varnish. However, in some cases, such as flexible packaging (plastic bags and wrappers), only the printed image is over-coated with the varnish.

Lithography, or **offset printing**, is a process in which a photochemically treated plate transfers an inked image onto a rubber cylinder. The cylinder then transfers the image onto the substrate (Figure 2-2).

Flexography and **letterpress** are direct printing processes in which raised images are transferred directly to the substrate. Flexography uses a flexible plate that carries a relief image that is transferred directly to the substrate. Letterpress utilizes rigid images that deposit the inks directly to the substrate (Figure 2-3).

Gravure printing, which is also a direct process, uses a metal cylinder on which the images are etched. Ink is drawn into the recessed (etched) areas on the cylinder as it rotates through the ink reservoir and is then transferred to the substrate. The non-image areas of the cylinder are polished and ink is removed from the polished areas with a flexible blade (Figure 2-4).

Screen-printing, as the name implies, uses a cloth “screen” that has been treated with an impermeable coating in the non-image areas. The screen is placed on the substrate and a squeegee is used to force the ink through the non-treated area of the screen to deposit the image on the substrate (Figure 2-5).

Plateless, or **ink-jet**, printing deposits the image by spraying droplets of ink onto the substrate. There is no contact between the substrate and the ink application device. There are other methods of plateless printing, but ink-jet printing is the most prevalent.

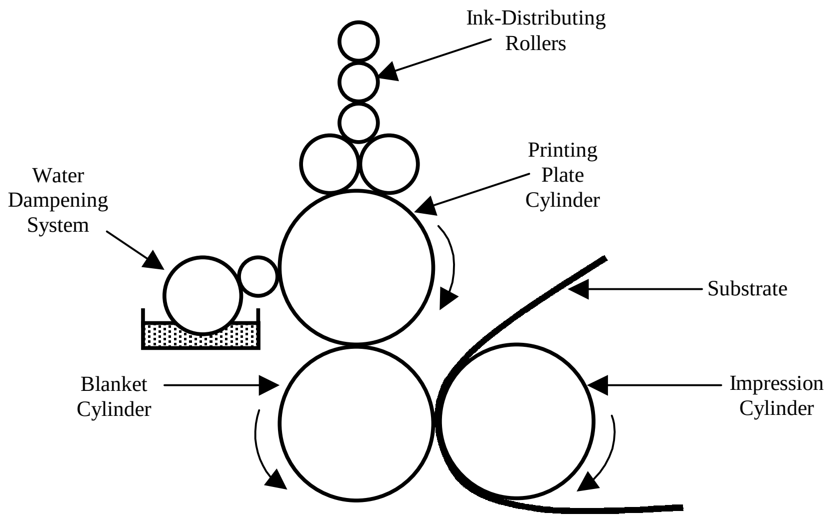


Figure 2-2
Lithography Process

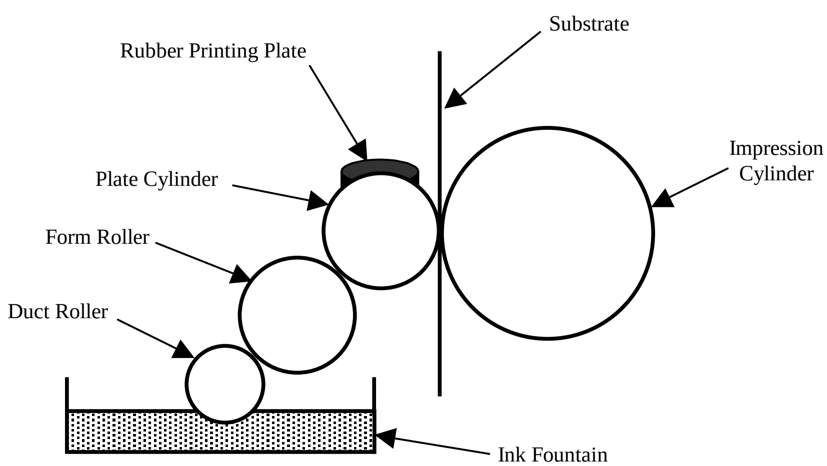


Figure 2-3
Flexography Process

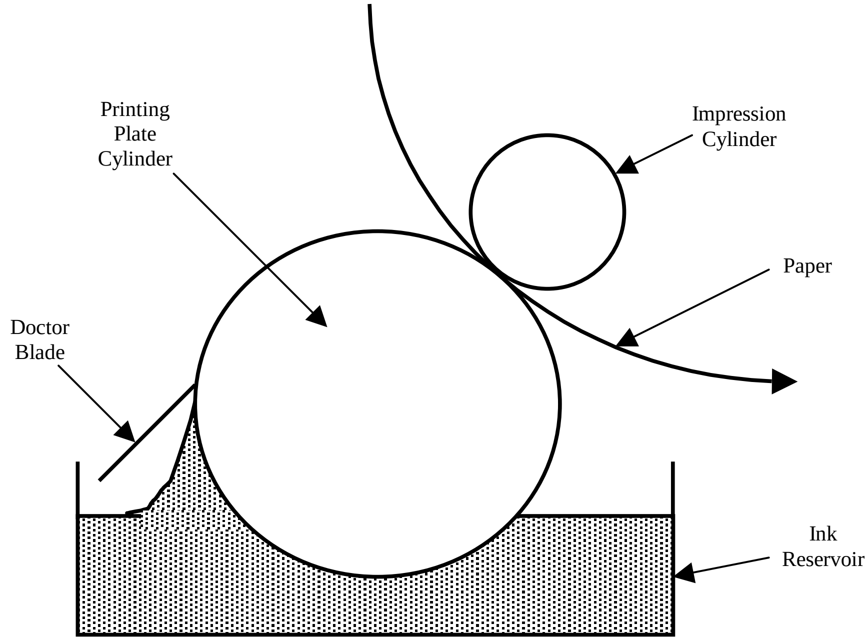


Figure 2-4
Gravure Process

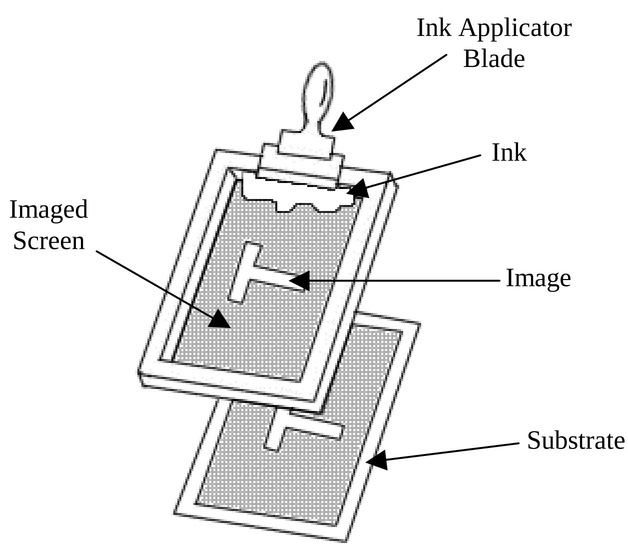


Figure 2-5
Screen Printing Process

Drying and Curing of Printing Inks and Varnishes

There are several different types of inks and varnishes used by the publishing and packaging industries. The type of ink or varnish used for a particular application depends on the substrate, the effect desired, the printing process, and the drying and curing process. Inks and varnishes can be classified by the methods in which drying and/or curing take place. The primary methods by which inks dry and cure are:

Oxidation (Air Drying): The ink absorbs oxygen to become a solid. Certain oils (e.g., linseed and soybean) polymerize in the presence of oxygen and convert from a liquid to a solid. Air-drying is used primarily in letterpress and lithography.

Polymerization: The resins used to make the ink or varnish are reactive materials that polymerize (cure) upon exposure to elevated temperatures or ultraviolet (UV) light or electron beam (EB) radiation. Polymerization inks are used in lithography, flexography, letterpress, and screen-printing.

Penetration: The resin is absorbed by the substrate. Penetration inks are used mostly in the newspaper industry.

Evaporation: The solvents in the ink evaporate, leaving a dry ink film. Evaporation inks are commonly used in lithography, flexography, and gravure.

Precipitation: In this process, a water spray precipitates the pigments and resins to form a dry ink film. This method is used primarily for drying overprint varnishes.

Drying by evaporation is the most common method used by the printing industry. The evaporation process can be accelerated by force drying through the application of heated air. The most common method of force drying inks and overprint varnishes is with convection heating. In convection heating, natural gas and other fossil fuels are burned to heat air, which is then circulated over the surface of the substrate. Infrared (IR) heating is also used extensively by the printing industry to accelerate the drying and curing of inks and varnishes.

Curing of polymerization inks is accomplished with both thermal (convection heating or IR heating) and non-thermal processes (ultraviolet light or electron beam radiation). However, UV and EB curing require specially formulated inks and varnishes.

Printing Ink Curing Processes

UV Light Curing Process

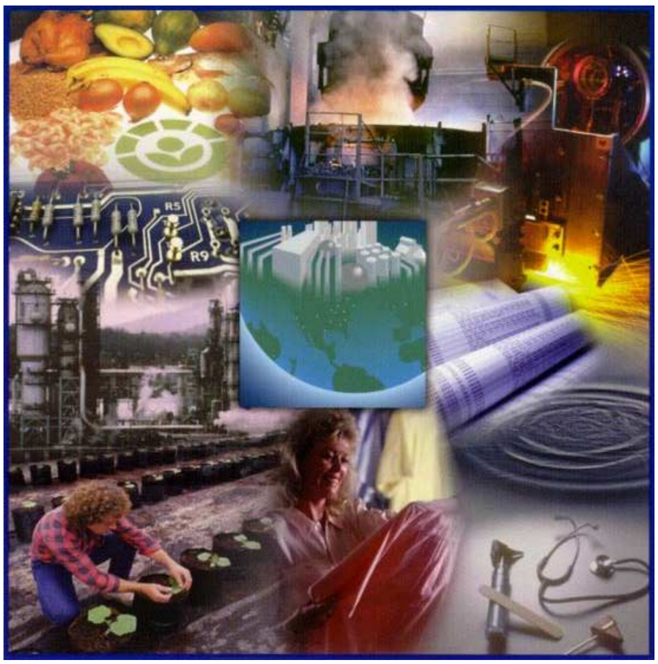
About half of the energy consumed by the printing industry is used for drying and curing processes. Large amounts of heated air must be exhausted from the drying and curing ovens to remove solvents or water from the oven atmosphere. More energy is then required to replace the heated air that has been exhausted. UV curing can save over 50% of the energy required for this process. UV-curable inks contain no solvents or water, thus less exhaust is needed to evacuate fumes, and no heat is required for curing. Table 2-2 shows the relative energy requirements for drying and curing various inks and varnishes.

Table 2-2
The Relative Energy Requirements for Drying and Curing Various Inks and Varnishes

Type	Energy Required per square meter	Relative Energy
UV Clear Overprint Varnish	.046 MJ	1
UV Printing Ink (pigmented)	.16 MJ	3.5
Acid-catalyzed Overprint Varnish	.23 MJ	5
Conventional Litho Ink	.34 MJ	7.4
Solvent Based Flexo/Litho Ink	.51 MJ	11.2
Water Based Acrylic Emulsion	.76 MJ	16.5

UV-curable inks and varnishes are formulated with special polymers, oligomers, and monomers that undergo a photochemical process known as a “free radical reaction” and polymerize when exposed to ultraviolet light. A “photo-initiator” absorbs the UV light and starts the photochemical reaction. The monomers, or pre-polymers, are the building blocks of oligomers and polymers, and are liquid materials that are used in place of solvents or water to reduce the viscosity of the ink or varnish. The monomers cross-link with the oligomers and polymers when the reaction takes place; thus 100% of the material is utilized and no volatile materials are emitted. UV-curable inks and varnishes typically contain no solvents or water and will not dry or cure until they are exposed to ultraviolet light. UV-curable materials cannot be force-dried or thermally cured. (For more information see section on “Curing with UV Radiation”.)

IDENTIFYING OPPORTUNITIES



To identify an opportunity for using UV curable coatings, one must first understand the nature of the business and capital investment decisions facing manufacturers who apply coatings. Then one must identify a specific company, qualify it as a prospect, and analyze the situation in detail. This section discusses those activities at length and provides tools for applying these methods in the real world. Proceeding from the general to the specific, it ultimately introduces the reader to a step-by-step analysis for evaluating UV coating opportunities.

3
IDENTIFYING OPPORTUNITIES

Background

For each component to be coated, there are a variety of means to apply and cure the coating. Sometimes, the selection of an optimal process is not straightforward. However, it is clear that certain circumstances need to be in place in order to be potential applications for UV coatings. Initially, the lower temperature cure was the primary reason to use UV technology. Publishing and high quality packaging applications involve *heat sensitive* materials that can be damaged by higher temperature coatings porcesses, and are thus excellent UV coatings applications. This situation has gradually evolved to include many applications beyond heat sensitve materials.

Today, there are many other benefits that are driving UV to the forefront. The challenge then becomes how to locate these potential opportunities. In the case of a heat sensitive curing application, the utility representative needs to ask several questions and listen very carefully to uncover the UV opportunity. The manufacturer may have altered the process, perhaps added two or three manufacturing steps, to work around the coating of the heat sensitive material. Perhaps the quality of the part has been compromised, but the manufacturer can still supply a market that has lower quality specifications. The manufacturer is likely not aware that there is a way to improve the quality or speed of a particular process by using UV technology. In any case, some knowledge must be exchanged which opens up the manufacturer to include UV performance benefits in new equipment decisions.

To identify an opportunity, one must first identify a need. The focus of this section is how to uncover those needs that may not be readily apparent to a manufacturer who is applying coatings.

Capital Investment Decisions

Adding or replacing finishing line equipment is a capital investment – an expenditure of hundreds of thousands of dollars on equipment that will last for many years. In addition to identifying a customer's need for a coating system, the utility representative must also be knowledgeable about the availability of capital to that customer, the expected financial rate of return, and any other external factors such as new environmental regulations, competition and so forth. In short, the utility representative must truly know the customer, or risk the possibility of losing an electrotechnology opportunity with that particular customer.

Opportunities Defined

The suitability of a UV coating application will depend on the type of metal, wood or plastic part, performance specifications, heat sensitivity issues, and external factors such as environmental emission constraints, availability of capital and a host of other factors. For example, UV coatings were initially sucessful in environmentally sensitive applications, in some cases reducing emissions by up to 99%. These early applications were then broadened to include other higher performance markets, because significant quality improvement was possible by replacing laquer-based materials. Another outcome was the possibility of increasing productivity by increasing line speeds and reducing failure rates. The drivers in the decision making process include many of these factors, and can be difficult to quantify. The purpose of this section is to identify the strengths and weaknesses of UV systems so that the reader can first understand the "best fit" applications, and then to begin to identify similar applications at other customer locations.

Typical Applications for UV-Curable Inks and Varnishes

The two major markets for UV inks are publishing and high quality packaging, e.g., flexible films, plastic containers (cups, jars, tubes, bottles), aseptic containers (beverage cans, food packaging), etc. Firms that make decals and signs (usually screen-printed) also make use of UV inks. Clear UV overprint varnishes are used on cans and for magazine covers, book covers, brochures, and similar products. The following table lists the types of printing processes described earlier and the curing methods commonly used.

Table 3-1
Types of Printing Processes and the Curing Methods Commonly Used

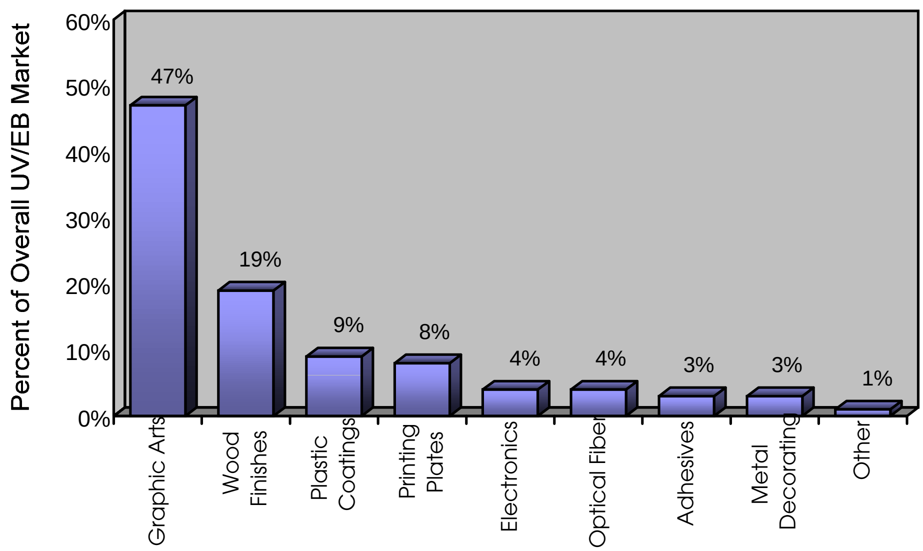
	Gravure Publishing (newsprint)	Gravure Packaging	Lithography	Flexography	Screen Printing
Drying and curing methods employed	Convection, infrared	Convection, infrared, UV	Convection, infrared, UV	Convection, infrared, UV	Convection, infrared, UV

Note: This list is not intended to be all encompassing. The state-of-the-art of UV ink and varnish technology continues to advance at a high rate, thus the potential applications for UV curing in the printing industry continue to expand.

Because ultraviolet light travels in a straight line, the best opportunities for UV-curable coatings are in applications involving flat parts such as flooring, shelving, paneling, partitions, and metal coils. Additionally, parts that can be seen as flat by the UV emitters, i.e. – cylindrical parts such as cans and fire extinguishers, or square parts such as cabinets, that can be rotated as they pass through the curing chamber, are excellent candidates for UV curing.

Nonetheless, geometrically complex shapes should not be entirely ruled out. The line-of-sight problem can be overcome in many cases through the use of reflectors that can direct the UV light to areas of parts that would otherwise be shadowed. By redirecting the light, UV curing can be possible on many parts with complex shapes. The UV curing of coatings on wooden chairs is a classic example of applying the technology to geometrically complex parts through the use of reflectors. However, parts with deep recesses, such as toolboxes and microwave ovens, are not good candidates since it would be impossible to get uniform curing of the coating due to shadows and the large deviation in the distance of the coated surfaces from the UV emitters.

Industry usage for the combined market segments of UV/EB curable products is tracked by the RadTech industry association (UV is estimated to represent 90% of this market). According to this group, total annual industry usage of formulated UV/EB curable products amounted to over 154 million pounds in 1999. The major markets are shown in Figure 3-1.



Source: Lawson Survey

Figure 3-1
UV/EB Volume Usage by Market Segment

Industry growth rates are projected at 10% annually. Individual market growth rates are shown in Table 3-2, and are projected at over 30% in some segments.

Table 3-2
Projected market growth rates for UV/EB coatings, inks and adhesives.

Market Segment	Growth Rate	Market Segment	Growth Rate
Ink Jet Printing	37%	Sprayable Coatings – 3D	12%
Medical Devices	30%	Wood Products- Fillers, Sealers	12%
Fiber Optics	25%	Metal Decorating	11%
Solid Modeling/Prototyping	25%	Release Coatings	10%
Adhesives	25%	Photo Resists	10%
UV Cured Powders	20%	Flooring Finishes	9%
UV Flexo Inks and Coatings	18%	Screen Inks	8%
Automotive Applications	16%	Paper/Paper Board Clear Coatings	8%
Plastic Coatings	15%	Off Set Inks	6%
Electronics	14%		

Source: Lawson Survey

SIC Codes for Identifying Potential UV Coating Applications

SIC codes can be a good source to help identify UV coating opportunities. Commercial coating shops can generally be found in SIC 3479 (metal coating and allied services). The identification of captive coating operations is somewhat more difficult. However, there are specific industries that can be expected to coat metal, wood, or plastic parts as an internal manufacturing operation or as an outsourced activity. Pertinent SIC codes are listed in Table 3-3 for identifying captive coatings operations with UV potential applications.

Table 3-3
Potential Markets for UV Applications.

End Use Applications	SIC Group	End Use Applications	SIC Group
Wood Finishing	243, 249	Packaging	267
Furniture	251, 252, 253, 254, 259	Printing	273, 274, 275, 276, 277
Printing Plates	279	Gaskets and Sealing Devices	305
Vinyl Flooring	308	Hardcoats on Plastics	308
Glass Products	323	Metal Decorating	341, 347
Transformers and Switchgear	361	Motors and Generators	362
Household Appliances	363	Compact Discs	365
Electronics	367	Automotive	371
Aircraft	372	Musical Instruments	393
Toys & Games	394, 399	Sporting Goods	394
Signs and Advertising	399		

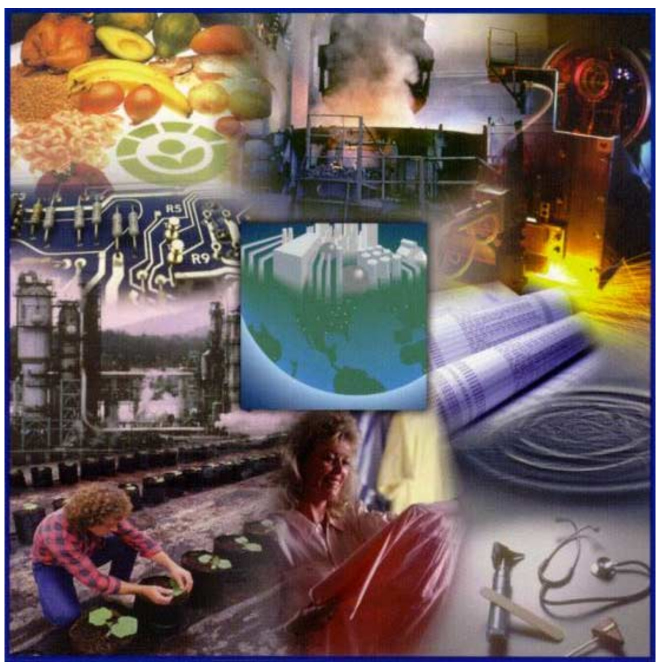
Application Opportunity Checklist

The checklist shown below is not a substitute for a detailed analysis. Those using this guide should use it as a preliminary screening tool for assessing what are often site-specific industrial applications. If three or more of the following conditions apply to a unique potential application, further investigation of UV curable coatings is warranted.

- Is there a requirement to increase production speed?
- Is there a requirement to increase production capacity?
- Is there a requirement to improve quality?
- What is the maximum temperature of processing, and what additional parameters affect this?
- Are there environmental considerations limiting the generation of VOCs or HAPs?
- What is the shape of the part? Oddly shaped or large parts are not good UV applications.

- Is the manufacturer willing to accept higher equipment costs and higher coating material costs to improve quality, improve the work environment, lower overall operating costs and lower environmental costs?
- Is floor space at a premium in this plant?
- Is the production line automated?
- Is the current or proposed process located in a heated or cooled space?

THE SALES PROCESS



This section outlines the coating sales process in broad terms, then provides a series of helpful questionnaires and checklists to assist the buyer and his or her advisors.

4
THE SALES PROCESS

Introduction

The acquisition of any finishing system is a complicated process that requires extensive information exchange between the buyer and the prospective vendor or vendors. This section outlines the process in broad terms, then provides a series of questionnaires and checklists that will be helpful to the buyer and the buyer's advisors.

Analysis and Selection

The two major steps to solve a coating problem are 1) an analysis of the coating requirements, and 2) the evaluation and final selection of the equipment to meet these requirements most effectively. In the case of a commercial coater, these requirements will vary depending on the type of parts to be coated. Though this can make the situation more complicated, the commercial coater can look at a range of required coating parameters for the more important segments of his business, and select the most appropriate equipment to meet this range of needs.

Due to the differences between commercial and captive coaters, this section is divided accordingly to illustrate the differences in approach between the two segments.

Commercial Coaters

The general characterization of a “commercial” coater is typically a small business which is owner operated and very independent. The owner likely grew up with the business and is comfortable making do with aging equipment. The prospect of considering new processing methods is often met with a strong defensive posture. Because the business is typically small, a full-time engineering or technical staff is not likely to exist, and the owner must rely on his instinct for what is viable and what is not. Any attempt at being prescriptive about how they run their business may be met with an invitation to leave.

On the other hand, they enjoy talking about their business and will willingly provide information about their business and the areas in which they perceive themselves to be particularly competent. It is at this point that questions about what they do and do not do may be asked. For instance, “Do you currently use radiation cured coatings?” or “Are you required to use lower temperature cure coatings to meet certain manufacturer's specifications?”, “Do you get many inquiries from your customers in these areas?” The answers to these questions will give some indication whether to pursue the issue further, or suggest leaving literature about the technology and follow-up at a later date.

You need to establish trust that you, either directly or indirectly, are a credible source of information about coating. The nature of the commercial coater's business may inhibit him from being a pioneer with new processes. If, however, he believes he has a partner in investigating the viability of a new process, he will be much more likely to proceed. You will not be successful by focusing on the disadvantages of conventional coating methods. Rather, you must be prepared to overcome potential objections by highlighting the advantages of UV curable coatings.

Commercial coaters can be a valuable source of information about the types of manufacturing occurring within that geographic region. Their customers are manufacturing components that require coating. It is quite likely that other manufacturers (same SIC's) producing the same type of parts also require coating. These other manufacturers may be large enough or have other reasons, for having their own in-house coating treat departments. This can become a method for locating "captive" coaters.

Captive Coaters

Quite unlike the typical commercial coater profiled above, the captive coater is one process or department of a much larger manufacturing process. Very likely, at one time in their history, these manufacturing companies utilized the services of a commercial coater and for some services, perhaps still do. Companies that operate their own "in-house" coating process tend to be much larger organizationally than the typical commercial coater and are therefore more likely to maintain an engineering or technical staff. It is necessary to identify the "key" members or decision-makers within these organizations. Attempts to sell to members of an organization who do not have the authority to make the decisions regarding the selection and purchase of equipment is often a dead-end sales exercise. It will typically take some time to learn the organization, but getting to the right people within the organization is crucial for successful sales results.

The greatest opportunity to sell UV curable coating equipment is likely to be the "captive" coating market. This is supported by several facts:

- First, there are a significantly greater number of captive coating operations than commercial.
- Second, the advantages of UV coating are more appropriately applied when the system can be designed to fit a particular part, as opposed to a tremendous variety of parts.
- Third, captive coating operations tend to be able to raise or justify the necessary capital equipment dollars if the overall product cost can be reduced.

This last issue also requires that the coating equipment be more closely matched or engineered to gain the greatest cost savings.

Timing is still one of the most critical elements of the sale. Even though capital equipment dollars may be more readily available (compared to a commercial shop), rarely will a company replace equipment that is not fully depreciated. Therefore, it is paramount that one be in the right place at the right time. It will typically be a situation where production capacity or quality issues are the initiators for investigations into other methods or technologies, to overcome the current production issues. Being able to supply technology options or solutions for the customer's production concerns will go a long way towards establishing credibility for being included in the planning phase for future equipment decisions.

General Sales Approach

This document assumes that the reader is fully trained in sales or marketing, so it is not the objective of this section to instruct in those disciplines. There are as many legitimate approaches to sales as there are competent sales people. Furthermore, most sales managers have strong views about what works best in their field. The purpose of the sales approach outlined below is not to instruct in sales *per se*. It is simply to have a structure for presenting sales-related information specific to electric process heating . If the outline is useful in other ways, that is a bonus. In any case, sales personnel should follow the guidance of their own management staff.

Background Study

In order to sell UV coatings systems, it is important that the sales person have a clear overview of this industry, such as traditional methods of coating and the advantages and disadvantages of utilizing UV coatings in place of more traditional methods. The material presented in this document should provide a head start in that direction.

Identifying Prospects

Sales prospects may be handed to you by your superior or by the marketing department. Otherwise, it will be necessary to identify prospects on your own. The previous section, *Identifying Opportunities*, outlined the industries that are most likely to use UV curable coatings. This information can serve as overall guidance on what to look for, leaving the question of where to look. Possible sources include trade associations, trade shows, trade directories, the internet, yellow pages, your corporate service personnel, and company client records. Current clients can also be an important source of referrals to new customers, and are frequently quite willing to provide such information.

Qualifying Leads

This is the process of estimating, for each prospective customer, the probability that you will be able to close a sale. That probability depends on the customer's need for new technology, their financial ability to purchase, where the authority for decision-making lies, and many other factors. The most likely prospects for sales of UV curable coatings systems are companies with the following attributes:

- A de facto high regard for quality

- An existing production bottleneck
- Lower temperature cure
- Anticipated tighter pollution control regulations
- Limited floor space
- Financial resources to purchase equipment
- Approach by a knowledgeable sales person

The absence of any one of these, except the latter, is not fatal, but their collective presence points toward a successful sale.

Collecting Information

The more one knows about the customer, the higher the chances for success. This aspect of sales is so important that a checklist for information gathering is presented at the end of this section. Prior to the first contact, one should have a clear overview of the company and its products. If possible, one should determine which products are manufactured at the site under consideration and should have reasonable cause to suspect that coating parts are required at that facility.

Initial Telephone Contact

The in-person "cold call" has a long tradition in American sales, but nowadays it is rarely a cost effective approach and is frowned upon by many customers. Except in cases where a salesperson was truly "in the vicinity on other business and decided to drop in for a moment" (a standard line), all sales calls should be preceded by telephone contact. Prior telephone contact is not only a standard courtesy, but also contributes significantly to sales efficiency. Before placing the call, it is important to define for yourself the specific purpose of the call. For example, one typically might want to: determine whether coating is a likely requirement for parts manufactured at this facility, identify the plant manager or production foreman, and secure an appointment for a visit. Outline in writing the information you wish to gather and points you wish to make before placing the call.

The Sales Call

Preparation

Nothing reveals sales professionalism more than careful preparation for a sales call. It increases efficiency, improves confidence, and increases the probability of success. Customers interpret preparation as a sign of respect for them and their time. In preparing for the call, it is crucial that the purpose of the call be very clear. The purpose may range from simply becoming acquainted, or gathering and leaving information, to closing a sale. In addition to the generic preparation necessary for all sales calls, the person who wishes to sell UV coating technology must do additional preparation. One should anticipate the kinds of technologies that may already be in use or may be needed at the site being visited, and review their salient points. A written list of questions should also be prepared, perhaps reviewing the checklist at the end of this section. Finally, one should review the advantages and disadvantages of each technology that might be under consideration by the customer, as well as frequently encountered objections and your best response.

The Agenda

A written agenda is an important tool often overlooked by sales personnel. An agenda can highlight the preparedness of the sales person, place the objectives in full view, significantly reduce time spent on extraneous topics, and help to keep the visit on schedule. Hidden agendas should not exist.

Information Gathering

Perhaps the biggest mistake made by beginning sales personnel is talking too much. During the initial sales call, the sales person should generally be asking questions, listening, and taking notes. On subsequent calls, prior to the sales presentation, one should continue the process of gathering information of the types outlined in the checklist. Selling before one has collected as much pertinent information as possible, significantly reduces the probability of success. At the minimum, one must determine the volume, composition, and shape of products that are to be coated; when in the production process coating is required; curing temperature; conveyer types and line speeds; and the primary reasons why the company is considering or might consider new equipment. At least this information should be clear before one contacts potential equipment suppliers.

The Sales Presentation

Elements of presentation style, such as diction, dress, organization, voice, sequence, and gestures will not be addressed here. However, it is crucial that following elements be present:

- The credibility and competence of the supply company must be established or reinforced
- The salesperson must demonstrate an understanding of the needs and desires of the manufacturer
- The customer must be told how the supplier’s technology will meet his/her company’s needs
- The customer must be told why the recommended technology is a better choice than competing technologies
- The salesperson must explain why her/his company’s product is a better choice than competing products
- The customer must be told of similar installations where the same technology is used successfully
- The customer must be told precisely what product is being offered, including intangibles
- A proposed delivery schedule must be presented
- The customer must be shown what the payback will be for the purchase

The Closing

In the process of selling UV finishing systems, the utility representative will rarely have the lead role in the closing. Since the sales transaction is most likely between the customer and the equipment supplier, the supplier's personnel will probably close the sale. Because the utility representative may be present at such an event, it is wise to understand the process. The following approach is typical of a successful closing, but may vary according to personal style. The successful closing always begins with careful planning. At the closing visit, a sales presentation is made (see paragraph above), and an offer is made. Objections are raised by the customer and dealt with quickly by the salesperson. One or more "trial closings" may be performed by the salesperson, with questions of the form, "Would you buy our product if…?" These are aimed at determining whether the customer is ready to buy. When the time is right, the salesperson asks explicitly and directly for the order and becomes resolutely silent. After the customer responds, some negotiation usually ensues, and the major aspects of the deal are agreed upon. In some cases, the salesperson declares the need for consultation with the office, and some steps are repeated. If a deal cannot be closed, the salesperson always leaves the door open for a future sale.

Follow-up After the Sale

Experienced sales and marketing personnel know that it is much easier to keep an existing customer than to acquire a new one. Many professional sales people routinely contact the customer soon after the sale and emphasize what a good decision they made. The larger the purchase, the more important the call. Since the decision has already been made, your credibility is higher and the reassurance is always welcome. That, however, is just the beginning. The sales person should introduce the customer to technical support staff, check periodically to ensure that problems are being handled promptly, serve as liaison to the equipment and materials suppliers as necessary, and generally not be perceived as walking away after the sale. A very high percentage of all equipment sales are to repeat customers and to new customers referred by existing customers. It is wise to preserve the relationship.

Information Gathering Checklist

Following is a checklist of information that one might gather through telephone contacts and visits to the customer site. In some cases, such information can be found through a search of the literature, especially trade press, or through database searching, e.g. on the Internet. It is not suggested that one attempt to memorize this list or even attempt to collect all the information outlined. It is recommended, however, that the sales person read the list carefully and contemplate how the information can be helpful and to whom. Doing so will heighten sensitivity to the need for information and predispose the sales person to collect it routinely. It should also be noted that the more of these questions you can answer, the more effective potential suppliers will be.

A publication that may prove to be a valuable tool for collecting information is the Electrotechnologies Application Questionnaire (EAQ) #TB-109095. When used in conjunction with the following list of questions, significant information about the company and its coating process may be gathered for use during the sales process. The questions below are listed by subject.

General knowledge about customer

- What parts do you coat at this facility?
- What types of coating equipment do you have?
- What are the major markets served by the company and by the products in question?
- Are there any areas that you would like to see improved that are causing the company to consider purchasing new equipment? (Increase production speed, reduce environmental emissions, lower operating costs, lower scrap rates, add capacity, reduce floor space, reduce noise levels, improve air quality, automate equipment?)

UV curable coatings can increase production speed and reduce floor space

- What is the current capacity of the specific production line and of the whole plant?
  - How many parts of each type are produced and coated each year?
  - What are the line speeds of the production lines in question?
  - How many days and how many shifts do the production lines operate?
- Does the company have plans to expand production capacity at the present site? (UV coatings can increase the line speed and therefore can increase the production capacity).
- Where are the current production bottlenecks?
  - Can you eliminate any processing steps by combining them?
  - Do you see other ways to automate existing processes?
- What is the level of automation in the plant?
  - What is the attitude of the company toward automation?
- Are off-site coating services causing production interruptions or delays?
- What are the shapes and dimensions of the parts? (UV coating is a line of sight technology which may require the use of reflectors to coat more intricate shapes)
- What are the volume requirements for each part?
- What is the cost of floor space in the plant under consideration?

UV coatings can increase the level of quality

- What kinds of coatings are used for each part?
- How important is the beauty of the finish?
- Are there any problems with the current production lines?
- Are there problems applying the coatings?
- Are there problems curing the coatings?
- Are there surface preparation problems?
- What is the current scrap rate?
- What is the typical and desired film thickness of coatings applied?
- Are process variations a consistent cause for quality related rejections?
- Are off-site coating services causing quality related rejections?

UV coatings can reduce environmental emissions

- Do you or the company anticipate any regulatory changes, especially environmental?
- What solvents are used in current coatings lines?
- Does the company have or expect any regulatory compliance problems?
    - Has EPA designated this plant's location a non-attainment zone?
    - Has the company had any environmental issues with the community?
    - Are coatings overspray costs an increasing problem?
- Is the company looking to improve air quality in the plant or reduce outdoor emissions?

UV coatings can increase energy efficiency

- At what capacity does the current coating line run?
    - Do the gas convection curing lines idle for any length of time?
    - What is the ramp up and ramp down time?
    - How often do you typically need to ramp up a curing oven?
- How frequently do they or will they change parts on the production line under consideration?
- Are the time/temperature requirements changed often?
- Can you eliminate any processing steps, e.g. by combining them?
- What are the annual energy costs for the company and for the processes under study?
- What are the current total energy costs and the energy cost per part?
- What types of energy sources are currently available at plant and what is their capacity?

UV coatings can reduce costs by improving the level of worker comfort and safety

- How does the company handle worker safety or comfort issues?
- Are workman compensation premiums high?
- Does the insurance carrier at this facility require that maintenance or security personnel be on the premises during idle production (off-shift, weekends and holidays) when gas-fired curing systems are in operation?
- Would business interruption/continuation insurance premiums be reduced if gas-fired curing equipment were replaced?
- Is plant appearance/clean lines a major concern at this facility?
- Is the noise level an issue of concern at the plant?
- Is the production area air conditioned? Heated?
- Is there a high turnover of production personnel?
    - What is the skill level of the current operators?
    - Are skilled equipment maintenance personnel approaching retirement?

Capital Investment Issues

- Does the company have plans to buy new equipment?
- Does the company already have specifications for a new or modified line?
- How does the company make capital purchases?
    - What does the company consider the standard payback period for capital equipment?
    - Do you evaluate purchases primarily on first cost?
    - Do you also look at operating costs including energy costs, environmental costs, labor costs, scrap rates, throughput, etc.?

- Does the company have capital set aside to buy new equipment?
- Does the plant operate fairly autonomously, or is there strong control from outside?
    - Are there other similar plants in the company?
    - Does the company have plans to build new plants?
- How much influence will your contacts have in the final purchase decision?
    - Who approves capital expenditures?
- Do you need to add capacity?
    - What is the current load on existing equipment (percent of maximum capacity)?
    - What is the age of current equipment?
    - Do you have a time frame for adding equipment?

Other General Questions

- What are the major markets served by the company and by the products in question?
    - Who competes with your customer and what are their strengths?
    - What are the current trends in sales for the products in question?
- What are the projected capacity needs for the next five years?
- What are the competitive pressures? (cost, quality, product changes, foreign competition?)
- Does the customer have any prejudices regarding various forms of energy?
- Does the company have prejudices for or against any particular type of curing technology?
- How familiar are key individuals with UV curing technology?
- Are the parts to be coated metallic? Plastic? Wood?
- Are changes of any kind anticipated in the client company and how might they be relevant?
- What has been your company's previous experience with this customer?
- Is the shop union or non-union?
- What is the company's general attitude toward change?
- What is the urgency for change?

Handling Objections

In the paragraphs that follow, we look at some of the objections encountered in selling UV coatings equipment. Each sales person will develop her or his own techniques for dealing with such objections. The suggestions offered here are only examples of possible ways to handle such objections.

"The Cost of UV Powder is Too Expensive"

This is the most common objection to installing a UV curable coatings system. During the initial introduction of UV powders, this cost factor has pushed the applications to markets where the premium cost can be most easily justified. But UV powders have been applied for the last 15 years, and the market continues to grow 10% annually. This high growth has continued because the cost of UV powder has become a secondary issue for the more progressive manufacturers. Those manufacturers who apply UV coatings are generally those who are able to recognize the full cost (including quality, environmental, line speed, and other production issues) of their coated products over their entire life cycle.

- What is the value of improved quality?
- What is the value of a higher line speed? Of a higher production rate?
- What is the value of lower emissions? Reduced product scrap? Less coatings waste?
- What is the value of improved energy efficiency?

The greater the ability of the coater to analyze these cost issues, the higher the potential to make a UV system sale, given that the application falls within the targeted market segments spelled out in section 3 of this report, *Identifying Opportunities*.

“The Equipment is Too Expensive”

There is a frequently encountered misconception in the community that the initial purchase cost of UV curing equipment is higher than that of gas-fired equipment. This is usually not the case. The best tactic may be to avoid second guessing and assertions contradicting the misconception and focus instead on trying to gain approval to do some true cost assessments.

“Electricity is Too Expensive”

In most cases, UV coating installations are so much more efficient than their gas counterparts, that the expense for the amount of electricity needed is less than the expense for the amount of gas needed. It is not uncommon to see overall energy efficiency improvements of 60 to 90%. In addition, any rational cost analysis must take into account factors other than the cost of energy. The cost of operating the electrical equipment usually can be shown to be significantly lower than comparable gas equipment. And finally, even if the cost of operating the electrical equipment was higher, it still should not be an issue if other advantages are gained. The important issue with competing technologies is the total cost per part, not the energy cost per part. A useful tool for demonstrating “process” costs versus ‘energy” costs is the **Flexo Ink Cost Comparison Worksheet** (SW-114866). This is a user friendly software program that generates a side-by-side annual operating cost for energy cost and process cost comparisons between various methods to cure ink for printing applications. This same methodology can be expanded to include other UV curable coatings.

"Electric Power is Not Available"

Sometimes a potential customer may shy away from an electrotechnology heating due to the belief that there is insufficient power supply to the plant. One first should determine by serious calculations whether that is in fact the case. If it is not, the problem disappears. If it is true, the next step is to determine whether the potential business is worth offering price concessions or other financial support to install additional supply, e.g. a new or upgraded sub-station. In general, handling such objections should be well within the skill set of the utility sales person.

Line of Sight Issues

The line of sight issue is often overplayed by those whose products attempt to compete with UV. If the shadowed surface is not too large and is adjacent to an irradiated surface, the alleged problem simply does not exist. Heat is conducted from irradiated surface to shadowed surface and curing occurs without a problem. In most other cases, the problem can be solved by intelligent placement of reflectors or by rotating the workpiece. In addition, there is always some convective air movement, even in UV systems, and that convection may be sufficient to cure surfaces that cannot see the emitters or reflectors.

"I Am Really Not Interested"

This often means, "Right now I am busy and under so much pressure that I barely have time to be polite." If you sense that this is the case, the best course is the concourse, i.e., leave quickly and try to reschedule later. Other times, the meaning is literal, i.e., the person truly is not interested. Also in this case, they expect you to accept their message and leave. However, if the mood is friendly and un-rushed, it may be worthwhile to invest a bit more time. An approach that often works is to try and determine precisely what they are not interested in and why. Once that is known, other issues and techniques reign.

In questioning clients, note that they are seldom warmed by questions such as "Are you not interested in saving money?", or "Is your lack of interest based on knowledge or ignorance?". These examples may be too obvious, but the point is to pose delicate questions in such situations, not brutal, cutesy, or cynical ones, even if they are directly to the point (such as the second example above).

Technology Angst

Many coaters who have used gas convection curing ovens for many years feel they understand them, can predict how they will behave, and are generally very comfortable with them. They feel very anxious about purchasing and operating a new piece of equipment utilizing a technology that they do not fully understand. Convincing them to buy a UV coating system can be difficult. These people need to be handled slowly and treated gently, but they will become more comfortable once they realize the prevalence of UV systems. Address their concerns about quality, reliability, and safety by using successful case histories as examples.

“Requires Skilled Operators”

The learning curve for using UV systems is relatively short. Typically, a manufacturer of a UV system will price in the equipment installion or offer technical assistance for a fee. In either case, assistance is available to run initial quantities of parts to establish surface preparation and coating techniques, followed by time/temperature curing cycles. After experience is gained, the coating operation would try other customer’s parts of similar size and configuration. The next step would be to modify the process parameters to handle different part configurations and to begin to understand the range of capabilities of the UV curing equipment.

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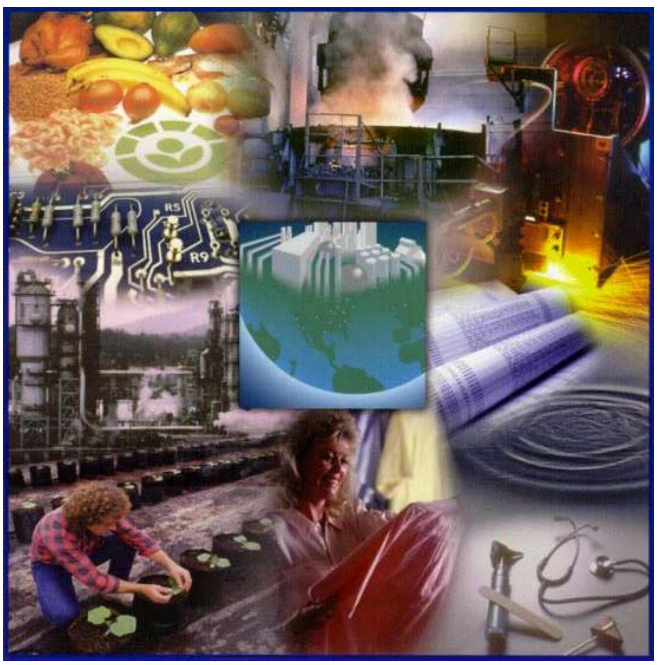


This section contains a bibliography of books and periodicals on coatings, and a listing of industry associations whose members are involved in UV coating, plus other organizations providing pertinent information. Web addresses are included as a part of each entry.

5
REFERENCES

1. *Industrial Paint and Powder*, Monthly Publication, Cahner Publications, 2000 Clearwater Drive, Oak Brook, IL 60523 Phone: 630-320-7000 Fax: 630-320-7373 www.ippmagazine.com

2. *Powder Coating*, Monthly Publication, 1300 E 66th St., Minneapolis, MN 55423 Phone: 612-866-2242 Fax: 612-866-1939 www.pcoating.com

3. *Finishers' Management*, Monthly Publication, 4350 DiPaolo Center, Glenview, IL 60025 Phone: 847-699-1700 Fax: 847-699-1703 www.finishers-management.com

4. *PCI Paint and Coatings Industry*, Monthly Publication, Business News Publishing, 755 Big Beaver Rd. Troy, MI 48084 Phone: 810-362-3700 Fax: 810-362-0317 www.pcimag.com

5. *RadTech Report*, Monthly Publication, RadTech International , 3 Bethesda Metro Center, Suite 700, Bethesda, MD 20814 Phone: 301-664-8408 Fax: 301-657-9776 www.radtech.org

6. *Metal Finishing Industry Market Survey*, Surface Finishing Industry Council, 112-J Elden St. Herndon, VA 20170 Phone: 703-709-1035 Fax: 703-709-1036

7. *Products Finishing*, Monthly Publication, Gardner Publications, 6915 Valley Ave, Cincinnati, OH 45244 Phone: 513-527-8800 Fax: 513-527-8801 www.pfonline.com

8. *Modern Paint and Coatings*, Monthly Publication, PTN Publishing, 445 Broad Hollow Rd, Melville, NY 11747 Phone: 516-845-2700 Fax: 516-845-7109

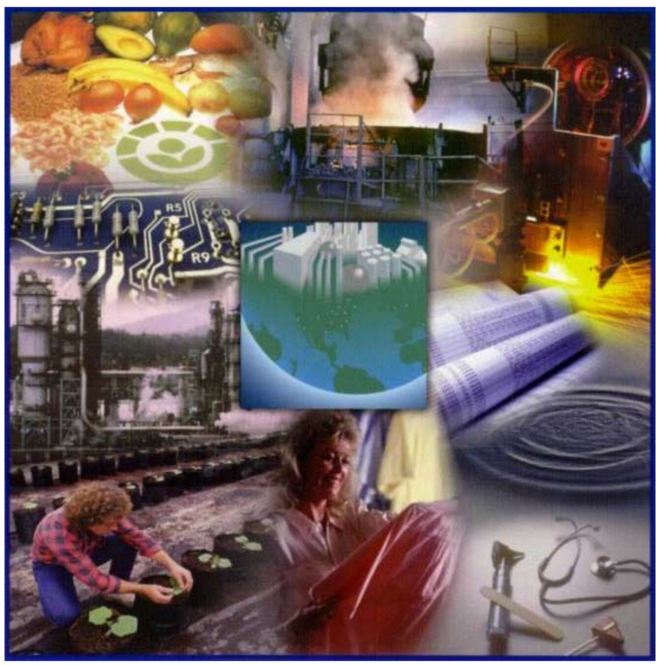
9. *Automotive Finishing*, Quarterly Publication, Gardner Publications, 6915 Valley Ave, Cincinnati, OH 45244 Phone: 513-527-8800 Fax: 513-527-8801 www.afonline.com

The following are EPRI CMF publications:

- *Flexo Ink Cost Comparison Worksheet*, Software, EPRI Center for Materials Fabrication, 1999, SW-114866
- *Ultraviolet Curing Technology*, TechCommentary, EPRI Center for Materials Fabrication, Vol. 4, No. 4, 1994
- *Electricity Use in the Printing Process*, TechCommentary, EPRI Center for Materials Fabrication, Vol. 11, No. 1, 1995
- *UV Curable Coatings for Wood Meet Manufacturer's Challenges*, TechApplication, EPRI Center for Materials Fabrication, 1999, TA-112685

- *UV Curing of Coatings on Metals,* TechApplication, EPRI Center for Materials Fabrication, 1999, Vol. 1, No. 16, 1991
- *UV Curing in the Label Industry,* TechApplication, EPRI Center for Materials Fabrication, 1999, Vol. 1, No. 17, 1987
- *Infrared Heating, Drying and Curing*, TechCommentary, EPRI Center for Materials Fabrication, Vol. 8, No. 1, 1992
- *Electricity in Plastics Processing*, Tech Commentary, EPRI Center for Materials Fabrication, Vol. 10, No. 1, 1994

VENDOR LIST



This section provides contact information for companies involved in the design and manufacture of products related to UV curing systems. Since most of these products are custom designed for the application where they will be used, bringing one into operation usually involves the engineering of the entire project, and the incorporation of the coating system into the customer's manufacturing process.

6
VENDOR LIST

AAA Press International Inc., 3160 N. Kennicott Avenue, Arlington Heights, IL 60004, PH: (847) 818-1100, Fax (847) 818-0071, Toll Free: (800) 678-7222, www.aaapress.com

Amba Lamps North America Inc., 5105 Tollview Drive #113, Rolling Meadows, IL 60008, PH: (847) 670-1414, Fax (847) 670-1456, www.ambalamps.co.uk

American Ultraviolet Co., 212 S. Mt. Zion Road, Lebanon, IN 46052, PH: (765) 483-9514, Fax (765) 483-9525, www.americanultraviolet.com

Amjo Ir/Uv Curing Systems, Route 1, Box 195, Marshall, MO 65340, PH: (816) 886-7408, Fax (816) 886-4329

Apex Machine Co./Capex, 3034 NE 12 Terrace, Ft. Lauderdale, FL 33334, PH: (954) 566-1595, Fax (954) 563-3386

Atlantic Ultraviolet Company, 375 Marcus Boulevard , Hauppauge, NY 11788, PH: (631) 273-0500, Fax (631) 273-0771, www.atlanticuv.com

BASF Corp., Coatings Raw Materials Division, 11501 Steele Creek Road, Charlotte, NC 28273, PH: (704) 587-7933, FAX: (704) 587-8224, www.basf.com

Delle Vedove USA Inc., 6031 Harris Tech. Boulevard, Charlotte, NC 28269, PH: (704) 598-0020, FAX: (704) 598-3950, www.dellevedove.com

Dymax Corp., 51 Greenwoods Road, Torrington CT 06790, PH: (860) 482-1010, Fax (860) 496-0608, www.dymax.com

Ferro Corporation, 1000 Lakeside Avenue, Cleveland, Ohio 44114-7000, PH: (216) 641-8580, Fax (216) 875-7233, www.ferro.com

Flint Ink Corp., 4600 Arrowhead Drive , Ann Arbor MI 48107, PH: (734) 622-6516, Fax (734) 622-6105 , www.flintink.com

Fusion UV Curing Systems , 910 Clopper Road, Gaithersburg, MD 20878-1357, PH: (301) 527-2660, Fax (301) 527-2661, www.fusionuv.com

H.B. Fuller Co., 3450 LaBore Road, Street Paul, MN 55110, PH: (651) 236-5622, FAX: (651) 236-5650, www.hbfuller.com

Honle UV America Inc., 201 Boston Post Road West, #405, Marlboro, MA 01752-1855, PH: (508) 229-7774, Fax (508) 229-8530, www.honleuv.com

INX International Ink Co., 3274 Autumn Woods Trail, Marietta, GA 30064, PH: (770) 428-2555, FAX: (770) 429-0962, www.inxink.com

Kohl & Madden Printing Ink Corporation, 222 Bridge Plaza South, Fort Lee, NJ 07024, PH: (201) 886-1203, FAX: (201) 886-8405, Toll Free: (800) 793-0022, www.kohlmadden.com

Kolorcure Corporation, 1180 Lyon Road, Batavia, IL 60510, PH: (630) 879-9050, FAX: (630) 879-9449, www.kolorcure.com

Laurence-David Inc., 1400 S. Bertelsen Road, Eugene, OR 97402, PH: (541) 484-1212, FAX: (541) 342-5974, Toll Free: 1-800-452-2645, Web site: www.ldavid.com

Lilly Industries, Inc. , 521 W. McCarty Street, Indianapolis IN 46225, PH: (317) 687-6729, Fax (317) 687-6736, www.lillyindustries.com

Monarch Color Corp., 5327 Brookshire Boulevard, Charlotte, NC 28216, PH: (704) 394-4626, FAX: (704) 394-4042

Morton International Inc., 100 N. Riverside Plaza, Chicago, IL 60606, PH: (312) 807-3421, FAX: (312) 807-3328, Toll Free: 1-800-251-5952, Web site: www.morton.com

Nor-Cote International Inc., 506 Lafayette Avenue, Crawfordsville IN 47933 , PH: (765)362-9180, Fax (765)364-5408, , Toll Free: (800) 488-9180, www.norcote.com

Nordson, 300 Nordson Drive, Amherst, OH 44001, PH: (440) –985-4000, Fax (888) 229-4580, Toll Free: (800) 433-9319, www.nordson.com

Northwest Coatings Corp., 7221 S. 10th Street, Oak Creek, WI 53154, PH: (414) 762-3330, FAX: (414) 762-9132, www.northwestcoatings.com

Nutro Corporation, 11515 Alameda Drive, Strongsville, OH 44136-3099, PH: (440) 572-3800, Fax (440) 572-5584, www.nutro.com

PPG Industries Inc., P.O. Box 1009, Allison Park PA, 15101, PH: (412)492-5234, FAX: (412)492-5221, http://www.ppg.com

Progressive Ink Company LLC, 4150 Carr Lane Court, St. Louis, MO 63119, PH: (314) 645-3333, FAX: (314) 768-5540, Toll Free: 1-800-325-9088, Web site: www.progressiveink.com

R&D Coatings Inc., P.O. Box 325, Wexford PA 15090, PH: (412) 771-8110, FAX: (412) 771-9001, www.rdcoatings.com

Sartomer, 502 Thomas Jones Way, Exton, PA 19341, PH: (610) 363-4100, FAX: (610) 363-4174, www.sartomer.com

Sherwin-Williams Co. , 101 Prospect Avenue NW, Cleveland OH 44115, PH: (216) 566-1899, Fax (216) 566-2775, www.sherwin-williams.com

Sony Chemicals Corp., 1001 Technology Drive, Mt. Pleasant, PA 15666, PH: (724) 696-7500, FAX: (724) 696-7555, www.sonychemicals.com

Sunrez Corporation, 392 Coogan Way, El Cajon, CA 92020, PH: (619) 442-3353, FAX: (619) 442-3036, www.sunrez.com

UCB Chemicals Corp., 2000 Lake Park Drive, Smyrna GA, 30080, PH: (770)437-5609, FAX: (770)319-8228, www.ucb-group.com

Ultraviolet Systems & Equipment, Inc., 9135 Spring Branch Drive, Suite 202, Houston, TX 77080-7437, PH: (713) 461-7766, FAX: (713) 461-7260, Toll Free: (800) 962-4480, www.ultravioletsystems.com

UV Coatings Ltd., 140 Sheldon Road, Berea, OH 44017, PH: (440) 234-8444, FAX: (440) 234-8464, Web site: www.zvoc.com

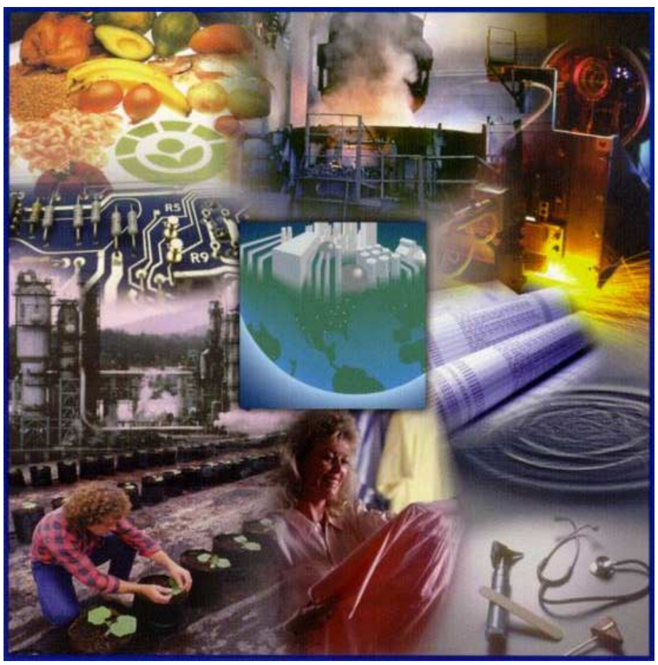
UVEXS Inc., 1260 Birchwood Drive, Sunnyvale, CA 94089, PH: (408) 737-7100, FAX: (408) 737-7199, Toll Free: 1-800-852-2911, Web site: www.uvexs.com

UVTechnology, Inc., 7188 Main Street, Cincinnati, OH 45244-3012, PH: (513) 271-2777, FAX: (513)271-1191, Toll Free (800) 266-2166, Web site: www.uvt.com

Valspar Corp. , 1501 Reedsdale Street, Suite 400, Pittsburgh PA, 15233, PH: (412)231-6100, Fax (412)231-6446, http://www.valspar.com

Wikoff Color Corp. , 1886 Merritt Road, Ft. Mill SC, 29715, PH: (803)543-2210, Fax (803) 548-5728, http://www.wikoff.com

APPENDIX



This section provides a glossary of terms relevant to the coatings industry.

A
APPENDIX

Glossary of Terms Related to Coatings

Additives - chemical modifiers mixed with a resin to improve the properties of the polymer. Additives include pigments and dyes, solvents, plasticizers, flame retardants, preservatives, foaming agents, stabilizers, lubricants and curing agents.

Aerosol - a liquid or solid dispersed in a gas, e.g. shaving cream.

Conduction - the transfer of heat through a stationary medium, which can be a solid or a fluid, due to a temperature difference within the medium. When heat is transferred by conduction, high-energy molecules collide with lower energy molecules within the same object and transfer some of their energy. Those energized (now warmer) molecules then collide with others in a chain reaction that transfers warmth (molecular kinetic energy) throughout the object. So conduction is the transfer of heat from a warmer area to a cooler area within an object.

Convection - a special case of conduction. Convection is the transfer of heat between a surface and a moving fluid, when they are at different temperatures. The fluid can be a gas, a liquid or a solid. High-energy molecules on the surface of an object collide with molecules of a fluid medium and transfer some of their energy to the fluid. The energized (warmer) molecules in the fluid move to another place, where they collide with the molecules of a different (cooler) object, transferring some of their newly acquired energy to that object. In conduction, thermal energy is transferred through a medium; in convection, the medium itself moves and carries the thermal energy with it. Convection can be **natural**, as when the warm air in a room rises to the ceiling, or when cold water from the top of a lake sinks to the bottom and is replaced at the top by warmer water from the bottom. Convection can also be **forced,** as when warm or cool air is transferred from one place to another by a fan.

Dispersion - particles (solid, liquid or gaseous) suspended in a liquid, solid or gaseous medium, e.g. fog or smog. Also defined as the separation of visible light into its different colors by refraction or diffraction, i.e., the “rainbow effect”.

Diffraction - the phenomenon by which a wave spreads out after passing through a gap in an opaque barrier, or seems to go around an opaque object (the gap or the object must be similar in size to the wavelength). Diffraction is why we can hear around corners. Very long waves, e.g. some radio waves, can go around large buildings and over hills, which is why a radio can receive a signal even if it is not in line of sight from the source. Radar, on the other hand, has a shorter wavelength and cannot go around buildings or over hills. It must have a direct line of sight.

Because of diffraction, we cannot see objects through a light microscope if the object is smaller than the wavelengths of visible light. Light just goes around them. This has led to the invention of the electron microscope, with ultra-high frequency electron waves.

Elastomers - rubber-like polymers that are cross-linked like thermosetting polymers, but have elastic properties. At room temperature, they can be stretched to twice their original length and return to their original size without damage to the polymer. Elastomers can be applied as very thick coatings and often may retain their cohesion even if flexed, vibrated, struck or otherwise abused. Neoprene is a common example.

Emission - The production of electromagnetic radiation (photons) by matter. In every case, photons are produced by an accelerating charge. The charge may be circling the nucleus of an atom as an electron, it may be the positive charge of a proton, it may be free electrons oscillating back and forth in the antenna of a radio transmitter, or innumerable other situations.

Emulsion - a liquid dispersed in another liquid, e.g. milk or mayonnaise.

Fluorescence - Fluorescence is the absorption of photons by matter and the immediate release of photons of a longer wavelength. Fluorescence ceases when its source of stimulating radiation is no longer available.

Fillers - tiny particles of various shapes and compositions added to a plastic or paint to modify its properties or to lower costs by replacing more expensive components.

Fluid - a material that flows. It can be a gas, a liquid or a solid. Gases flow readily. Liquid flow is dependent on viscosity. For instance, glass is a liquid, but because its viscosity is too high to permit perceptible flow it is not a fluid. Conversely, solid particles of powdered polymers do flow freely in a fluidized bed and in that form are considered a fluid.

Foam - a liquid dispersed in a gas, e.g. fire extinguisher foam.

Gel - a liquid dispersed in a solid, e.g. Jello®, jellies, aspic, and napalm.

Incandescence - The emission of photons by a material as a result of its thermal energy.

Industrial coatings - typically some form of a dispersion or colloidal mixture. Such a mixture is made up of substance in one phase (gas, liquid, or solid) suspended in another phase.

Infrared Radiation (IR) - IR is light that is emitted or absorbed as a result of changes in the translational energy of free electrons, the amplitude of vibration between the nuclei of a molecule or crystal lattice, or the rotation of a molecule. Since these are the same motions associated with thermal energy, IR is often called thermal radiation.

Inorganic coatings - such as porcelain enamel, ceramic glazes, and plating or anodizing materials, consist of various metals and/or minerals. Organic coatings (liquid paints and powder coatings) contain resins, pigments, fillers, and a number of other additives.

Interference - A phenomenon that occurs when two wave systems encounter each other. The effects of interference are that the waves totally or partially reinforce or neutralize each other. If their peaks coincide, they may reinforce each other (constructive interference). If the peak of one coincides with the trough of the other, they may neutralize each other (destructive interference).

Irridescence - occurs when light strikes a film or sheet with two surfaces, e.g. plastic or glass. Some photons are reflected from the first surface and some from the second surface. A photon not reflected by the first surface but reflected off the second surface will exit through the plane of the first surface. However, the relationship between the film thickness and the frequency of the photon can lead to cancellation of another photon of the same frequency. Thus, for a given film thickness, the reflection of light is reduced at certain specific frequencies. If the thickness of a film is not uniform, and it is irradiated by white light, some portions of the film may cancel out all the blue light, others may cancel red light, and others may cancel violet or indigo. The phenomenon can play tricks on our eyes such as causing soap bubbles and oil slicks to reflect white light as all colors of the rainbow. Grooved materials such as compact discs also display this phenomenon.

Luminescence - The emission of ultraviolet, visible or infrared photons by excited materials due to relaxation to a lower energy level of a free electron or orbital electron and molecular vibrations or rotations or lattice vibrations. Luminescence is distinguished from incandescence in that luminescence is not the result of thermal energy in a body.

Phosphorescence - Phosphorescence is the absorption of photons by matter and the delayed release of photons of the same or longer wavelength. Phosphorescent paints energized by light will glow for some time after their original light source has been removed, i.e.; they “glow in the dark”.

Photoluminescence - Photoluminescence is the emission of photons by a material that was excited through absorption of a photon. Fluorescence is a common example.

Photons - tiny packets, or “quanta”, of energy that have the properties of particles and of waves. The higher the energy of a photon, the shorter the wavelength, and the higher the frequency of its wave properties. The lower the energy a photon has the longer the wavelength, and the lower the frequency of its wave properties.

Plastic - an adjective that means “moldable like clay and a noun that refers to modern day plastic materials. Plastics are organic compounds, or polymers that can be used for a variety of purposes and can be molded into various permanent shapes. There are both thermoplastic and thermosetting polymers. The terms plastic and resin are commonly used in overlapping senses. However, resin applies more specifically to the chemically homogenous polymers that are used as starting materials in the production of paints and plastics.

Plasticizers - chemicals added to a polymer to make it more plastic (less rigid). Plasticizers can be described as internal lubricants that allow the long polymer molecules to slip and slide past each other, permitting the plastic to be more flexible.

Polymerization - the chemical process of linking short molecules (monomers) together in chains that grow longer and longer as polymerization continues. Some examples of monomers are ethylene, vinyl acetate and styrene. Short chains of such molecules are called oligomers and the long chains are called polymers or plastics. A single polymer chain can be as long as one meter. When the monomers are chained into polymers, they are called polyethylene, polyvinyl acetate and polystyrene, respectively. In some polymers the chains are linear, but in many they are branched and inter-linked in various ways.

Radiation - energy emitted or transmitted in the form of waves. Although the term radiation can include acoustic and particle radiation, only electromagnetic radiation is of interest with regard to curing coatings.

Reflectance - the percentage of incident light that is returned from a specific medium. Reflectance depends on the composition of the medium, its surface characteristics, on the wavelength of the light, the angle of incidence, and the angle at which the returned light is measured.

Reflection - a process by which photons from outside a medium cross its outer boundary into the medium, are absorbed by atoms in the medium and photons of the same energy level (wavelength/frequency) are emitted by the medium across the same boundary as the photons that entered.

Refraction - The change of direction when light (electromagnetic radiation) passes from a vacuum into a medium, or from one medium to another of different density, as a result of a change in velocity (speed). Its oscillation frequency does not change, but its speed does and direction may. If the light ray is exactly perpendicular to the surface of the medium it encounters, the direction doesn’t change, but if it strikes the surface at any other angle, the direction is changed. The change is speed depends on the density (or their permittivity or permeability) of the two media and the wavelength of the light. The denser the medium and shorter the wavelength of the light, the more the light speed will be slowed. The more the light is slowed, the greater its refraction. The index of refraction of a medium is the ratio of the speed of light in that medium to the speed of light in a vacuum.

Reinforcements - fibers, particles, or lamina (ribbons or sheets) used as ingredients in plastic to form composites that improve the physical properties of the material, e.g. tensile strength, stiffness, impact strength, etc. Fiberglass is a well-known plastic reinforcement used to repair auto bodies, and graphite fibers often are used to strengthen the plastics in sports gear.

Re-radiation - The emission of radiation following absorption.

Resin – Sometimes referred to as binders, resins are typically a clear to yellow or brown material used as varnish, adhesive, ink and sealant. Natural resins are tough, gooey, solid or semi-solid secretions of plants and animals, such as tree gums, rosin, shellac, and amber. In addition to these natural resins, there are also a wide variety of synthetic resins, or polymers, that are used in industry today for manufacturing all types of products, including paints. Resins are classified as thermoplastic when they soften with heat or thermosetting when they harden with heat. Whether natural or synthetic, resins are one of the basic ingredients in organic coatings.

Sol or Suspension - small solid particles dispersed in a liquid, e.g. ink.

Solid foam - a solid dispersed in a gas, e.g. Styrofoam®.

Solid sol - a solid dispersed in a solid, e.g. some alloys of metal or plastic.

Thermoluminescence - Thermoluminescence is probably a misnomer. It is not the emission of photons by matter excited by thermal energy. Perhaps a more accurate description is that thermoluminescence is phosphorescence that occurs earlier that normal due to the addition of thermal energy.

Thermoplastic Materials- Thermoplastic resins are formed in a dissolved or molten state and become solid when polymerized and cooled. Unlike thermosetting materials, they are not highly cross-linked and can be made soft and pliable again when heated. Upon cooling, they regain their solid properties. Candles are an example of a thermoplastic material. When a candle is lit, the heat from the burning wick softens and melts the wax. The melted wax can then be recovered and formed into a new candle. Thermoplastic coatings include polyethylene, polystyrene, acetates, polyamides, and vinyl.

Thermosetting Materials - Thermosetting plastics are polymers that become solid by chemical reaction during curing, and then do not soften or change their shape when reheated. When fully cured, the polymer forms long chains to become a single, highly cross-linked molecule that may be reminiscent of an interwoven three-dimensional spider web. When fully cured, or cross-linked, they set in a particular shape and cannot be made pliable again by re-heating. Eggs are examples of a thermosetting material. When the raw materials are heated to their “curing” temperature, large complex molecules begin to form (proteins, in the case of eggs) and the material then retains its shape upon cooling. Re-heating eggs or thermoset plastics will not cause them to re-melt or become pliable again. Thermoset coatings include epoxies, phenolics, acrylics, polyesters and polyurethanes.

Ultraviolet (UV) Light - UV light has more energy than visible light and cannot be seen by the human eye (some bees can see ultraviolet light, which helps them find delectable flowers). Because of its high energy, ultraviolet light can be dangerous to humans and other living things. It can knock valence (outer) electrons from their orbits, (which is why UV light is called ionizing radiation) and significantly change the chemical nature of the material it irradiates. For example, UV at the right frequency can kill the fungus in your bowling shoes or bacteria in cooling water systems. Similarly, because of its ionizing potential, over-exposure to UV from any source, including the sun, can cause serious skin problems.

Visible Light - Visible light comes in many energy levels, but over a very narrow range of the electromagnetic spectrum. We arbitrarily group the wavelengths of visible light into bands, which we call, colors: red, orange, yellow, green, blue, indigo, and violet. The portion of the spectrum that humans can see is only a small portion that lies between (and overlaps) UV light and IR.

Target:
Materials Fabrication Industry

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