SAFETY AND HANDLING OF UV/EB CURING MATERIALS

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Introduction

Ultraviolet (UV) and electron beam (EB) curing has been recognized as a commercially successful low to zero VOC coating and adhesives technology for over 25 years. However, many misconceptions still exist concerning the safety of the materials and equipment used in UV/EB curing. Such misconceptions have overshadowed the fact that UV/EB materials are, in general, less hazardous and easier to control than most solvents. In some cases, a misunderstanding of safety issues has blocked adoption of this powerful compliance technology.

This paper discusses the physical hazards of UV/EB technology, provides data on raw material toxicity, and describes the engineering controls and industrial hygiene practices which have been developed to assure workplace safety. The practical evaluation of workplace hazards and safe handling practices will enable potential end users of UV/EB technology to make a rational decision when chosing options for compliance.

Historical Perspective

When UV/EB technology first was introduced as a commercial technology, there still was little understanding of the toxicology of acrylate monomers. In these early days, many hydroxy functional molecules were acrylated in an effort to identify UV curing materials with valuable performance features. Unfortunately, a few of these newly developed acrylates were severely irritating.

The commercial offering of these poorly understood substances, combined with the poor industrial hygiene practices associated with handling of conventional coatings and inks, as well as worker and end user inexperience with UV/EB materials, inevitably led to incidents of severe worker reactions to some of the formulated UV/EB curing products.

Carcinogenicity concerns raised by toxicity testing of acrylates in the early 1980's[1] further raised questions about the safety of working with acrylates.

This prior history has led to negative generalizations and misconceptions about UV/EB safety, in spite of the later development of less irritating materials and publication of more favorable toxicity test results.

Physical Hazards Of UV/EB Technology

Non-Ionizing (Ultraviolet) Radiation

The biological effects of ultraviolet radiation result mostly from exposure to wavelengths below 325 nm and resemble the typical symptoms of sunburn:

Skin: erythema (redness), dryness, wrinkling, darkening
Eyes: inflammation, pain, photophobia, tearing, temporary blindness, cataracts

These hazards are easily minimized by simple engineering, administrative and hygiene controls. Curing equipment is provided with shielding to minimize escape of UV light into the workplace. ACGIH and NIOSH have established exposure limits for UV light:

Near UV (315 - 400 nm) 1 milliwatt/cm^2 for exposures > 16 min
Actinic (200 - 315 nm) 0.1 milliwatt/cm^2 for 8-hour exposure

Adherence to these exposure limits prevents skin and eye effects in most workers. Sensitized individuals may exhibit effects even at low exposures, and they should not work in the vicinity of UV curing equipment or be exposed to sunlight.

As with all industrial processes, written procedures, worker training and documentation are critical requirements to assure productive and safe use of the processing equipment. This applies to all aspects of the use of industrial technology and will be a common theme throughout this paper.

Ionizing (Electron Beam) Radiation

The potential physical hazards of electron beam curing result from possible leakage of high velocity electrons and x-rays from the curing station. Physiological consequences would be similar to X-ray burns and therefore strict measures are taken to eliminate this possibilty. Engineering controls include proper equipment design to assure that the electron beam is directed at the target area, and that stray electrons and X-rays are minimized. Shielding is provided to prevent any leakage of electrons or X-rays into the work environment. EB curing equipment is installed under manufacturer supervision to assure that it is working as designed. The EB unit is provided with a radiation detector which automatically shuts down the power if a high level alarm is exceeded.

The federal government has set permissible exposure levels to X-rays, and employees working with the EB curing equipment wear monitoring badges to detect and quantify any exposure to stray radiation. State and local governments have regulations controlling the use of radiation producing equipment, and all EB units must be licensed.

Extensive specialized training is required before any worker is permitted to operate EB curing equipment. Again, good written operating procedures and documentation are important for safe use of the equipment.

Ozone

Ozone is a pungent smelling, irritating gas which is generated by reaction of atmospheric oygen exposed to UV/EB radiation. The physiological symptoms of exposure include respiratory irritation, fatigue and headache. Proper ventilating equipment minimizes this hazard in the workplace.

UV/EB Curing Materials

Table 1 shows a listing of acrylate monomers commonly used in UV/EB curing formulations and their acronyms.

Table 1. Common UV/EB Curing Acrylate Monomers

Acronym	Chemical Description
2-PEA	2-phenoxyethyl acrylate
BCEA	beta-carboxyethyl acrylate
EOEOEA	ethoxyethoxyethyl acrylate
GPTA	glycerol propoxylate triacrylate
HDODA	hexane diol diacrylate
PETA	pentaerythritol tri/tetra acrylate
PNPGDA	propoxylated neopentyl glycol diacrylate
TMPEOTA	trimethylolpropane ethoxy triacrylate
TMPTA	trimethylolpropane triacrylate
TRPGDA	tripropylene glycol diacrylate
TTEGDA	tetraethylene glycol diacrylate

UV/EB curing acrylate oligomers are low molecular weight polymers which have pendant acrylate groups. The polymer backbone (acrylic, amino, epoxy, polyester, silicone, urethane, etc.) contributes the basic properties of the cured article, while the acrylate groups serve to link up the lower molecular weight species in the curing reaction.

In addition to oligomers and monomers, typical UV/EB curing formulations also can contain additives, such as photoinitiators, pigments, slip agents, adhesion promoters etc.

Chemical Toxicity Of UV/EB Curing Materials

Chemical toxicity is a safety concern in any industrial process which utilizes chemicals, and UV/EB curing is no exception. Most people can work safely with these products by using the proper protective clothing and handling procedures.

Acrylate Acute Toxicity

In general, UV/EB curing acrylates have low systemic toxicity, but they can cause skin and eye irritation or burns. Since they do not cause immediate irritation, exposure can go unnoticed. Some individuals may also become sensitized to these chemicals as a result of contact. Individuals who become sensitized should discontinue working in the areas where exposure can occur.

Most acrylate oligomers and monomers have a low vapor pressure, and inhalation of vapors is unlikely to occur at room temperatures. Some of these products may form stable aerosols which can be inhaled and may also cause skin and eye irritation.

Low molecular weight acrylate monomers represent the most physiologically active materials in this class, due to the low molecular weight and high level of acrylate functionality.

The substantially higher molecular weight and lower net acrylate functionality of acrylate oligomers result in a lower level of physiological activity than the acrylate monomers. Skin and eye irritation due to oligomer exposure normally are minimal to mild, and the oligomers exhibit very low acute toxicity.

The following table summarizes the typical toxicological profile of the low molecular weight acrylate monomers.

Table 2. Low Molecular Weight Acrylate Monomer Toxicity Overview

Ingestion	High LD50 (EPA rating* III to IV)
Inhalation	Low volatile emissions, vapor pressures mostly < 0.1 mm Hg @ 25^{o}C, high LC50
Skin Absorption	Low absorbsion through skin, high LD50
Dermal Irritation	Mild to moderate (EPA rating* II to IV) Delayed action, exposure can go unnoticed Skin blisters can develop on prolonged contact
Eye Irritation	Mild to severe (EPA rating* I to III)
Chronic	Skin sensitization can occur. Not an animal teratogen. Not on any list of carcinogens. Some animal skin painting studies have shown a weak carcinogenic effect. No other significant chronic effects known.

*) 40 CFR 162.10

Draize testing[2] is the generally accepted measure of the potential for chemical skin and eye irritation. However, caution should be exercised when interpreting Draize scores. Although Draize scores appear to be precise numerical ratings, they are averages and should be viewed as rough estimates of irritation potential. It has been shown that repeating Draize tests for the same material, either within or between laboratories, often yields significantly different results. This variation results from the subjective nature of the test itself, human error, animal variability, and the numerous variations that exist in testing protocols.

Skin irritation potential also can be reported as the "primary dermal irritation index" or "PII", which is the sum of the 24 and 72 hour Draize scores, devided by two and rounded to the nearest tenth.[3]

Unfortunately, often too much reliance is placed on the Draize score or PII as an absolute indicator of chemical skin and eye hazards, and this is not always the best basis for making decisions about workplace safety.

Tables 3 and 4 show Draize test results for a number of commonly used commercial acrylate monomers, approximately in order of greater irritation potential.

Table 3. Acrylate Monomer Skin Irritation

Material	Irritation	Draize Score[2]
GPTA	Minimal	1.5/8.0
TRPGDA	Minimal	2.5/8.0
TMPEOTA	Minimal	2.6/8.0
TTEGDA	Moderate	4.4/8.0
PETA	Moderate	4.6/8.0
TMPTA	Moderate	5.0/8.0
HDODA	Severe	6.2/8.0

Table 4. Acrylate Monomer Eye Irritation

Monomer	Irritation	Draize Score[2]
TRPGDA	Minimal	7.4/110
HDODA	Mild	16.0/110
TMPEOTA	Moderate	44/110
TMPTA	Moderate	46.0/110
GPTA	Severe	II (EPA scoring*)
TTEGDA	Severe	103.3/110
PETA	Severe	109.2/110

*) 40 CFR 162.10

Acrylate monomers in general have low acute toxicity, as shown in Tables 5 and 6.

Table 5. Acrylate Monomer Acute Oral Toxicity

Monomer	LD50 (rat)
PETA	1,350 mg/kg
EOEOEA	1,860 mg/kg
HDODA	> 5,000 mg/kg
TMPTA	> 5,000 mg/kg
2-PEA	> 5,000 mg/kg
TRPGDA	6,800 mg/kg
PNPGDA	15,000 mg/kg

Table 6. Acrylate Monomer Acute Dermal Toxicity

Monomer	LD50 (rabbit)
PETA	> 2,000 mg/kg
TRPGDA	> 2,000 mg/kg
HDODA	> 3,600 mg/kg
PNPGDA	5,000 mg/kg
GPTA	> 13,000 mg/kg

Acrylate Chronic Toxicity

In 1986 and 1987 several NIOSH surveys described actual workplace experience with acrylates in commercial plants where formulating and/or UV/EB curing had been used for years[4]. Of the eight plants surveyed, seven reported either no or only infrequent cases of dermatitis and no lost work days due to skin reactions. Where recommendations were made, they included better selection of personal protective equipment and more care to be taken with clean up solvents.

In the one plant where dermatitis was a problem, NIOSH made extensive recommendations for improved use of personal protective equipment and engineering controls. The recommendations were implemented and have been effective in substantially eliminating the earlier dermatitis problems. The plant is still using UV/EB curing successfully today.

The NIOSH surveys found no evidence of excess cancers.

A number of chronic toxicity studies have been conducted for acrylate monomers with mixed and conflicting results (see reference 6 for a number of citations). A recent skin painting study of TRPGDA by Nylander-French[5] showed evidence of carcinogenicity, but the results are questionable, since the test animal has been rejected by other groups because it is overly

sensitive to external stimulus. The conflicting acrylate test results have caused much debate and confusion about assumptions that acrylates as a class are carcinogenic.

In an attempt to resolve this question, the joint CMA/EPA sponsored Specialty Acrylates And Methacrylates (SAM) Panel has just completed and reported on long-term acryalte skin painting studies[6]. The tests were conducted at the maximum tolerated dose. A dermal cancer bioassay showed no carcinogenic effect, and the test material showed no systemic toxicity.

Based on the absence of epedemiological evidence for acrylate carcinogenicity and the favorable long-term skin painting test results, the SAM Panel has requested that EPA drop their automatic SNUR policy for new low molecular weight acrylates and rescind existing acrylate SNUR's.

Cycloaliphatic Epoxy Toxicity

Cycloaliphatic epoxy compounds are gaining favor in certain specialty UV curing applications. Table 7 shows an overview of the toxicity of these materials.

Table 7. Cycloaliphatic Epoxy Toxicity Overview

Ingestion	Low toxicity, high LD50
Inhalation	Low volatile emissions, vapor pressures mostly < 0.1 mm Hg @ 25^{o}C
Skin Absorption	Low absorbsion through skin, high LD50
Dermal Irritation	Mild (EPA rating* IV)
Eye Irritation	Mild to moderate (EPA rating* II to III)
Chronic	Limited evidence of carcinogenicity

*) 40 CFR 162.10

Photoinitiators And Additives

Photoinitiators, pigments and additives vary widely in their toxicity and handling characteristics. Individual MSDS must be consulted to determine safe handling of these materials.

Safe Handling Of UV/EB Curing Materials

The following sections cover safe handling of UV/EB curing materials in great detail. This review is based on good industrial hygiene practice and handling principles, and does not imply that there are any extraordinary or severe hazards associated with these materials.

The great majority of commercial UV/EB curing usage is based on acrylate chemistry. While the primary focus here is the safe handling of acrylates, the same principles of worker training and good industrial hygiene practices apply as well to the less common epoxy systems.

Minimizing The Risk Of Dermatitis

Elimination Of Severe Irritants And Development Of New Less Irritating Monomers

Early unfavorable experience quickly caused producers to drop highly irritating materials, such as neopentyl glycol diacrylate, from their commercial product line. Recognition of the irritation issues associated with acrylates also prompted development of lower irritation materials. Acrylated alkoxylated compounds in general exhibit less irritating effects, and a wide range of these materials is offered commercially.

Prevent Skin And Eye Contact

UV/EB curing oligomers and monomers should not be permitted to enter the eyes, and direct skin contact should be avoided. Proper eye protection must be worn at all times when handling oligomers and monomers. Face shields and other equipment may be used to protect the face. Contact lenses should never be worn.

The type of protective clothing recommended depends on the type of potential exposure; in all cases, protective clothing must be clean and have long sleeves. For routine laboratory operations, an impervious apron of polyethylene or neoprene is preferred. Impervious gloves such as neoprene are also recommended. A combination of barrier cream and protective gloves is recommended. Barrier creams alone are not recommended, because they provide a false sense of security. Barrier creams should be applied to clean hands and should not be applied after exposure. Good practice is to wash gloves frequently with soap and water.

When working with larger quantities of materials or where greater exposure hazards might be present, (such as when loading or unloading tanks or reactors, treating spills, sampling products, bleeding, draining, or flushing lines) additional precautions should be taken. Under these conditions it is essential that proper eye protection, rubber boots, and gloves of impervious materials be used. In areas where an aerosol is likely, an impervious slicker suit should be worn.

Protective clothing contaminated with small amounts of UV/EB curing materials can be laundered separately in an alkaline detergent and re-used. If protective clothing becomes heavily contaminated, it should be properly discarded by placing in a sealed plastic bag and incinerating.

Discard all contaminated shoes, belts or other leather goods, which can not be decontaminated adequately to allow safe use.

Prevent Or Control Aerosols

The vapor pressures of most acrylate oligomers and monomers are so low that vapor inhalation usually is not a problem. Under normal conditions no special respirator equipment is required, but ventilation for odor control is advisable.
However, these products may form aerosols when spraying acrylate formulations, at liquid transfer points or during application with high speed rollers. Aerosols also can form under the conditions of fire or uncontrolled polymerization. A fresh air mask or an organic vapor respirator should be worn whenever aerosols are present.

While most UV/EB curing materials have very low vapor pressure, they may be used in conjunction with solvents, diluting monomers or other coreactants of much greater volatility. Consequently, buildings used for processing or storage must be well ventilated to prevent local accumulation of solvent vapors. Point of operation or local exhaust is more effective where solvent vapors or aerosols are emitted from local sources.

Safe Clean Up Procedures

It is important to remember that UV/EB curing materials do not evaporate, so spills and incidental contamination will remain until cleaned up. Equipment touched with contaminated gloves can be the source of exposure if touched later by unprotected skin.

Wipe up spills, contact areas immediately. Work areas should be kept clean, and all equipment and tools soiled with UV/EB curing materials should be thoroughly cleaned after use. Note that, since UV/EB curing materials do not dry out or cure under normal conditions, they remain liquid and can be cleaned up easily with less agressive solvents, such as soap and water or citrus and vegetable oil cleaners. Solvents can be used for cleaning equipment, but only if the appropriate protective clothing is worn, and if a safe means of disposal is available.

Personal Hygiene

Hands should be washed with soap and water immediately after handling any containers or equipment which have come in contact with the oligomers and monomers. Routine wash-ups should be carried out before breaks, at lunchtime, and after work as part of the safety program. Solvents should not be used for cleaning the hands or skin, because they may increase the penetration of these products into the skin, and dermatitis may occur. Hand creams or lotions should be used at the end of the work period to reduce the drying of the skin caused by frequent washing.

As with any chemical, food and beverages should not be consumed in areas where UV/EB curing materials are handled.

Premature Polymerization

UV/EB curing materials are designed to be reactive under controlled conditions, and care must be taken to prevent premature polymerization. In most cases, uncontrolled polymerization simply results in solidification of the material in its original container or in localized gels, making it unusable.

A few products, particularly those with very high acrylate content (certain tri-, tetra-, and hexa-functional acrylates) have the potential to generate a great deal of heat during uncontrolled bulk polymerization, which can cause rapid pressure build-up in closed containers. With these highly reactive matrials, pyrolysis may occur, with the formation of volatile degradation products which are acrid and irritating.

Any unexplained change in temperature may indicate the onset of polymerization. Bulging drums or any unexplained change in bulk temperature may indicate the onset of premature polymerization.

The following basic principals and procedures normally assure stable handling and storage of UV/EB curing materials.

Polymerization Inhibitors
All acrylated materials are supplied with a low concentration free radical inhibitor to prevent uncontrolled polymerization when they are stored properly. Most of these inhibitors are effective only in the presence of dissolved oxygen. Consequently, these products should not be subjected to conditions that will displace oxygen, such as sparging with nitrogen.

Do not exceed the supplier's recommended shelf life, since inhibitor concentration can decline over time, and acrylates can have widely varying shelf stability.

Thawing Acrylates

Some acrylate oligomers and monomers may freeze or crystallize in cold weather or even under normal storage conditions. When these products crystallize, the inhibitor may become unevenly distributed, leaving some portions of the material inadequately inhibited.

Frozen containers of product can be conveniently melted by heating in a warm water bath or a warm room for 24 to 48 hours at a maximum temperature of 100 to 130°F, following the supplier's recommendations. Thawed material should be agitated to redistribute the inhibitor.

If acrylate monomers freeze in bulk storage tanks, they can be melted by circulating tempered water through tank coils or jackets. The monomers should be stirred or recirculated while heating the tank to redistribute the inhibitor.

Avoid Excessive Localized Heating

Adhere to the supplier's recommended maximum storage and handling temperatures. Never use steam or electrical heating systems such as tapes, coils, mantles, or jackets to thaw frozen

acrylates, since these can produce localized hot spots that might lead to uncontrolled polymerization or product deterioration. Take care not to position acrylate drums immediately next to steam lines, which can lead to local hot spots.

Piston, lobe or gear pumps should be avoided to prevent frictional heat related gel formation. Low viscosity monomers can be transferred using centrifugal pumps, preferably with recessed impellers to keep the material flowing away from the seal surfaces.

Air powered diaphragm pumps are recommend for pumping higher viscosity oligomers and oligomer/monomer blends. In many cases, these also are the best choice for handling monomers. These pumps can generally be run dry or deadheaded with out damaging the pumps or causing the material in them to degrade or gel.

Avoid Exposure To Light And Contact With Polymerization Initiators

UV/EB curing materials should be stored in amber glass or opaque containers to avoid exposure to light and UV sources. Containers must be kept closed and away from oxidizing agents, acids, alkalis, peroxides, polymerization initiators, free radical initiators, x-ray or ultraviolet radiation, photosensitizers, or azo compounds.

Acrylates can undergo vigorous addition reactions with some amines and thiols; cationic cycloaliphatic epoxy UV curing systems can react with strong acids, amines, thiols and anhydrides. Unintended contact with these materials should be avoided.

Reactive metals which can promote free radical reactions, such as unlined carbon steel, copper alloys, brass and bronze should not be used as materials of construction in direct contact with acrylates.

Storage And Transfer Of Acrylates

Drums

Drums should be stored with bungs side upward and maintained at the recommended temperature. The bungs should be loosened occasionally to relieve any buildup of internal pressure.

Care should be used when handling drums to prevent damage to the protective lining, which can cause discoloration or degradation of the product and possible leakage. Any leaking drums should be removed to an adequately ventilated area, and the contents should be transferred to a clean, suitable container

Drum unloading areas should have adequate ventilation and a sump to contain spills. Drums should be emptied using equipment designed to minimize spillage and operator contact with the drum contents. Operators must be dressed in the proper protective clothing. Always attach a static grounding device, even if the drum contents are not combustible. Immediately after

completing the transfer process, equipment should be carefully cleaned, with care taken not to contaminate the area. Empty drums can be sent to a recycler for reconditioning and re-use.

Bulk Storage

UV/EB curing materials normally can be safely stored in lined carbon steel (such as Heresite P413D or equivalent baked phenolic), 304 and 316 stainless steel. The few materials which contain free acrylic acid must be handled and stored as corrosives. The storage tanks should be equipped with continuous temperature monitoring devices with remote readout for each to allow detection of heat increase resulting from premature polymerization. Tanks should be well insulated and should have internal coils capable of supplying heat as well as cooling. All valves, piping, and pumps must be constructed of 304 or 316 stainless steel to avoid iron contamination.

Material Transfer

Equipment which minimizes any potential direct contact with the workers should be used where possible. Since most acrylate products have low volatility and high flash points, they pose very little threat from auto-ignition and can be safely conveyed and blown clear through lines by air pressure. Nitrogen or other inert gases should not be used for pressure, since these gases may remove dissolved oxygen, causing the inhibitor to become ineffective.

Spill Controll And Waste Disposal

All spills and leaks of UV/EB curing materials should be cleaned up immediately. As general good practice, remove all sources of ignition.

Only personnel wearing the proper protective clothing and adequately trained in clean-up and disposal procedures should be permitted in the area. A fresh air mask or organic vapor respirator, chemical safety goggles, impervious gloves, clothing, and rubber boots are recommended. Leaking containers should be removed to well ventilated areas where leakage can be safely contained. Towels and cloths used to clean up spills should never be reused, but disposed of immediately.

Large spills can be absorbed using a dry absorbant. Good ventilation should be provided until the area has been cleaned up. Transfer the contaminated absorbent into suitable containers for disposal.

Contaminated areas should be thoroughly washed with a strong alkaline detergent. Washings should be collected for appropriate disposal, and care should be taken to prevent inadvertent contamination of underground water. The use of solvents for clean up of large contaminated areas is not recommended, since the solvent would introduce significant new toxicity, fire and environmental hazards.

All clean-up and disposal must be carried out in compliance with federal, state, and local regulations regarding health, air, and water pollution.

Regulatory Considerations

Most UV/EB curing materials are not regulated by DOT as flammable or corrosive. Exceptions are BCEA, which has a high content of combustible acrylic acid, and styrene. With these exceptions, and unless diluted with flammable solvents, UV/EB curing materials generally are not "hazardous waste" (toxic, corrosive, flammable or reactive) as defined under RCRA regulations. However, as with all chemicals, contaminated materials and wastes should be disposed of in accordance with federal and local requirements.

UV/EB curing materials contain little to no VOC, no "HAPS", and are not currently specified in any federal or state Community Right-To-Know list.

Worker training

Clearly defined work procedures and effective worker training are essential for safe application of any industrial technology. UV/EB curing is no exception, and many early problems were due to poorly understood safe handling principles and poor hygiene habits with solvent systems which do not produce an immediately noticable physiological reaction.

Comparison Between Solvent And UV/EB Systems

The immediate dermatitis effect which can occur when UV/EB formulations containing acrylates are mishandled acts as a warning that handling procedures must be improved. Unfortunately, it also raises concerns about working with these materials, because the consequences of poor hygiene practices are so noticeable.

Solvent systems often do not have such immediate warning properties, even though the consequences of poor industrial hygiene practice can be severe. As a result, UV/EB curing systems may incorrectly be perceived as more hazardous than conventional technology. The following table provides some perspective on the relative hazards of solvent and UV/EB systems.

Table 8. Comparison Between Solvent And UV/EB Systems

Hazard	Solvents	UV/EB Materials
Acute Toxicity	Narcosis, kidney damage, blood damage, fetal toxicity, liver damage, dermatitis, death	Dermatitis, blisters
Chronic Toxicity	Known carcinogens and suspect carcinogens, cirrhosis, permanent nerve damage, blood damage, kidney damage, reproductive damage	Not carcinogenic below maximum tolerated dose (skin damage irritation), not mutagenic in oral and dermal testing, possible sensitization
Exposure Routes	inhalation, eyes, skin absorption, ingestion	eyes, skin surface, ingestion
Flammable, Combustible	mostly yes	mostly no
Explosive Vapors	mostly yes	mostly no
VOC	yes	no
Hazardous Waste	yes	mostly no
Reactive	no	yes

Conclusions

Early inexperience with handling acrylates and poor work habits resulted in cases of occupational dermatitis. These incidents and early toxicity testing reports generated concerns and some misconceptions about the safety of UV/EB curing technology.

Subsequent testing has shown that earlier concerns about acrylate toxicity were overstated. UV/EB curing materials have low systemic toxicity, and acrylates as a class can not be assumed to be carcinogenic via dermal exposure. Severely irritating products have been eliminated from commercial use, and new, less irritating materials are available for formulating UV/EB curing systems.

Good industrial hygiene practices, knowledge of safe handling procedures and worker training are essential for safe handling of any chemical. When these principles are followed, experience has shown that UV/EB curing technology can be handled safely in widely varying industrial applications.

In general, UV/EB curing materials are less hazardous than solvents in the work environment.

References

1. L.S. Andrews And J.J. Clary, “Review Of The Toxicity Of Mutifunctional Acrylates”, Journal Of Toxicology And Environmental Health, 19, 149-164 (1986)

2. a) J.H. Draize, G. Woodard and H.O. Calvery, “methods for the study of irritation and toxicity of substances applied topically to the skin and mucous membranes”, J. Pharm. & Exp. Ther, 82, 377 (1944); b) J. H. Draize, “Appraisal Of The Safety Of Chemicals In Food, Drugs And Cosmetics-Dermal Toxicity”, Association Of Food And Drug Officials Of The U.S., Topeka, KS, 46-59 (1959); c) J. H. Draize, “Appraisal Of The Safety Of Chemicals In Food, Drugs And Cosmetics-Dermal Toxicity”, Association Of Food And Drug Officials Of The U.S., Austin, TX, 36-45 (1959)

3. 16 CFR 1500.3

4. a) Charles S. McCammon et al., “Industrial Hygiene Walk-Through Survey Report Of BASF Corporation - Inmont Division, Cincinnati, Ohio”, Industrial Hygiene Section, Industrywide Studies Branch, Division Of Surveillance, Hazard Evaluations And Field Studies, National Institute For Occupational Safety And Health, Centers For Disease Control, Cincinnati, Ohio, Report Number 157.13 (1986); b) “Industrial Hygiene Walk-Through Survey Report Of Armstrong World Industries, Inc., Lancaster Floor Plant, Lancaster, Pennsylvania”, *ibid.*, Report Number 157.16 (1987); c) “Industrial Hygiene Walk-Through Survey Report Of Industrial Heating And Finishing Co., Inc, Pelham, Alabama”, *ibid.*, Report Number 157.22 (1987); d) “Industrial Hygiene Walk-Through Survey Report Of Digital Equipment Corporation, Greenville PWB Facility, Greenville, South Carolina”, *ibid.*, Report Number 157.19 (1987); e) “Industrial Hygiene Walk-Through Survey Report Of Tetra Pak Incorporated, Denton, USA Plant, Denton, Texas”, *ibid.*, Report Number 157.18 (1987); f) “Industrial Hygiene Walk-Through Survey Report Of Metallized Products, Inc., Winchester, Massachusetts”, *ibid.*, Report Number 157.21 (1987); g) “Industrial Hygiene Walk-Through Survey Report Of Universal Woods, Inc., Louisville, Kentucky”, *ibid.*, Report Number 157.20 (1987)

5. L.A. Nylander-French, “Identification Of Risk To Workers In The Ultraviolet Radiation Curing Wood Surface Coating Industry”, Doctoral Thesis, Department Of Environmental Technology And Work Science, The Royal Institue Of Technology, Stockholm, Sweden

6. a) M.K. Stanley, “Testing Overview Of The Specialty Acrylate/Methacrylate (SAM) Panel”, Proceedings of the RadTech International North America Conference, Nashville, TN, (1996) pp.144-147; b) G.L. Adams, “Specialty Acrylates And Methacrylates Panel Progress Report”, *ibid.*, pp. 148-150