UV Equipment and Design Factors
Manufacturing Market

DDU Enterprises, Inc.
www.doctoruv.com
UV CURING

- Process to cure coatings, inks, adhesives
- Polymerization and cross-linking is initiated by UV
- Coating is converted from a liquid to a solid in a fraction of a second
- Replaces solvent-based drying processes
- Every existing method of decorating, coating or bonding has been converted to UV Curing
Converting - Siliconizing
Release liners, papers, film

Converting - Coating
Flexible packaging, film

Converting - Narrow Web
Labels, flexible packaging, silicone release

Web Offset Printing
Packaging, business forms, direct mail

Converting - Flooring
Vinyl sheets and tiles
Pressure Sensitive Adhesives
Tapes and labels

Automotive
Interior & exterior plastic, metal, and glass

Plastic - Functional Coating, Non-Automotive
Construction materials, office furniture, and leisure craft

Wide Web Printing
Flexible packaging, wrappers

Sheetfed Offset Printing
Commercial & plastic sheet printing
CD/DVD “lacquering,” printing, and bonding

Plastic Container Decoration
Cosmetic, toothpaste, food containers

Metal Pipe Coating
Metal tubes

Metal-Flat Sheet Deco
Aerosol, food cans

Metal-2-Piece Cans
Beverage containers-decoration and rim coating
Wood Coating - Profiles
Molding, picture frames

Wood Coating - Flat Sheet
Particle board, sheets, doors

Fiber, Ribbon & Cable
Optical fiber, coloring, ribbon, wire marking

Wood Coating - 3D Objects
Case goods, chairs, furniture

Glass Coating
Bottles, tumblers, mirrors
Consumer Products
Eyeglass lenses, pen bodies, tools, golf balls

Medical Devices
Manufacturing and assembly

Electronics
Marking, encapsulation, conformal coating

Flat Sheet Screen Printing & Decorating
Posters, signs, vehicle advertising

Lab/Development Units
Conveyors, static cure, process research lab equipment for coating evaluation
Categories of UV Curing

- **LINEAR**
  Usually Flat Surfaces
  Typically Linear Travel
  Tubular Bulbs Most Common

- **FLOOD (AREA)**
  Flat or Complex Surfaces
  Lower Irradiance Levels
  None to Several Degrees of Motion
  Various Configurations of Lamps

- **SPOT**
  High Intensity, Small Areas
  Short Projection Field, or
  Liquid Light Guides
Two types of medium pressure mercury vapor UV lamp are commonly used in industry:

- Arc (Electrode) Lamp
- Microwave (Electrodeless) Lamp
RADIANT OUTPUT STABILITY

Percent of Initial Radiant Output

Arc Lamp

High Power or many starts & stops

Hours of Operation

0 1000 2000 3000

100
Microwave-Powered (Electrodeless) Lamp
ELECTRODELESS LAMP BULB

QUARTZ MOUNTING STUB
RADIANT OUTPUT STABILITY

Hours of Operation

Percent of Initial Radiant Output

Arc Lamp

High Power or many starts & stops

1000 2000 3000
RADIANT OUTPUT STABILITY
Microwave Lamp Compared to Arc Lamp

Microwave-Powered Bulb

Percent of Initial Radiant Output

Arc Lamp

High Power or many starts & stops

Hours of Operation

0 1000 2000 3000 >5000

0 100
UV Curing Exposure Factors
“Big 4”

Factors Affecting Cure
- Irradiance ("Intensity" of UV at a surface)
- Exposure Time (or speed)
- UV Spectral Output Distribution (wavelengths)
- Infrared Energy (Affects surface temperature)
LAMP DESIGN FACTORS AFFECTING IRRADIANCE

- Power Input (watts)
- Bulb Efficiency
- Bulb Diameter
- Reflector Shape
- Reflectivity
- Maintenance
  (Surface Cleanliness)
A Tubular Lamp Has TWO Distinct Optical Patterns
Why High Peak Irradiance UV?

Beer-Lambert Law
the higher the intensity at the surface,
the higher the intensity at any point within
the coating

greater depth of penetration of UV
improved cure at the substrate / ink interface
better adhesion to the substrate
more uniform degree of cure throughout the film
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UV Curing Exposure Factors
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Factors Affecting Cure

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UVC UVB UVA

100nm 200nm 425nm 750nm 10 μ
t 750 microns 10 microns

1nm = 10^-9 meter. nm
1micron = 10^-6 meter. μ
1angstrom = 10^-10 meter. Å
The spectral output of UV lamps can be expressed in 10-nanometer bands – this integrates the effects of line and continuous spectral emission. It makes calculation easy by reducing the UV lamp spectra to 25 data points.
Strongest Radiance

Bulb Type

Q

V

D

H

H+

200 250 300 350 400 450 500

Wavelength, nm

430 470

400 450

350 400

240 320

210 320
UV Bulb Spectra & Optimal Processes

H-bulb
  Clear lacquers, adhesives, silicone release coatings

D-bulb (90% of all Medical applications)
  Inks and pigmented systems, industrial bonding adhesives

V-bulb
  White / Black pigmented coatings, visible light curing systems, gloss control

Q-bulb
  Systems using camphor-quinone photoinitiators

M-bulb
  Special bulb for coatings containing UV absorbers
UV Curing Exposure Factors
“Big 4”

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Optimize Spectral Output for Maximum
Managing Heat

Infrared radiation from the UV bulb has the greatest heating effect on the surface.

Exotherm and cooling air temperature have less effect.
IR Production and the Stefan-Boltzmann Law

\[ P = e \cdot \sigma \cdot T^4 \cdot A \]

- **Emitted Heat [W]**
- **Stefan-Boltzmann Constant**
- **Bulb surface area (only variable)**
  - Narrower bulbs produce less IR
- **Emission of Surface (Constant for Quartz)**
- **Surface temperature approx. 800°C = 1073K**
IR Production and the Stupid Novice Heat Law

ENOUGH HEAT TO START A FIRE
AND BURN YOUR BED PAN {F}

VH CONTSANT (Very Hot)

BURN IN HELL HEAT

ENOUGH HEAT TO MELT
YOUR CATHETERS

\[ P = e \cdot \sigma \cdot T^4 \cdot A \]

DON’T TOUCH THIS
SURFACE HEAT
In this example, significant reduction in peak temperature is accompanied by a slight reduction in speed.
A METHOD FOR IMPROVING UV CURING PERFORMANCE AND EFFECTIVE USE OF UV LAMPS:

THE PROCESS “WINDOW”
Process "Window"

The range of a measurable production variable within which "cure" meets an acceptance requirement.
1. Using a cure ladder, determine the upper and lower limits of achievement of target properties
2. Find the upper and lower limits of all properties critical to success

3. Plot these limits on the energy diagram
4. Identify the limiting properties and evaluate how they are affected by changes in:

**UV Wavelength, Irradiance, IR, or formulation.**

Peak irradiance affects depth of cure and efficiency;
Short wavelengths affect surface properties;
Long wavelengths affect deeper and bulk properties
This method can be used to improve any UV curing process, but requires a set of versatile UV lab tools.
Curing Through Plastics
UV Transmission of Clear Polycarbonate

% Transmission

Wavelength - nm
UV ABSORPTION of COMPONENT MATERIALS

Relative Absorption, %

- Polycarbonate
- Adhesive
- Photoinitiator

Wavelength, nm
3D Cure is limited by the least-illuminated surface.

All other surfaces receive excess energy
A Useful “language” for describing the “attitude” of a UV lamp in space
Golf Ball

A Simple example of two degrees of motion, using two lamps, ± 45° pitch.
Medical Device Examples
Medical Fluid Bags

Directions:
1. Close roller clamp.
2. Fill container with desired nutrient or formula and close bag.
3. Attach to IV pole with built-in hanger.
4. Insert drip chamber into drip chamber brackets.
6. Stretch silicone tubing around roller. Insert retainer into bracket.
7. Open roller clamps and begin feeding.

Precautions:
- It is recommended that device be replaced at least every 24 hours.
- Discard after single use.
- Do not re-sterilize.

Approximate Volume in mL:
- 1200 mL
- 1000 mL
- 800 mL
- 600 mL
- 500 mL
- 300 mL
- 200 mL
- 100 mL
- 50 mL
- NOT FOR IV USE

Medical devices
Gurnee, IL
Photo courtesy of Cal Med Corp.
Photo courtesy of Cal Med Corp.
A Successful UV Process....

Partnership between...

Ink, coating, adhesive

UV lamp system