PDHonline Course G263 (2 PDH)

Light-Cure Adhesives

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LIGHT-CURE ADHESIVES

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INTRODUCTION:

At the present time, adhesive manufacturers offer products classified as Cyanoacrylates, Epoxies, Hot Melts, Silicones, Urethanes, Acrylics (one-part and two-part) and Light-cures. These classifications provide products from manufacturers with specific characteristics that allow for bonding, gasketing, potting and encapsulating, retaining, thread-locking and thread-sealing. This course provides information on one very specific and very special adhesive category--- **LIGHT-CURE.**

Light-cure adhesive technology offers a new approach to bonding similar or dissimilar substrates by using either ultraviolet light (UV) or light within the visible spectrum. Extremely rapid cure times, superior depth of cure, (up to four inches) and easy dispensability are only three of the benefits when using these adhesives combined with the appropriate processes. The newer visible light-cure materials can offer adhesion comparable to most commercially available UV adhesives, with particularly high adhesion on polycarbonate and polyvinylchloride (PVC) materials. All equate to lower cost of assembly, more freedom when designing components and products and the saving of valuable production time. This method of adhesion is extremely valuable when bonding thin films, needing heightened safety relative to skin and eyes and when bonding heat sensitive materials. This process can lessen, or eliminate, the need for costly and harmful chemicals from the workplace and can be solvent-free and non-hazardous. The use of light-cure adhesives will result in a very clean and “friendly” worker environment with no significant material disposal costs. There is no need to mix, prime or rush to apply the adhesive due to minimal time to dispense. We will discuss other benefits and some disadvantages later on in our course.

HISTORY:

Approximately forty (40) years ago, the adhesive industry introduced an **acrylic-based** adhesive that cured or solidified upon exposure to ultraviolet light. This was a tremendous breakthrough for the manufacturers and within a short period of time these adhesives became commercially available. This offered distinct advantages over traditional adhesives categories such as cyanoacrylates (CAs) and epoxies. Rapid cure times, adhesion to a variety of substrates and the ability to fill large gaps; i.e. 0.030 to 0.050 inches, were real winners with designers and assembly “shops”. It allowed for greater flexibility in design and assembly. Recent developments have produced adhesives that will cure using light within the visible spectrum. This offers great possibilities over adhesives previously requiring UV cure. These adhesives, UV/V (Ultraviolet/ Visible) were introduced in the 1990’s and involve employment of existing broadband-emitting UV light sources able to utilize an enlarged portion of the light spectrum. The mechanism by which this happens is the introduction of photo initiators that react exclusively with light in the visible wavelengths; i.e. those which exceed 425 nm. Development, as you might suspect, is still occurring and each year materials with improved mechanical characteristics and ease in application are being introduced into the commercial marketplace.

COMPANIES OFFERING LIGHT-CURE ADHESIVES:

In researching those companies that manufacture and provide light-cure adhesives, we find from Global Spec, eighty-three (83) entries. Some of the more prominent names are as follows:

1.) Loctite (Henkel) 2.) Dymax 3.) 3 M 4.) Master Bond

5.) ThreeBond, Inc. 6.) Electro-Lite Corp. 7.) Hernon Mfg. Inc 8.) Protavic American

9.) ND Industries, Inc.

From the list above, Loctite, Dymax, 3 M, Master Bond and ThreeBond are definitely the most prominent with engineering support staffs that can answer any questions that might arise. These companies are actively working to develop compounds "customized" to meet the exacting and specific needs of product designers. The chemistry of customized products is definitely proprietary and most companies needing special light-cure adhesives will "tie up" the material for a period of time before allowing its introduction into the mass market. I have personally worked with Loctite and 3M and can state that they will definitely work with an engineer to provide specialty products when needed. I am sure that for the sake of competition, the other companies will do likewise.

Let me mention here that the abbreviated list above is only for manufacturers. If you include distributors, the offerings grow to well over one hundred. This is just for light-cure adhesives. Distributors and manufacturers of CAs, epoxies, silicones, etc will create a list of hundreds if not thousands. It is a remarkably competitive market which definitely caters to the design engineer.

TYPICAL APPLICATIONS:

When we discuss applications, we find they generally fall into one of several basic categories; i.e. 1.) Bonding, 2.) Sealing, 3.) Cured-In-Place Gaskets, 4.) Potting and 5.) Coating. With this in mind, we can see the following product applications now using the light-cure technology:

1.) Musical instruments 2.) Toys 3.) Sporting equipment 4.) Jewelry

5.) Optics (eye glasses) 6.) Needles 7.) Syringes 8.) Lighting

9.) Electronic Asms. 10.) Appliance assembly (refrigeration, laundry, etc.)

11.) Strain relief for wires and cord sets 12.) Conformal coating for PC boards

13.) Parts tacking 14.) Coil terminating 15.) Tamper-proofing

The development of light-curing adhesives has been enhanced by the latest generation of curing equipment. This equipment includes both flood and point source configurations using bulb or lamp based systems. In addition, equipment utilizing LED technology is now available for use with these adhesives. The benefit here is that LEDs generate focused wavelengths that create appreciably tighter output range relative to regular visible lamp technologies. Furthermore, because superfluous light and

heat are not emitted, LED technology has proven to be both highly efficient and highly cost effective. As might be expected, as a result of their small size, LED curing systems provide an LED light source that is perfect for curing tiny component parts. The photographs and graphics below will give you an idea as to what types of products are now being produced using light-cure technology.

The assembly of commutators for dc motors has historically involved metal processes such as soldering and brazing. However, both require postjoining finishing steps so the commutator can remain in balance rotate at high speed (typically 3,600 rpm). Securing the leads with low-mass LCMs in a hand-tool motor lets designers eliminate some postjoining finishing.

FIGURE 1

Lenses of fog-light nacelles were originally bonded and sealed to the housing using silicone. However, production was slow (24 hr) because of long cure cycles. Switching to LCM adhesives not only reduced adhesive curing time but also helped speed assembly by permitting pressure tests of bonded nacelles online.

FIGURE 2

FIGURE 3 OUTDOOR TRAFFIC LIGHTS

FIGURE 4 GLASSES & COMMUNICATION EQUIPMENT

ADVANTAGES AND DISADVANTAGES:

Let us list now the relative advantages and disadvantages of using UV and V light-curing adhesives.

ADVANTAGES:

1.) Reduced labor costs

2.) Simplified automation when automation is used

3.) Easier alignment of parts before cure

4.) Improved in-line inspection

5.) Reduced work in-process

6.) Shorter cycle times due to rapid curing of components

7.) Shorter lead times to customer possibly leading to reduced inventories

8.) Fewer assembly stations required due to rapid cure times

9.) No racking during cure

10.) No mixing generally required

11.) No pot life issues meaning generally much less waste of materials

12.) Reduced dispensing costs

13.) No hazardous waste due to purging or poor mixing

14.) No static mixers

15.) Easier to operate and maintain dispensing systems

16.) Better work acceptance

17.) No explosion proof equipment required

18.) Reduced health issues

19.) Reduced regulatory costs; i.e. reduced restrictions on volatile organic compounds

20.) Reduced disposal costs

21.) Very fast cure times

22.) Ideal for heat sensitive films and thin components

23.) Lower energy consumption required during processing of adhesive systems

24.) Visible light-cure adhesives cure through colored or tinted substrates

25.) Allows for miniaturization of component parts needing bonding or potting

26.) Improved manufacturing yield, quality and reliability

27.) Low odor

28.) RoHS compliant

29.) UL recognized materials available

30.) Low entrainment of moisture due to rapid cure times

31.) Solvent free

32.) Reduced material and process costs

The figure below will indicate comparative costs between adhesives. Please note that this figure is only representative and actual dollar amounts may vary depending upon the process, the adhesive and the annual number of products manufactured.

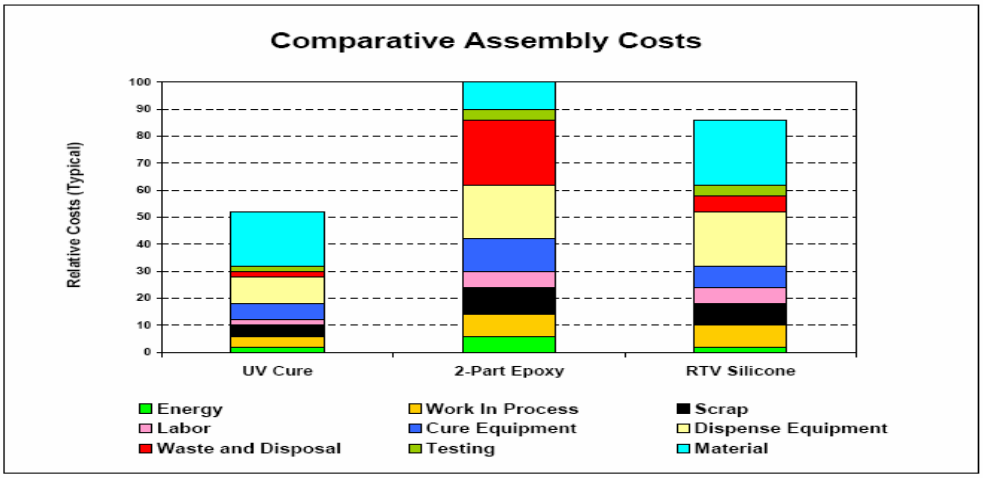


FIGURE 5 COMPARATIVE ASSEMBLY COSTS

DISADVANTAGES:

As with any process or adhesive material, there are several disadvantages. These are as follows:

1.) Expenditure for curing equipment is necessary

2.) Shielding when UV light is used may be necessary

3.) UV blocking eye protection may be necessary depending upon the processing equipment

4.) A radiometer may be necessary to measure the intensity of the UV light

5.) When using UV light, the light source MUST reach the bond line if complete cure is to be had. This means that transmission of light through at least one substrate is crucial. Some substrates have UV inhibitors to lessen or eliminate degradation of the component. These inhibitors will inhibit the penetration and lessen adhesion necessitating another method of bonding. (This is by far the biggest disadvantage for UV curing.) A graphic depiction is given below that illustrates the principal.

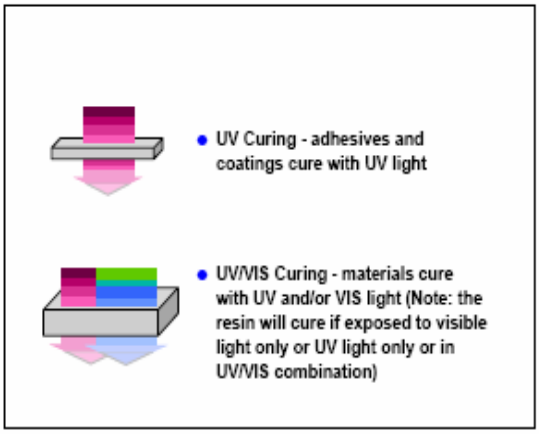


FIGURE 6 UV CURING

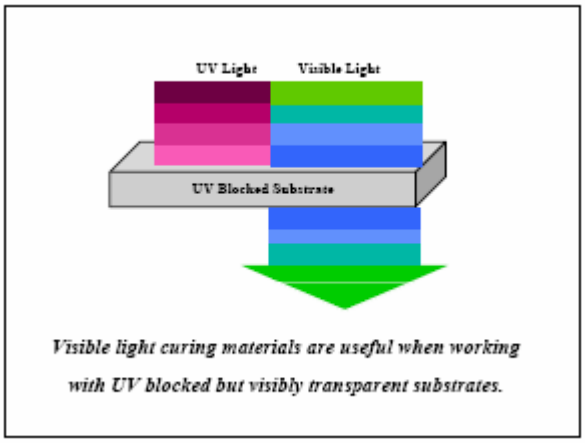


FIGURE 7 UV BLOCKED

6.) The mechanical properties may not meet specified requirements for tensile strength, shear strength, peel strength, etc.

7.) In some cases when potting depth is a factor, materials may not cure through.

8.) Rapid cure may be too fast allowing no repositioning of mating components

9.) Engineering specifications must be exact and specific denoting brand, part number and method of application relative to adhesive.

10.) Educating workers applying light-cure adhesives is a **MUST**.

NOTE: As always, it is very important to work with the vendor of the adhesive product you are considering. This insures proper usage of the adhesive material. Also, as mentioned earlier, each vendor can and will "customize" materials to meet your individual needs. This provides a product representing a win / win for both vendor and client.

FUNDAMENTALS:

We wish now to consider the "fundamentals" of the UV curing process. In doing so, we will first investigate the very basics of the Electromagnetic Spectrum. This information is critical to understanding how the curing process works. Light-curing adhesives cure or harden to form thermoset resins when exposed to UV light of the appropriate wavelength and intensity. The uncured liquid adhesive contains both the monomer and the photoinitiator. When UV light is introduced, the UV photoinitiators absorb the light energy and divide or fragment into reactive species called free radicals. The free radicals then cause the monomers to link up and form thermoset polymers. The figure below gives a basic representation relative to the steps in "setting" a light-cure adhesive. The fourth picture (lower right) showing the final cured adhesive.

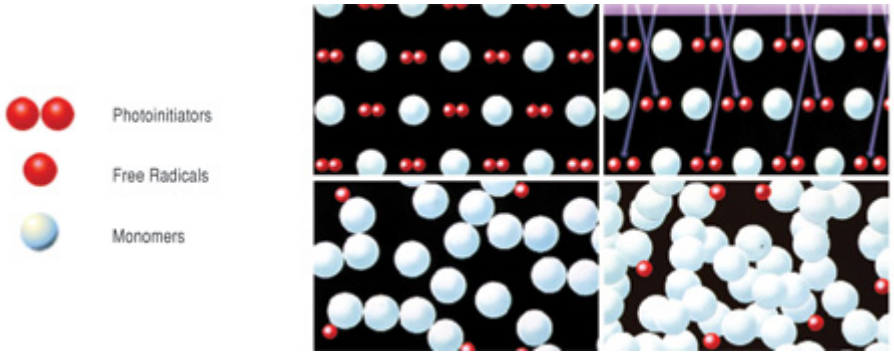


Figure 8—Process of Curing

Figure nine below shows a diagram of the Electromagnetic Spectrum with wavelength being on the "X" axis.

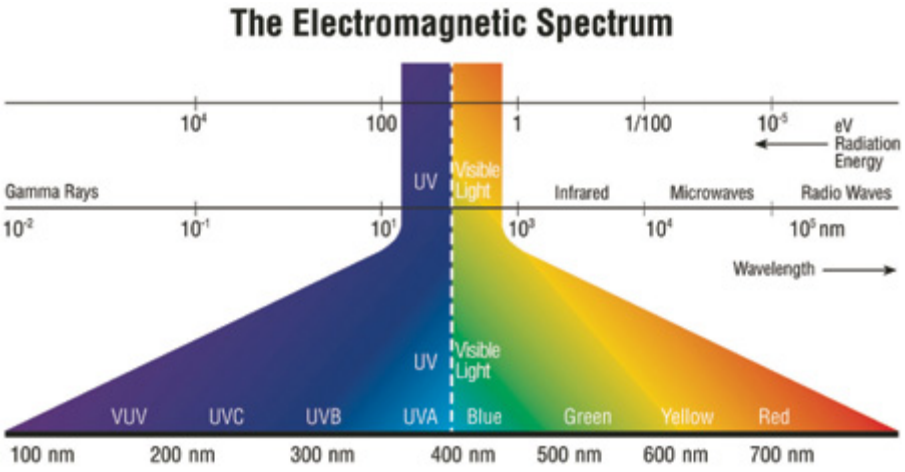


FIGURE 9—ELECTROMAGNETIC SPECTRUM

The electromagnetic spectrum is a continuum of all electromagnetic waves arranged according to frequency and wavelength. The spectrum organizes radiant energy by type. Visible light is a particular type of electromagnetic radiation that can be seen and sensed by the human eye. This energy exists at a wide range of wavelength. The shortest wave lengths are gamma rays. The longest wave lengths are radio and TV waves, which have wavelengths up to many kilometers. Figure ten below will give a pictorial definition of wavelength.

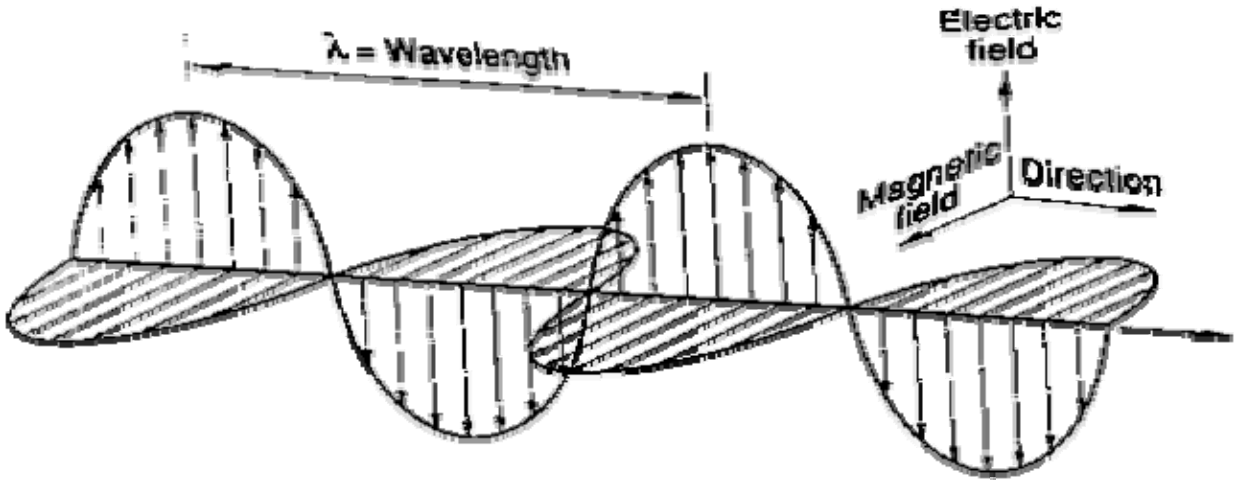
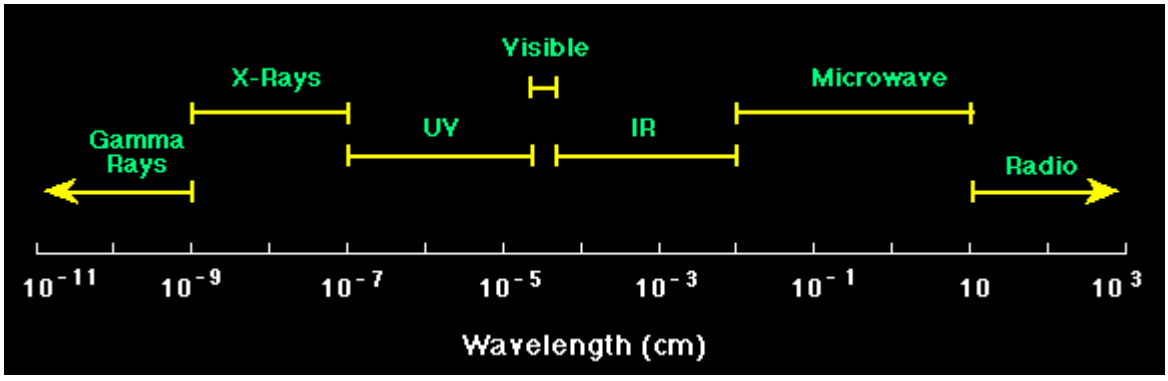


FIGURE 10—WAVELENGTH

As you can see, the definition of wavelength (λ) is the distance between the crests of a sinusoidal wave. Another way to display wavelengths is given by Figure eleven below.



FIRUGE 11—WAVELENGTHS

The UV spectrum occurs between wavelengths of 10 ^-7 and 10^-5 or between 200nm and 425 nm. These wavelengths are considered to be “usable” ultraviolight light. High-intensity light sources are required to cure UV adhesives**. (NOTE: Light in this range can severely damage the skin and eyes and therefore, operators are required to wear protection such as shielding, eyewear and gloves.)** Most UV

light systems offer a broad spectrum of output from 200nm to 700nm but they also emit infrared (IR) or heat energy. Temperatures under some UV lamps can exceed 150 ° F. This represents a real problem for thermally sensitive parts such as thermoplastics that can discolor and / or distort under these conditions. A by-product of start-up can be the emission of ozone, a poisonous gas that must be vented from the assembly line. This is a characteristic of older systems.

In the early 1990s, adhesive formulators introduced UV/visible (UV/V) adhesive systems that respond to 200nm to 390nm UV light as well as 400nm to 410nm light. The upper end of the wavelength is at the cusp of the visible light spectrum. This technology cures many of the existing broadband-emitting UV problems and takes advantage of a slightly greater portion of the spectrum. The addition of the 400nm to 410nm visible photoinhibitors improves curing and performance characteristics of UV/V adhesives.

GUIDELINES FOR PROCESSES:

In order to develop a successful light-curing process it is necessary to understand and adhere to the following concepts:

- **HIGHER INTENSITY = FASTER CURES.** Intensity is the light energy reaching the surface per unit of time and is generally measured in mW/cm^2. Higher intensity light (of the proper wavelength) will generally provide for a more rapid cure time. A well designed UV light curing process incorporates a curing system with **excess intensity**. Excess intensity provides a safety margin and longer bulb life.

- **SHORTWAVE AND LONGWAVE BULBS.** The company DYMAX offers curing systems with either shortwave or longwave bulbs. Shortwave bulbs emphasize UVB and UBC whereas longwave bulbs emphasize UVA and visible light. Longwave bulbs are recommended for curing most UV/V adhesives due to their superior depth of cure and substantial visible light intensity. The table below will give you an idea of what is available relative to bulb design and usage. You can see that there is depreciation in intensity after 2,000 hours of usage.

TABLE 1 RECOMMENDED LIGHTGUIDES

Table 1 – Recommended Lightguides *(sold separately)*

Part Number	Lightguide Description *(all noted are liquid filled. quartz fiber are also available)*		BlueWave™ 200 Minimum Initial Intensity[1] (W/cm^2)	BlueWave™ 200 Typical Intensity at 2,000 Hours[1] (W/cm^2)	BlueWave 50 AS Minimum Initial Intensity[1] (W/cm^2)	BlueWave 50 AS Typical Intensity at 2,000 Hours[1] (W/cm^2)
5720	Single pole	5 mm x 1 Meter	17.0	8.0	3.0	1.4
5721	Single pole	5 mm x 1.5 Meters	16.0	7.5	2.8	1.3
5722	Single pole	8 mm x 1 Meter	13.0	6.5	2.3	1.1
38476	Two pole	3 mm x 1 Meter	10.5	5.2	1.9	0.9
38477	Three pole	3 mm x 1 Meter	9.0	4.5	1.6	0.8
38478	Four pole	3 mm x 1 Meter	7.4	3.7	1.3	0.7

[1] *As measured with a DYMAX ACCU-CAL™ 50 Radiometer (320-395 nm). Excessive on/off cycles and improper cooling may affect bulb degradation and therefore no warranty is expressed or implied.*

- **DISTANCE AND SUBSTRATES AFFECT INTENSITY.** The distance from a light curing lamp always affects intensity. Intensity decreases with increasing distance from both spot lamps and flood curing lamps. Intensity is also reduced when curing through substrates that transmit less than 100% of the light used for curing. Recent advances in adhesives reduce this problem and existing technology allows for curing through most translucent substrates. As you can see below, as the distance from the light source increases, there is dispersion and ever widening of the area covered by the light. The loss of intensity can prove very detrimental to cure hardness and cure depth.

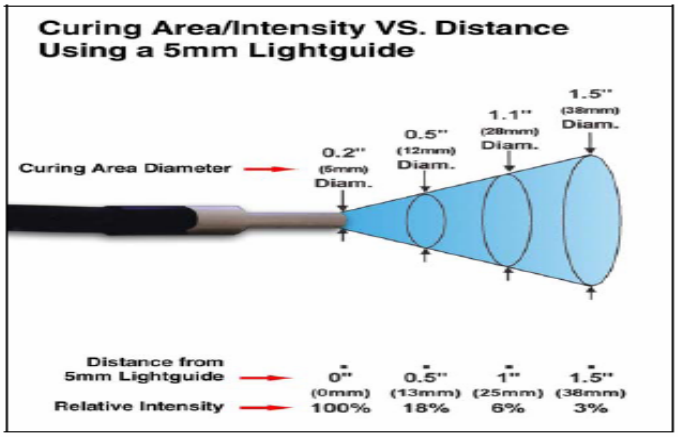


FIGURE 12—CURING AREA/INTENSITY VS DISTANCE

- **LIMITED DEPTH OF CURE.** Since light curing materials themselves absorb light, each has a maximum depth of cure. This depth of cure is usually at least between 0.250 and 0.500 inches but it does vary depending upon the material used, the light source, the intensity of that source and the time the adhesive is exposed to the light. The diagram below is from 3M and as you can see, the depth of cure is basically a function of the cure time. Please note that for LC-1211, the visible light source will produce a depth of cure superior than the UV light source. This will definitely vary from material to material.

Light Cure Adhesive
LC-1211

Cure Depth vs. Exposure Time

Note: The following technical information and data should be considered representative or typical only and should not be used for specification purposes.

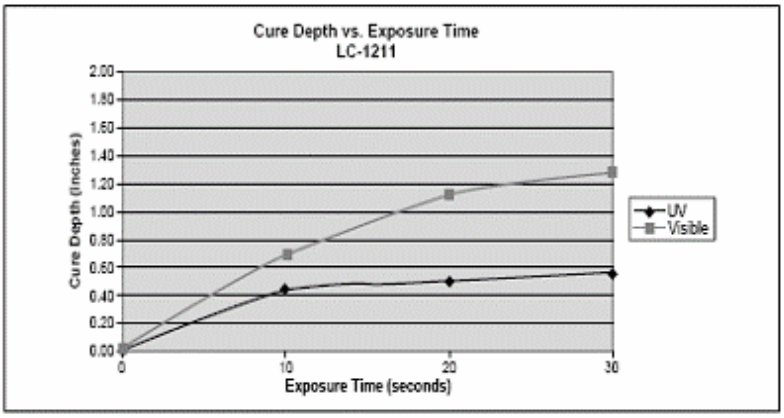


FIGURE 13—CURE DEPTH VS EXPOSURE TIME

- **DETERMINING DEPTH OF CURE.** Changing from a liquid to a solid is a very simple definition of cure. Curing is complete when further light exposure no longer improves product properties. Quantitative testing can also determine the minimum exposure required for complete cure. I definitely recommend that this approach be used when qualifying an adhesive for any purpose. The proper amount of testing **MUST** be conducted to demonstrate successful curing. This also could lead to lower costs by virtue of speeding up the conveyor system or even using a lesser amount of adhesive. It's also critical to properly specify the bulb to be used, the intensity and the distance from the bulb to the substrate. Testing can do all of this for you.

- **SHADOWS.** It is very important to make sure that light reaches the bond line and that there are no shadows to preclude attainment of the proper exposure. Wavelength, intensity and duration are definitely required and must be properly specified. This can be a cause for incomplete curing and lack of hardness to a cured sample.

- **OXYGEN INHIBITION.** In some cases, UV adhesive surfaces exposed to oxygen during curing may remain tacky after cure. This is caused by oxygen inhibition. Oxygen in the air actually slows the cure at the top-most layer of an air-exposed coated surface. This tackiness does not necessarily indicate incomplete cure and can be observed with some materials, even after complete cure. There are basically four ways to improve this situation. These are 1.) Longer and /or higher intensity cure, 2.) Use of "shortwave" bulbs, 3.) Choose and alternate material and 4.) Blanket the substrates with an inert gas.

- **SPECTURAL OUTPUT.** Success in curing demands matching the spectral output of the bulb with the adhesive material itself. The best advice is to work very closely with the material supplier

and adopt his recommendations to insure the proper match. As we have seen, the type of bulb, distance from the source of light to the work, time of exposure, etc all contribute to success in curing.

- **CURING AREA.** The area of the substrate to cure may dictate the process and the type of lamps to use. Spot lamps are typically used to cure areas less than 0.500 inches in diameter. Flood or focused-beam lamps are used when curing larger areas; i.e. up to 8.00 x 8.00 inches. Multiple flood lamps can be used to cure even larger areas or provide for longer duration under the lamp. Some products may require a combination of spot, flood or focused-beam light sources. Please don't forget that LED sources can help solve very specific problems for some product designs.

- **SAFETY.** Proper equipment set-up and operator training are absolutely necessary and are the keys to developing a safe process. The right shielding and personal safety equipment are a real must. This is such an important concern we are devoting a section just towards providing a safe working area for employees.

- **CONTROLS.** We are going to discuss equipment and controls later on in the course but suffice it to say the right equipment, well maintained and properly controlled, is an absolute must for continued effectiveness. The proper controls can provide for an automated process that removes the majority of human error and increases output.

CHEMISTRY AND ADHESIVE CLASSIFICATIONS:

We have already stated that the very first light-cure adhesive was an **acrylic-base** type. This introduction occurred approximately forty years ago. Since that time, there have certainly been other types of adhesives, all with their own characteristics, reaching the commercial market place. Basically, there exists today a fairly broad range of materials meeting exacting specifications and standards. Light-cure adhesives may be **acrylic, cyanoacrylate, silicone** or **epoxy**. Each classification has mechanical characteristics peculiar to that classification and each will be better suited for a specific application depending upon the substrate(s) used. Each will have a "best" method of application, viscosity, hardness, cure time, depth of fill, etc so it is best to consult with the adhesive vendor prior to any specification or use. I would like now to demonstrate the range of materials and classifications by providing information from the Loctite Corporation. This information comes from their " Adhesive Sourcebook", Vol 5, 2005. Please note that all manufacturers provide the same type information relative to their products. I have used Loctite simply to demonstrate the products, adhesive classifications and recommended uses. There will be tables and charts later on in this write-up to demonstrate mechanical characteristics and selection guidelines.

ACRYLIC LIGHT-CURE:

Product 352: Very high viscosity. Requires UV or visible light for curing.

Product 3103: A thixotropic material that cures with UV or visible light. Very tough and durable.

Product 3105: High-strength, low viscosity. Primarily designed for PVC and polycarbonate materials.

Product 3492: Fast curing, low viscosity primarily designed for bonding glass to glass.

CYANOACRYLATE LIGHT-CURE:

Product 4306/4307: Instant cure, one-component, low viscosity formulated for the most rapid cure.

EPOXY LIGHT-CURE:

Product 3335: Excellent for surface cure, no oxygen inhibition. Low outgassing, excellent high temperature resistance.

Product 3336: UV cure only. Designed for potting, bonding and sealing.

Product 3340: Good thermal, water and chemical resistance with metal, plastic and glass substrates

SILICONE LIGHT-CURE:

Product 5031: High adhesion, visible light cure adhesive. Excellent for difficult-to-bond substrates.

I will mention that 3M has a line of UV/visible light-cure adhesives called the "LC" line. It includes the following products: LC-1112, LC-1113, LC-1114, LC-1211, LC-1212, LC-1213 and LC-1214. All have specific characteristics including tensile strength, shear strength, peel strength, etc.

DYMAX, ThreeBond and Master Bond have product entries into the commercial market and offer a variety of products with very specific formulations. Specification sheets and "hazmat" sheets exist for all product types and all product part and / or model numbers. We cannot list all in this course but they are available from the manufacturers on-line or "hard-copy".

MECHANICAL PROPERTIES OF LIGHT-CURE ADHESIVES:

The mechanical properties of light-cure adhesives are absolutely no less important (or different) than the properties of any other adhesive. As such, they must be considered relative to the substrates and mechanical requirements for proper bonding. In looking at a typical product and /or application, we wish to investigate the following:

1. Cure mechanism; i.e. UV and/or Visible Light
2. Cure speed (UV and Visible)
3. Hardness
4. Odor
5. Viscosity
6. RoHS compliance
7. Tensile strength
8. Peel strength

9. Shear strength
10. Specific gravity
11. Color
12. Elongation
13. Water absorption
14. Cure depth
15. Shelf life
16. Resistance to solvents
17. Storage temperature

All of these properties must be investigated prior to selecting a light-cure adhesive for a specific application. We wish now to take a look at adhesives vs properties, and in doing so, give an idea as to what is available in the commercial marketplace.

Product	Adhesive Technology	Viscosity [mPa. s]	Colour	Fixture Time [s] (@ 6mW/cm² @ 365 nm)	Suitable for			
					Glass	Plastic	Metal	Ceramic
Loctite® 350	Acrylic	4500	transparent, light amber	15	●	○	●	○
Loctite® 352	Acrylic	15000	transparent, amber	10	●		●	●
Loctite® 358	Acrylic	2500	transparent, amber	6	●	○	●	○
Loctite® 385	Acrylic	4000	transparent, amber	15	●		●	●
Loctite® 3051*	Acrylic	1200	clear	20	●	●	●	○
Loctite® 3081	Acrylic	100	clear	10	●	●	●	○
Loctite® 3491*	Acrylic	1100	clear	12	●	●	●	○
Loctite® 3494	Acrylic	6000	clear	8	●	●	●	○
Loctite® 3525	Acrylic	15000	clear	5	●	●	●	○
Loctite® 3851	Acrylic	5000	transparent, pale yellow	12	●		●	●
Loctite® 5083	Silicone	paste	translucent, colourless	>30	●	○	●	●
Loctite® 5088	Silicone	65000	translucent, straw coloured	>30	●	○	●	●
Loctite® 5091	Silicone	5000	translucent, slight milky	>30	●		●	●
Loctite® 158587	Acrylic	paste	transparent, light amber	15	●	○	●	○

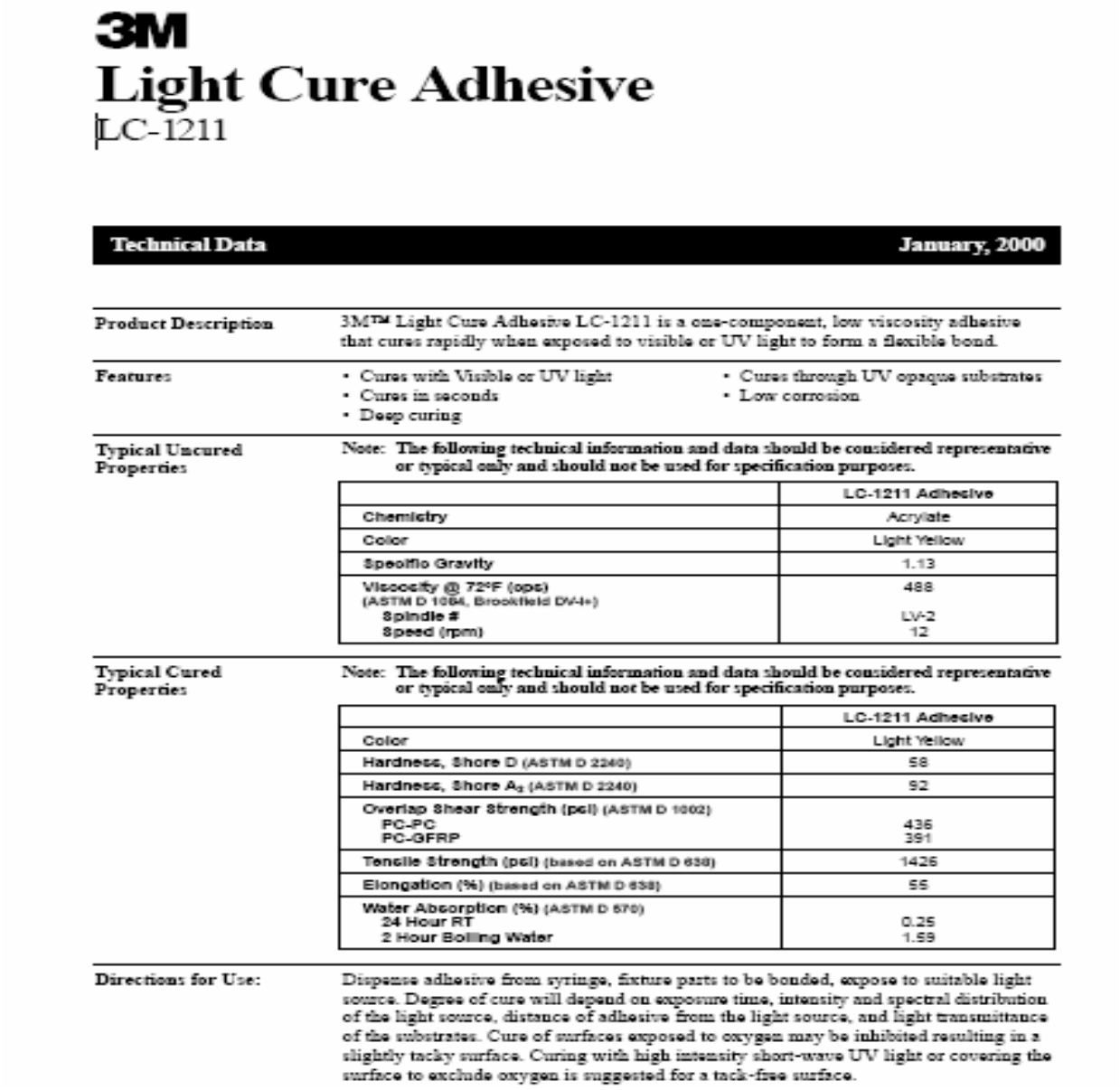
ISO 10993 certified or USP Class VI approved. Certificates of Compliance to ISO 10993 or USP Class VI approvals are available at www.loctite.com or through your local Henkel Representive.

● *excellent* ○ *good*

TABLE 2—LOCTITE SELECTOR GUIDE FOR INDIGO LIGHT-CURE ADHESIVES

This is a very basic chart from LOCTITE showing product type vs what that type is customarily used for; i.e. glass, plastic, metal, ceramic, etc. **It is a starting point that allows us to "zero in" on the proper adhesive classification**. Once that classification is selected, we can then go into the product data sheet to get additional specifics relative to recommended use. Please include in your investigation a look at the "Hazardous Material Data Sheet" for the product AND, if RoHS specifications exist, the material must comply or must be used only in the United States.

An example of a typical product data sheet is given below. Please note that 3M has given in the sheet; 1.) Product type; i.e. chemistry, 2.) Color, 3.) Specific Gravity, 4.) Viscosity, 5.) Hardness, 6.) Shear Strength, 7.) Tensile Strength, 8.) Elongation, 9.) Water Absorption, 10.) Directions for Use.



3M

Light Cure Adhesive

LC-1211

Technical Data **January, 2000**

Product Description

3M™ Light Cure Adhesive LC-1211 is a one-component, low viscosity adhesive that cures rapidly when exposed to visible or UV light to form a flexible bond.

Features

- Cures with Visible or UV light
- Cures in seconds
- Deep curing
- Cures through UV opaque substrates
- Low corrosion

Typical Uncured Properties

Note: **The following technical information and data should be considered representative or typical only and should not be used for specification purposes.**

	LC-1211 Adhesive
Chemistry	Acrylate
Color	Light Yellow
Specific Gravity	1.13
Viscosity @ 72°F (cps) (ASTM D 1084, Brookfield DV-II+) Spindle # Speed (rpm)	488 LV-2 12

Typical Cured Properties

Note: **The following technical information and data should be considered representative or typical only and should not be used for specification purposes.**

	LC-1211 Adhesive
Color	Light Yellow
Hardness, Shore D (ASTM D 2240)	58
Hardness, Shore A_2 (ASTM D 2240)	92
Overlap Shear Strength (psi) (ASTM D 1002) PC-PC PC-GFRP	 436 391
Tensile Strength (psi) (based on ASTM D 638)	1426
Elongation (%) (based on ASTM D 638)	55
Water Absorption (%) (ASTM D 570) 24 Hour RT 2 Hour Boiling Water	 0.25 1.59

Directions for Use:

Dispense adhesive from syringe, fixture parts to be bonded, expose to suitable light source. Degree of cure will depend on exposure time, intensity and spectral distribution of the light source, distance of adhesive from the light source, and light transmittance of the substrates. Cure of surfaces exposed to oxygen may be inhibited resulting in a slightly tacky surface. Curing with high intensity short-wave UV light or covering the surface to exclude oxygen is suggested for a tack-free surface.

FIGURE 14—PRODUCT DATA SHEET FOR 3M LC-1211

Another rendition depicting a light-cure selection guide is given as follows:

3M™ Light Cure Adhesives

	Product	LC-1112	LC-1113	LC-1211	LC-1212	LC-1213	LC-1214
	Cure Mechanism	UV	UV	Visible, UV	Visible, UV	Visible, UV	Visible, UV
	Cure Speed UV (sec)[1]	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	Cure Speed, Visible (sec)[2]	NA	NA	<5	2	2	<5
Typical Uncured Properties	Base Resin	Acrylate	Acrylate	Acrylate	Acrylate	Acrylate	Acrylate
	Color	Colorless	Colorless	Light Yellow	Light Yellow	Light Yellow	Red
	Specific Gravity	1.14	1.13	1.13	1.14	1.13	1.05
	Viscosity @72°F (cP)[3]	15,460	641	488	12,720	560	44,000
Typical Cured Properties	Color	Colorless	Colorless	Light Yellow	Light Yellow	Light Yellow	Yellow
	Shore D Hardness[4]	83	71	69	83	69	40
	Tensile Strength (psi)[5]	4600	2377	1426	4508	1929	1320
	Elongation (%)[5]	17	57	55	15	44	219
	2 lb Dead Lead Heat Resistance (°F/°C)	>300/149	>300/149	>300/149	>300/149	>300/149	>300/149
	Overlap Shear Strength, PC-PC (psi)[6]	411	522	436	455	566	540
	Max Cure Depth UV (in)[7] / Max Cure Depth Visible (in)[8]	0.69 / NA	0.56 / NA	0.94 / 2.52	>1.00 / 2.06	0.78 / 3.656	0.42 / 0.65
	Comments	Semi-rigid bond. Passes 3M corrosion test on copper and aluminum. [9]	Flexible bond. Improved glass and metal adhesion. Passes 3M corrosion test on copper and aluminum. [9]	Flexible bond. Passes 3M corrosion test on copper and aluminum. [9]	Semi-rigid bond. Improved glass and metal adhesion.	Flexible bond. Improved glass and metal adhesion.	Very flexible bond. Color change indicator (red to light yellow).

TABLE 3 3M LIGHT-CURE ADHESIVES

This figure gives the product number vs. material specifications for hardness, tensile strength, viscosity, shear strength, etc. These characteristics are critical for determining if the material is suitable for those loads applied to the substrates. You would never specify an adhesive to accomplish a job when that adhesive would delaminate when cyclic loads are applied and when those loads are greater than given for the material in question. This determination is absolutely no different than evaluating a welded joint, riveted joint, etc. If a tensile strength of 3,000 PSI were required for a particular joint, 3M LC-1112 and 3M LC-1212 would be the only choices when considering a light-cure adhesive. As mentioned above, you would definitely need to check out the HAZMAT sheet for safety considerations and any RoHS requirements if the assembled product is sold in the EU.

The following table is another cut from a selection guide source. The manufacturer is LOCTITE. From this you can see the considerations that are given to the engineer or engineering manager for selecting the proper type of adhesive.

LOCTITE® BRAND LIGHT CURE ACRYLIC ADHESIVES PROPERTIES CHART

PRODUCT	Item Number	Container	Appearance Clarity/Color	Cure Type	Key Substrates	Viscosity, cP Brookfield, 25°	Elongation at Break, %	Shore Hardnes	Temperature Range
349™ Impruv®	34931 34990	50 ml bottle 1 liter bottle	Clear/ straw	Ultraviolet	Glass, metal	9,500	300	D 70	-65°F to 266°F
352™	35241 35286	50 ml bottle 1 liter bottle	Clear/ light amber	Ultraviolet, heat, activator	Glass, metal	19,500	290	D 60	-65°F to 275°F
363™ Impruv®	36331 36390	50 ml bottle 1 liter bottle	Clear/ pale straw	Ultraviolet	Metal, thermoset plastic	250	88	D 50	-65°F to 356°F
366™	36631 12224	50 ml bottle 1 liter bottle	Clear/ light amber	Ultraviolet, heat, activator	Glass, metal	7,500	240	D 45	-65°F to 230°F
3100™	19862	25 ml syringe	Slightly hazy/ straw	Ultraviolet, visible	Glass, metal, thermoset plastic	6,000	210	D 66	-65°F to 300°F
3101™	19861	25 ml syringe	Slightly hazy/ straw	Ultraviolet, visible, heat, activator	Glass, metal, thermoset plastic	6,000	220	D 66	-65°F to 300°F
3102™	23690	1 liter bottle	Clear/ pale straw	Ultraviolet, visible	Polycarbonate, thermoplastic	3,750	265	D 59	-65°F to 300°F
3103™	23691 23692	25 ml syringe 1 liter bottle	Clear/ pale straw	Ultraviolet, visible	Polycarbonate, thermoplastic	10,000 Thixotropic	260	D 51	-65°F to 300°F
3104™	23694 23693	25 ml syringe 1 liter bottle	Clear/ pale straw	Ultraviolet, visible	Polycarbonate, thermoplastic, polyvinylchloride	160	50	D 69	-65°F to 300°F
3105™	23695 23696	25 ml syringe 1 liter bottle	Clear/ pale straw	Ultraviolet, visible	Polycarbonate, thermoplastic, polyvinylchloride	300	265	D 64	-65°F to 300°F
3106™	23697 23698	25 ml syringe 1 liter bottle	Clear/ pale straw	Ultraviolet, visible	Polycarbonate, thermoplastic, polyvinylchloride	5,000	250	D 53	-65°F to 300°F
3107™	28419 28466	6 ml tube 1 liter bottle	Clear/ straw/ fluorescent	Ultraviolet, visible	Plasticized PVC, thermoplastic	500	220	D 27	-65°F to 300°F
3108™	28400 28465	25 ml syringe 1 liter bottle	Translucent/ colorless	Ultraviolet	Thermoplastic, thermoset plastic	5,100	330	A 72	-65°F to 300°F
3175™	29505 29506	25 ml syringe 1 liter bottle	Clear/ straw	Ultraviolet	Various	4,000	14	D 70	-65°F to 300°F
3491™	28366 17944	25 ml syringe 1 liter bottle	Clear/ pale straw	Ultraviolet	Glass, metal	1,100	27	D 75	-65°F to 300°F
3492™	28367 18666	25 ml syringe 1 liter bottle	Clear/ pale straw	Ultraviolet	Glass, metal	500	5	D 79	-65°F to 300°F
3493™	28368	25 ml syringe	Clear/ pale straw	Ultraviolet	Glass, metal	5,500	260	D 75	-65°F to 300°F

TABLE 4 LIGHT-CURE ACRYLIC PROPERTIES

PROCESS CONSIDERATONS:

In looking at the overall system requirements, the following consideration needs to be factored into any one particular decision making process:

- **Choose Material**—We have taken a look at how this is accomplished. First, the system loads must be calculated so that those loads applied to any one joint are determined. The classical way to accomplish this is by developing a "free-body diagram" of the part or system of parts and apply the relative loads. You **MUST** consider all loads and the frequency of those loads applied. If the loading is cyclical, what is the frequency? What is the expected life of the product? Are there maintenance and repair schedules considered to examine the joint for continued viability? These are areas of concern that must be addressed.

- **Cure Time**—It may be critical to select an adhesive in which the cure time is rapid; i.e. under 10 seconds. It may be critical to select an adhesive in which the cure time is prolonged. A slower cure time may be necessary for proper positioning of parts and subassemblies.

- **Choose the Proper Curing System**—There are three basic system types: 1.) Spot, 2.) Flood and 3.) Focused Beam. These three systems are demonstrated by the following figure:

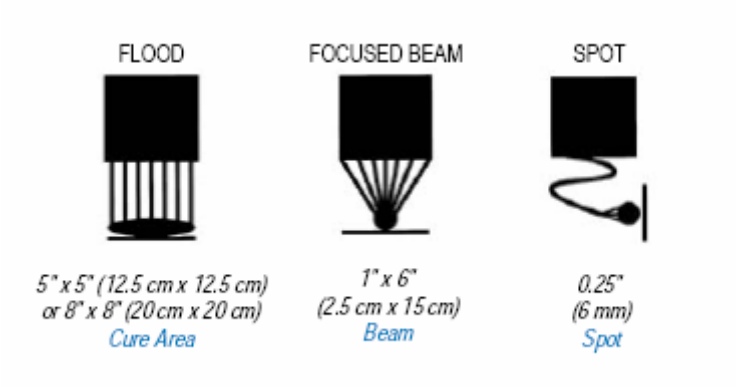


FIGURE 15 CURING SYSTEMS

A **spot system** generally provides a very high intensity light source over a much smaller area, typically less than 0.50 inches. These intensities usually produce a cure time between 0.50 and 5 seconds. Extremely rapid curing is sometimes needed as a result of product design. Spot lamp systems are ideal for curing small areas very quickly and can be easily integrated into an automatic assembly process or used as a turn-key bench-top process.

Flood lamp systems can offer moderate to high intensity light over a large area, typically 5" x 5" x 5" or 8" x 8". This type of system can cure many small parts simultaneously and can be incorporated into conveyors, automated assembly systems or used as turn-key bench-top curing systems.

Focused-beam systems provide very high intensity and narrow curing area. Assembly line speeds of 3 to 30 feet per minute are typical and conveyor systems are the conventional wisdom when using a focused-beam system. This intensity gives an exposure between 0.20 and 2 seconds depending upon the placement of the lamp relative to the work.

A combination of all three systems can be used depending upon line speed requirements and cure time needed. With this being said, the three steps given below will provide for the most effective system chosen.

- **Determine the Lowest Acceptable Intensity—**The lowest acceptable intensity is the one that fully cures the adhesive within the available cure time needed to accomplish production quantities. This is only determined through quantitative testing. Parts tested at various exposure intensities will determine the level of intensity required for any one given system.

- **Monitor and Maintain Light Source Intensity—**This is critical because there can be degradation of the system over time in which the hardness and cure depth are not reached. The intensity, at the part, must be checked frequently to insure the light source is within specifications.

- **Controls**—The last item to be considered in the systems area are the controls that will operate the entire process. Depending upon the parts to be produced, there will probably be a need for fixturing until the cure time is reached. This definitely needs to be considered. Also, shielding, shutters and protection against escaping UV radiation will need to be looked at before production begins. As stated before, when considering controls, automate the process as much as possible to remove human variation, or at least as much as possible.

SAFETY:

OSHA does not currently regulate UL light in the workplace but the American Conference of Governmental Industrial Hygienists (ACGIH) does recommend threshold limits for UV light. The strictest interpretation for eyes and skin is 1 mW/cm^2 for continuous exposure. To put this into perspective, cloudless summer days in Connecticut regularly exceed 3 mW/cm^2 of UV light. **The human eye cannot detect pure UV light, only visible light so a radiometer should be used to measure any stray UV light to confirm the safety of the curing process.** A workstation that continuously exposes a worker to UV radiation greater than 1 mW/cm^2 should be redesigned. There are two ways to protect the worker from excessive UV radiation: 1.) Shielding the operator and 2.) Shielding the source. When shielding the operator, eye and skin protection can be used. When shielding the source, sheet metal, rigid plastic film and shutters can be used. The figures below will give an indication as to what type of equipment is available to maintain an acceptable level of safety.

30" Wide UV Curing Conveyor

FIGURE 16 CONVEYOR SYSTEM

ACCU-CAL™ 50 Radiometer

FIGURE 17 RADIOMETER

ZIP™Shutter – Timed and manual modes. Foot pedal or PLC controlled. PN 37863

FIGURE 18 SHIELDING

Tinted "Over the Eyeglasses" Eye Protection 99.9% UV Blocking
PN 35285

Clear "Over the Eyeglasses" Eye Protection 99.9% UV Blocking
PN 35284

[1]DYMAX also provides special order "shortwave" bulbs that emit primarily UVB and UVC light. Contact DYMAX directly for information regarding the use of "shortwave" bulbs.

FIGURE 19 EYEWARE

CONCLUSIONS:

Light-cure adhesives represent an advancement that has allowed for products that could have not been manufactured two or three decades ago. Designs destined for the "basket" can now be visualized, prototyped, tested and mass produced with regularity and the only restraint is imagination.

LIGHT-CURE ADHESIVES

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