Manufacturer:
Dymax

Product Name:
Dymax BlueWave® 200 UV Curing Spot Lamp with Foot Switch (V3.1)

Manufacturer Part Number:
41015

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Validating a Spot-Curing Process

Ensure your light-curing process performs accurately every time

Since their initial introduction into manufacturing processes over 30 years ago, light-curable adhesives and coatings have continued to gain recognition as significant drivers for improved productivity and overall process cost reduction. In fact, they have become the preferred assembly method in many manufacturing industries. The basic components of a light-curing process consist of a light-curable adhesive, dispensing system, and curing energy source (spot, flood, or conveyor curing system). The key to a successful process is ensuring a compatible match among all aspects, therefore the best consultants are the companies that design, manufacture, and sell all three components. They have the technical expertise to make sure the entire process is compatible and will run smoothly without any problems.

Once an adhesive, dispensing method, and curing system is selected, the process must be qualified prior to production start-up, and then steadfastly maintained during actual production. Validating a curing process is essential to its success. The process of validation is different for each style curing system. In this paper we discuss how to validate a spot-curing system.

Validating a Spot-Cure System

Once a manufacturer has identified the adhesive, the amount of adhesive in each bond, and the light-curing spot lamp system they will be using, they will need to specify the exposure time and an acceptable intensity range. The following process is suggested to determine the exposure time and intensity range required:

1) Define Full Cure

Identify a parameter (or group of parameters) that can be practically measured to indicate full cure. Physical properties of the cured adhesive or coating are most often used for measurement and correlation to full cure. Full cure is defined as the point at which additional cure time or additional intensity no longer improves these physical properties. Commonly used criteria include bond strength, hardness, and surface tack. Measurements are typically made on parts that have returned to room temperature after curing exposure cycle.

2) Determine Minimum Intensity and Exposure Time

Determine the minimum exposure time and intensity required to achieve full cure. Users can determine the minimum intensity and exposure time in one of two ways:

Set exposure time and vary the intensity to determine the minimum intensity. Exposure time is selected first so as to avoid creating a bottleneck in the assembly process. This is also called the "tact time" with many manufacturers using LEAN practices. In most manufacturing processes, there is a rate-limiting step that dictates throughput. As long as exposure time is not slower than the rate-limiting step, it will not be the bottleneck. If the minimum intensity associated with the chosen exposure time results in unacceptable bulb life, either a higher intensity curing system or multiple curing systems may be required.

Set intensity and determine the minimum exposure time. The processing intensity is selected first, so as to provide acceptable bulb life. This option would be selected if Tact Time was not as much of a concern as maximizing bulb life. If the minimum exposure time associated with the chosen intensity is considered too long, a higher intensity or multiple curing systems may be required.

Distance must be a constant. The distance between the curing energy source and target cure area must remain a constant for all methods of measurement. This is a key factor in process control as curing energy levels quickly decrease over distance as seen in Figure 5.

Determining the minimum intensity required for full cure in a specific application requires empirical testing. This testing typically involves measuring some physical property indicative of cure (adhesion or hardness, for example) while varying either exposure time or intensity. Figure 1 shows how this testing might be accomplished by setting exposure time and varying intensity. Some of today's light-curing spot systems allow users to adjust intensity manually.

3) Determine Your Safety Factor

Apply a safety factor to the minimum intensity determined in step 2 to determine the lower intensity limit. For example, if the minimum intensity required to cure an assembly within 5 seconds is 4.0 W/cm^2, the lower intensity limit would be 6.0W/cm^2 with a 50% safety factor. A safety factor helps to insure that the UV curing process can withstand unavoidable variations in the parts and process. As applications and manufacturing environments can vary significantly, it remains the responsibility of the user to assess and establish the minimum intensity limits and safety factors.

4) Define the Upper Intensity Limit

Determine the highest intensity that still produces acceptable parts without causing damage to the bonded substrates or resins (typically caused by overheating). This intensity may or may not exceed the maximum intensity of the UV curing system employed.

Your UV light-curing process now has both a lower and upper intensity specification and employs a safety factor as shown in Figure 2. By utilizing these four guidelines, a spot-cure system user can be very confident that the appropriate cycle time and curing intensity range has been established for the specific application under consideration.

Figure 1. Curing Energy Profile (Exposure Time Held Constant)

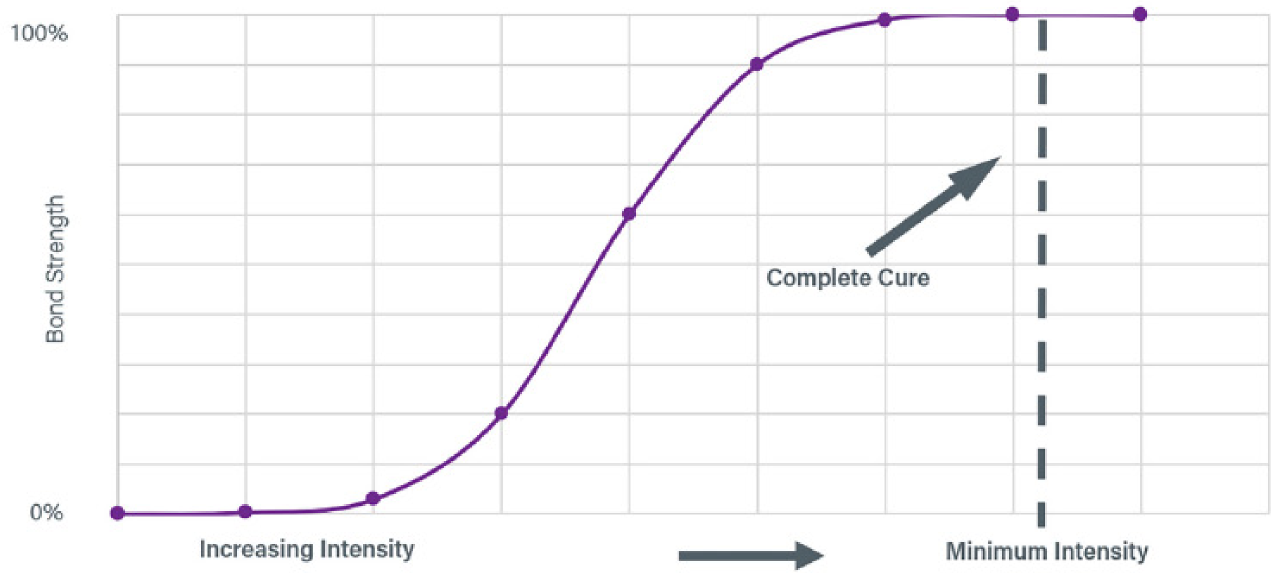

Figure 2. A Controlled UV Spot-Curing Process

Process Control

Once a process is validated, it is important for manufacturing to operate within the defined limits of the process. There are a number of concepts to consider when developing a controlled spot-curing process.

1) Monitor Intensity

Measuring intensity requires a radiometer, like the ACCU-CAL™ 50. (Figure 3) A radiometer measures intensity over a specified range of wavelengths. Intensity is best measured at the end of a lightguide, although a lightguide simulator can be used to distinguish bulb intensity from lightguide transmission. Measurement of lightguide transmission can identify if a lightguide is dirty or has been damaged. Recording intensities is necessary to document that the UV-curing process is controlled.

Figure 3. ACCU-CAL™ 50 Radiomenter

2) Adjust Intensity

Some spot-curing systems allow users to adjust intensity manually (Figure 4) or automatically. Since intensity tends to drop with time (whether manually or automatically controlled), the intensity set-point should be set closer to the upper intensity limit and should be periodically checked and re-adjusted. One manufacturer that offers automatic intensity control recommends re-adjusting intensity every 112 hours or sooner.

Figure 4. Manual Intensity Adjustment

3) Maintain a Consistent Distance from the Lightguide to the Part

Intensity varies dramatically with distance from the end of a lightguide. (Figure 5)

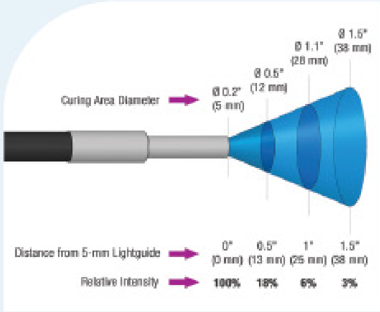

Figure 5. Curing Area/Intensity vs. Distance Using a 5-mm Lightguide

4) Maintain Lightguides

Dirty lightguides are the most common problem associated with proper operation of spot curing systems. Adhesives are the most common contaminates, but adhesive vapors can also build-up. In some applications, you may notice vapors emitting from the adhesive during the curing exposure step. These vapors can deposit on the end of the lightguide and reduce lightguide transmission by more than 50%. Because these vapors and cured adhesive residue are often chemically resistant, wiping with a solvent soaked cloth is typically ineffective due to the solvent resistance of many Light-curable materials. Scraping with a razor blade is often the best way to clean the end of a liquid or fused fiber optic lightguide. (Figure 6) Epoxied fiber-optic lightguides often require soaking in solvent.


Figure 6. Clean Lightguide End With a Razorblade

5) Documentation

Documentation methods and measurements are a critical aspect of any manufacturing process, and should be posted at the work station, not filed away. Documentation that is readily available is more likely to be followed. Documenting the following items is strongly recommended. Table 1 is an example of a UV-curing intensity record that incorporates the following items:

- Radiometer and detector serial number and calibration date
- Intensity measurements
- Setup and shutdown procedure
- Intensity limits of the process
- Exposure time
- Distance from the lightguide to the part
- Intensity measurement method and frequency
- Intensity re-adjustment method and frequency
- Lightguide cleaning method and frequency
- Bulb replacement method and bulb change history log

Table 1. Example of a UV Spot-Curing Intensity Record

Station 1 – UV Spot-Curing Intensity Record	
Equipment	ACCU-CAL™ 50, SN:15289M/16258 (calibrated Sept. 9, 2019, calibration due Mar. 9, 2020)
Radiometer Settings	Light source (5-mm lightguide), Mode – (Peak Intensity)
Frequency	7:30 am and 4:30 pm daily. Allow UV equipment 5 minutes warm-up before measurement.
Distance from Lightguide to Part	13 mm (0.51 in.)
Exposure Time	6 seconds
Intensity Limits	6.00W/cm² to 9.00W/cm².....set daily at 8.00W/cm²

Time	Intensity before cleaning	Intensity after cleaning	Intensity before resetting
7:28 am	6.71 W/cm²	7.97 W/cm²	8.00 W/cm²
4:34 pm	7.31 W/cm²	7.99 W/cm²	8.00 W/cm²
7:35 am	7.21 W/cm²	7.97 W/cm²	8.00 W/cm²

6) Eliminate or Understand Possible Variations

The more variation that is eliminated from a curing process, the more controlled the process will be. If a variation cannot be eliminated, it should be understood and worked into the process. We have already mentioned maintaining lightguide cleanliness, distance, and intensity. Other sources of variation include:

Lightguides: The number of bends and the bend radii can alter the output of a lightguide. Multi-pole lightguides require balancing (liquid only) to increase the uniformity of intensity output between each pole. If improperly installed, a lightguide mounted to a moving component such as an XYZ table could notice increased wear and degradation over a stationary lightguide.

Lamps: Natural variations in the components that construct lamps used in light-curing systems will lead to variations in initial intensity output. This will be most noticeable when changing out an old lamp for a new lamp. Lamps also degrade at different rates, depending upon their initial intensity, but all will exhibit similar degradation curves.

Radiometers: Radiometers consist of a meter and a detector. These two components are calibrated as a matched set. Interchanging a detector between meters will certainly lead to repeated inaccurate measurements that can be wildly out of range. The calibration process individually calibrates each radiometer set to a single transfer standard within an acceptable deviation limit.

When comparing two radiometers to each other, the stacking of deviations could indicate significant differences in measurement that may seem unacceptable, but each radiometer is in fact accurate when compared to the calibration standard. For this reason it is strongly recommended for a single radiometer to be used when monitoring the daily activities of a production line.

A second radiometer should only be used when the main radiometer is returned to Dymax for calibration. At this time, the radiometers should be compared together to understand what the deviation is between the two units, and will help the user to understand the difference in measurement they may begin to witness when using the secondary radiometer.