UVacise-Hands-On Exercises to Better Understand Your UV System, UV Measuring Instruments and UV Process

The purpose of UVacise is to understand the variables that must be controlled when using UV, and the interaction between the equipment and instruments.

The Benefits of UVacise

• "UVacise" — a series of exercises to help you understand your UV system, UV measurement instruments and UV process.

• UVacise — practiced in your manufacturing facility, not a fitness club. No class, club, initiation or monthly dues.

• If UVacise is practiced and its lessons applied, it may lead to time and money savings in your facility.

At SGIA '02 in St. Louis, I presented a hands-on workshop on UV measurement. This article is adapted from the workshop. Rather than listening to a classroom style lecture, workshop participants moved around to different exhibitors on the SGIA show floor. Several exhibitors (listed at the end of this article) helped with the workshop, agreeing to power their UV systems for its two sessions. Different UV systems were used. At each stop, workshop participants ran through a series of exercises that illustrated UV measurement principles and familiarized them with different types of UV measuring equipment.

The purpose of UVacise is to understand the variables that must be controlled when using UV, and the interaction between the equipment and instruments. It's not designed for comparing different UV instruments or UV systems. Communicate often when it comes to purchasing UV equipment. It is best to coordinate buying decisions for equipment with your formulator, substrate and press equipment suppliers. In that way, you'll be most likely to avoid problems and to match the equipment to the process.

With your UVacise regimen, you should be able to accomplish the following:

• Gain a better understanding of your system and understand what 'normal' performance is for your system.

• Recognize and compensate for changes in your UV system.

• Understand the cause and effect of changes in user controlled variables such as input power or process speed.

• Establish a preventative maintenance schedule.

• Gain a better understanding of your process and operate in the 'window' or 'zone' that produces good quality and consistent results.

• Improve your bottom line with increased throughput, reduced scrap and reduced downtime — especially unscheduled downtime.

Guidelines for the UVacise program

1. Before beginning an exercise program, experts recommend a checkup with your doctor. Before beginning the UVacise program, I recommend a checkup for your UV system with a UV doctor — a specialist who understands your UV equipment. Your 'specialist' may be the manufacturer or supplier of your UV equipment.

Your checkup should verify that your UV system has been installed and maintained as designed. Besides taking a look under the reflector, your specialist may also want to check the power supply, cooling (air/water) and transport mechanisms such as conveyors. Your UV system specialist may want to consult with other specialists (e.g., UV formulators and equipment and substrate suppliers) during the checkup. Working as a team, the specialists can offer technical assistance and guidance pertinent to your process.

2. Establish a mechanism for sharing your checkup results within your facility and with suppliers that have a need to know. Communicate often. Use language,

By **Jim Raymont,** Director EIT Instrument Markets

UV System Information

Line: Identify the production line. Use the press name, press type or location if you have multiple units.

System: Identify the UV system if there are multiple systems on a press. Examples: Station 4, varnish

Line Speed: Measurements in actual values (e.g. feet/minute, meters/minute) are more useful than relative indicator settings such as "Setting 4." Independently confirm values with a tachometer.

Bulb Type: Confirm the bulb type you use in your system. If you use different bulb types, mark the type of bulb currently installed to avoid confusion — tape or magnetic strips work well. Also, agree on bulb names — Do you use a mercury or an 'H' bulb? What type of bulb is your mercury additive bulb? Mercury-iron, mercury-gallium, metal halide, D or V?

Input Power: The electrical power (volts x amps) applied to the system, divided by the length (inch or centimeter) of the bulb. Typical system input power values range from 200–600 watts per inch (80–240 watts per centimeter).

Instrument Used: Allow equal comparisons. Also, note the bandwidth of the instrument and any user adjustable settings on the instrument.

Bulb Hours: Record if possible. This may allow you to better evaluate bulb life and stability.

Comments: Other system parameters, last maintenance action and date. For production, issues related to your inks and coatings could be recorded here.

terms and numbers that are clear, defined and easy to understand. *Note: The RadTech Website (www.radtech.org) has a Glossary of UV Measurement Terms that can help with communication.*

3. Document your equipment and process conditions before starting this program and while things are curing. A few of the seminar participants at SGIA '02 commented that the exercises were repetitive. Yes, they are, and I will not make any apologies. Using measurement equipment and maintaining a process window or zone is repetitive. The whole purpose of process control is to repeat the conditions that lead to good quality products. Hopefully, this repetition will not be a problem — especially if it allows you to consistently operate in the zone that makes your company money and saves you time. Being able to measure and maintain a set of conditions day-to-day and week-to-week is a good thing. I suggest that you record the information about your system for each exercise so that you can go back and refer to it later and have the collection and UV system conditions in one place. The form below, Table 1, should be used with each exercise. Refer to the UV System Information in the box to the left for a description of helpful information to add to Table 1. I have included comments to help you better understand the information that should be recorded. You may also want to track these variables on a process control worksheet/log.

4. Just as exercise programs or routines target different areas of the body, UVacise groups exercise different categories — UV systems UV measuring instruments and UV processes. Choose the exercises that are appropriate for your equipment.

The basics of UV measurement and the proper use of measurement equipment have been discussed in previous issues of the SGIA Journal. You can find the following articles online at SGIA.org.

• Third Quarter 2001, "Life After the Honeymoon — Getting to Know, Understand, Respect and Live With Your UV System and Process"

• Third Quarter 2002, "Radiometers — The Best of Intentions — Tips on Properly Using and Understanding the Numbers From Your Radiometer)."

UV System Information
Line: ______
System: ______
Line Speed: ______
Bulb Type: ______
Input Power: ______
Instrument Used: ______
Bulb Hours: ______
Comments: ______

Table 1

Speed/Exposure Time *(actual speed, in feet or meters/minute)*
Radiant Energy Density (J/cm^2)
Irradiance (W/cm^2)

Table 2

Speed (feet per minute)	10 fpm	20fpm	40 fpm	80fpm
Radiant Energy Density (MJ/cm^2)		400 mJ/cm^2		

Table 3

UV System Exercises

UVacise-Process Speed Variations

In this exercise, you'll take measurements at various line speeds/exposure times to examine the relationship between the exposure time and the radiant energy density (J/cm^2).

It is important to:

• Understand how changes in process speed impact the joules that reach your ink or coating

• Understand if the speed controller on your UV system is accurate and operates in a linear fashion

• Understand if your UV measurement equipment has any collection speed limitations

Exercise and Data

1. Fill in table 1 for the UV system you are using. Line speed will vary for this exercise.

2. Collect radiant energy density data at two or more line speeds/exposure times. Fill in table 2.

3. If your measurement instrument also records irradiance (W/cm^2) note those readings as well. See table 2.

Test Results/Comments

1. What did the radiant energy density do as line speed increased?

2. What happened to the irradiance values as line speed increased? Why?

3. The radiant energy density is inversely proportional to line speed. If line speed doubles, the radiant energy density should become approximately half the

original value. Did this happen in your example? See table 3.

4. The inverse relationship shown in the previous table between line speed and radiant energy density can help you to predict approximate joule values at different production speeds. A reading was taken at 6.1 meters/minute (20 feet/minute). Fill in the approximate joules/cm^2 that are expected at the different production speeds listed below.

5. Use the formula $E_x=E_aV_a/V_x$ to calculate radiant energy density values at any speed.
E_x= the energy density you are calculating.

E_a= the measured energy density measured.

V_a = the speed at which it was measured.

V_x = the new speed for which you are trying to calculate E_x.

If you have a few common production speeds it will be helpful to figure the joule values expected.

UVacise: Input Power Variations

To calculate input power for a UV system, multiply voltage by amperage, then divide by the length of the bulb (inches or centimeters). Typical results are 200–600 watts per inch and centimeter values 80–240 watts per centimeter. The applied power value does not indicate the amount of UV produced or the amount of effective UV delivered to the cure surface — this needs to be measured with a radiometer.

In this exercise, readings will be taken at two or three different power settings. All other variables on your UV system should remain the same between the tests. For each and every UV system that you use, it is important to document the expected irradiance and energy density values at different input power settings.

Exercise and Data

When switching between applied power settings, allow the system a few minutes to stabilize after the switch is made. Consult the owners manual for your system for more information. Use a new table 1 to fill in the values (Input Power will vary for this exercise) and 4.

Test Results/Comments

1. What happened to the radiant energy density when the power on the system increased?

2. What happened to the irradiance value when the power on the system increased?

Applied Power Setteing (WPI)	Radiant Energy Density (J/cm^2)	Irradiance (W/cm^2)

Table 4

3. Did the values track each other?

4. Were the increases linear in respect to the increase in the WPI power setting?

UVacise: Variable Power Supplies

UV systems have evolved, and many can now be ordered with power supplies that step the power in small increments instead of in two or three fixed steps. The variable-power feature on your system can be adjusted, based on process parameters, once you have documented its performance. If you have a variable power supply system, consult your manual for guidelines on the minimum power suggested for the type of bulb you are using. Also allow the system to stabilize for a few minutes after making changes. Fill in the values on a new table 1 (Input Power will vary for this exercise)

Exercise and Data

1. How small are the adjustment steps with this system?

2. What does this manufacturer recommend as the minimum power to operate the system?

3. How does your power supply make the changes?

4. Use your UV measurement equipment to take readings at the suggested input power settings in the table 5.

Suggested Power Setting	50%	60%	70%	80%	90%	100%
Radiant Energy Density (J/cm^2)						
Irradiance (W/cm^2)						

Table 5

Test Results/Comments

1. Compare the values. How do they track?

2. Were the results linear? Does increasing the power setting from 50 percent to 100 percent double the effective UV reaching the cure surface?

3. What advantages does a variable power supply offer a printer?

UVacise — UV System Changes Focus

UV systems are carefully designed and manufactured to deliver UV in a specific manner and pattern to the substrate. The materials, reflector shape, bulb diameter, cooling mechanism and physical distances have all been carefully selected and matched to the design. Any changes to the system can result in changes in the manner and pattern in which UV is delivered to the substrate. Substituting improper or different parts can change the amount or pattern of UV delivered to the substrate. A malfunction in the cooling system (e.g. clogged air, reduced water flow) can cause the system to overheat. Changes may also occur as a result of improper reassembly of equipment after maintenance.

One change that is seen sometimes, and can easily be duplicated and demonstrated, is the focus of the UV system. The focus of a UV system is a function of distance. Some processes work well in a sharply focused system while others lend themselves better to systems that are not tightly focused.

Changes can occur when *(refer to Figure 1)*:

1. The position or shape of UV reflector or housing changes in relation to the substrate. Common causes are incorrect assembly or mounting the equipment in a different location after maintenance.

2. The position of the substrate changes in relation to the system. This could happen if the conveyor belt is loose or bounces around under the UV system.

3. The bulb changes in relationship to the reflector. This could happen through improper or forced assembly during maintenance (use of a hammer to beat the reflector into position) or though changes in the cooling where a bulb over heats and sags. Many times this is seen on a wide arc lamp system where the cooling has changed and is no longer adequate. The bulb bows and sags out of position.

Exercise and Data

1. If a profiling radiometer is available, use it for this exercise. Profiling radiometers plot the irradiance as a function of time. They work best for detecting the changes in focus in a UV system. If a profiling radiometer is not available, look for changes on your radiometer, especially on peak irradiance.

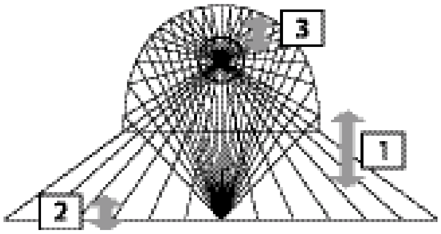


Figure 1

2. Fill in the data for your system in a new table 1.

Use a profiling radiometer (if possible) as it is normally setup to measure your system.

3. Change the focus on your systems: *(See Figure 2)*

• Raise the UV system up or down to make it closer or further away from the measurement surface. Some systems have a turntable to allow you raise or lower the UV source

• If there is room, another option is to run your measurement system through on a raised board or platform

5. Compare data from the two different height positions. Look closely at the irradiance values.

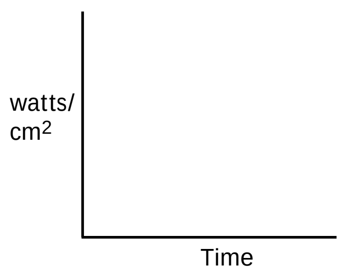
Test Results/Comments

1. If the instrument used was a profiling radiometer, save or draw the different shaped curves for the two positions *(See Figure 1)*. How do they compare?

2. How do the irradiance and radiant energy density values compare on your system when you change the focus?

UVacise-Effective Cure Width

The effective cure width is the length across your bulb that produces sufficient cure for your process. Placing your substrate in the marked effective UV cure width area will increase your throughput. Most systems use a bulb that is 10.2–15.2 cm (4–6 inches) longer than the widest substrate. It is important to document the effective cure width and to also look for variations across the width of the bulb.



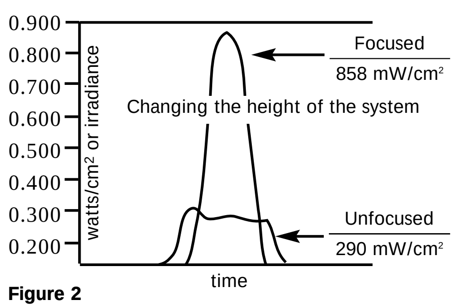


Figure 2

Changes can occur as the bulb and UV system age or as the cooling changes in the system. Changes can also be introduced if the system is reassembled incorrectly after maintenance. Differences in the UV output can lead to variations along either or both edges, and also sometimes in the middle of the substrate. Documenting each of your UV systems in several places across the width of the bulb will allow you to know when changes have occurred from either age or changes in the equipment.

Exercise and Data

1. A profiling radiometer or radiometer can be used for this exercise. If a profiling radiometer is used, I suggest leaving the radiometer on to keep the entire 'map' of the bulb on one file. The profiling radiometer will allow you to also check the focus of your system across the width of the bulb.

2. Fill in your system information in a new table 1.

4. Take readings every 10.2 cm–15.2 cm (4 inches–6 inches) across the width of your bulb. See table 6.

Test Results/Comments

1. Is your system consistent across the width of the bulb?

2. If need be, add a guide to your system to show where the substrate should be placed

3. Things to watch for on your own system:

• Most systems have slight variations across the width of the system. Get to know your system so that you can identify when changes take place in your system over time

• If both the left and right edge UV readings have decreased over time, check for aging in the bulb. If you are running substrate material that is the same or close to the same width as your effective cure width, it may be time to replace your UV bulb

• If you notice changes (they could be higher or lower) in the readings down the middle of your unit, check for possible sagging or bowing of the bulb. If possible, rotate the bulb 180º each time the reflector is cleaned. Sagging is easier to see with a profiling radiometer that plots the irradiance as a function of time

• If one side suddenly changes (higher or lower) check to make sure that the system has been re-assembled correctly after maintenance was performed

UVacise: Mercury Additive Bulbs

Mercury additive bulbs (also called doped, metal halide, gallium, iron, D, V) can be used in UV systems to produce a different spectral output than a standard mercury bulb. The spectral output from an additive bulb varies with the additive, and it can offer advantages for certain applications and coatings. The spectral output of the bulb must be matched to your chemistry formulation. The power supply of the UV system must also be able to support the additive bulb. If you are using additive bulbs in your facility, compare one to a mercury bulb. The best instrument for this is a multi-band radiometer, which allows you to measure short, medium and long wavelength UV with one reading.

Exercise and Data

1. Fill in a new table 1 for your UV system.

2. Without directly looking at the UV source, what differences do you notice about the color of the reflected visible light between the mercury bulb and the additive bulb?

3. Compare the radiant energy density and irradiance values in different UV regions between a mercury bulb and a mercury-additive bulb. Follow equipment instructions and allow the bulbs/equipment to cool when switching. Pay special attention to the spectral bandwidths and designations if using a multi-band radiometer. *(See Table 7)*

Test Results/Comments

1. Compare the values between the different bandwidths. What bulb type had the highest irradiance values in each spectral area? *(See Table 8)*

2. What are the irradiance ratios of UVA to UVV, UVB, UVC in Table 8:

The ratio of short to long wavelengths can help you to identify and confirm the type of bulb in your system. When the ratios change, it could indicate that maintenance is needed or that the bulb has aged.

UVacise: Exposure systems

Measurement, documentation and control of the UV on exposure machines used for films, plates and screens is just as important as measurement and process control on your curing units. Often, a sensor or integrator built into the exposure unit is the only thing used for process control.

Mercury additive bulbs can be used in UV systems to produce a different spectral output.

Units	**Left**				**Middle**				**Right**
Radiant Energy Density(J/cm^2)									
Irradiance (W/cm^2)									

Table 6

Bulb type	**Bandwidth**	**UVA**	**UVB**	**UVC**	**UVV**
	Inst Range (MN)				
Mercury	*Radiant Energy Density (J/cm^2)*				
	Irradiance (W/cm^2)				
Mercury Additive	*Radiant Energy Density (J/cm^2)*				
	Irradiance (W/cm^2)				

Table 7

Comparison	**Mercury**	**Mercury-Iron**	**Mercury-Gallium**
UVA : UVV			
UVA : UVB			
UVA : UVC			

Table 8

		Back		
Left		Front		Right

Table 9

Use a separate radiometer to confirm performance of the built in sensor, and also check different areas of the exposure surface for hot and cold spots and performance over time. *(See Table 9)*

Check to make sure that the radiometer you use has the correct dynamic range for the equipment. Instruments for high-intensity curing systems have a top dynamic range of 5 watts/cm^2 to 20 watts/cm^2. Instruments for exposure systems usually have top dynamic ranges in the hundreds of milliwatt range (0.10 W/cm^2) and can also read down into the microwatt ranges. (Metric system review: 1 Watt = 1,000 milliwatts= 1,000,000 microwatts.)

Exercise and Data

Determine what magnitude of UV is found in your exposure system. Also identify the bulb type and wavelength(s) to measure. Find an appropriate instrument. Check with the instrument manufacturer if you have questions. Fill in a new table 1. (Line Speed is most often measured in time (seconds) for exposure systems.)

Use your instrument and a grid system to map out an irradiance profile of your exposure system. Pick an exposure time and enter either the joules or watts in the grid. Fill in your system information in table 1. Line Speed is most often measured in time (seconds) for exposure systems.

Test Results/Comments

Evaluate your results to determine if you can expect consistent exposures in all areas of your film, plate or screen.

UV Measuring Instrument Exercises

Most types of radiometers were covered in the proceeding exercises on UV systems. The following two exercises look at two additional options for UV measurement. Decide if they will work for your process.

UVacise: Spectral Radiometers

Spectral radiometers measure and 'separate' UV light into very small bandwidths. Instead of reporting the UV in broad bands such as UVA (320-390 nm), spectral radiometers are able to separate UV into nanometers or fractions of a nanometer. (A nanometer is a billionth of a meter). The irradiance of the source is plotted not against time as with a profiling radiometer, but as a function of the wavelength.

Exercise and Data

Work with a manufacturer or supplier of spectral radiometers. Often, the manufacturer's representative or supplier can arrange for a demonstration of the instrument. Possible questions to ask during the demonstration:

1. What spectral range will the instrument(s) cover?

2. What is the resolution of the instrument?

3. Work together with the manufacturer or supplier to make measurements with the instrument.

4. In what units is the data collected?

5. What are some of the advantages of a spectral radiometer?

6. What type of applications or users could benefit from the type of information collected by a spectral radiometer?

6. What are some of the challenges for this instrument in the graphics industry?

UVacise: Radio-chromatic tabs

Radio-chromatic tabs offer an alternative to electro-optical based measurement instruments. There may be advantages for applications where space is extremely limited. The system needs to be evaluated for use with your system and type of UV source.

Exercise and Data

Work with a manufacturer or supplier of radio-chromatic tabs. See if the manufacturer's representative or supplier can arrange for a product demonstration. Possible questions to ask during the demonstration:

1. Examine the radio-chromatic system. On what types of UV print applications would the system be useful?

2. On what principle is the system based?

3. What is the spectral sensitivity range of the test strips?

4. Are some UV sources better suited than others for this system?

5. What are the maximum radiant energy density levels to which the strips can be exposed?

6. What units are used to report the UV on the dosimeter?

7. Follow the instructions for the system and run some test exposures to evaluate the system. Compare the readings for different line speeds or exposure conditions.

8. Can the results from the radio-chromatic system be coordinated with the results from a radiometer?

9. What advantages does the system have?

10. What disadvantages does the system have?

UV Process Exercises

Familiarity with your UV system and UV measurement instrument are important to UV success. Success with UV also depends on regular communication with your suppliers. Each supplier provides a piece to the UV puzzle. The pieces go together best when all suppliers understand the process and what is expected from their piece or contribution. If one supplier has different expectations or makes a change without communicating to you, the puzzle may not go together. This final exercise is a communication exercise with your ink or coating supplier(s). Repeat it with your other suppliers-substrate, bulb, UV, equipment, etc.

UVacise: Coordination and Communication

Communication between suppliers (ink, substrate) and equipment manufacturers (press, UV systems) is essential for successful UV curing. A small change in any variable can move you out of your process window and into the 'no-cure' zone. Lack of communication between suppliers and manufacturers during process design can result in combinations of equipment, inks and substrates that are not matched well to each other or the desired results. This mismatch can narrow the process window to a point where it is hard or even impossible to cure on a consistent basis. This exercise, while it does not directly have you measuring UV with a radiometer, is intended to explore some of the variables and points that need to be discussed with your ink supplier. Communication between suppliers is a key part of successful UV curing.

Exercise and Data

1. Coordinate this exercise with your ink and coating supplier.

2. Select a substrate that you currently use in your facility

3. Work with your supplier to determine the recommended ink/coating series for your substrate. Why is this series a good choice for your substrate?

4. What starting point cure or UV guidelines can your supplier offer for this ink series?

- Production speed
- Lamp settings
- Bulb type
- UV Radiant Energy Density (J/cm^2)
- UV Irradiance (W/cm^2)
- Other factors

5. Are there any heat or light exposure restrictions to the substrate?

Conclusion

1. Understand and learn about your UV system. Get a 'checkup' for your UV system.

2. Understand what 'normal' performance is for your system. Recognize and compensate/adjust for changes in your UV system to operate in the 'window' or 'zone' that produces good quality and consistent results. Set up a preventative maintenance program for your equipment.

3. Improve your bottom line through increased throughput, reduced scrap and reduced downtime — especially unscheduled downtime.

4. Communicate in language, terms and numbers that are clear, defined and easy to understand. Make buying decisions for equipment in coordination with your suppliers.

5. Using measurement equipment and maintaining a process window or zone is repetitive. Hopefully, this repetition will not be a problem — especially if it allows you to consistently operate in the 'zone' that makes your company money, saves you time and makes your job easier.

Alphabetical listing of companies that participated or supplied eequipment for the hans-on Measurement Seminar at SGIA '02 Convention:

American Ultraviolet
Dorn/SPE
EIT Instrument Markets
Fusion UV Systems
Hanovia
Honle UV America
International Light
Liberty International Technology
Mid-Tech Engineered Sales
Miltec UV
Nazdar
OLEC Corporation
Ultraviolet Systems & Equipment
UV Process Supply

Using measurement equipment and maintaining a process window or zone is repetitive.

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