

# Materials Testing for Durability to UVC Light Exposure

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[\*View Recorded Presentation\*](#)

# Q-Lab's Webinar Series

- Today is the 2nd of a two-part webinar series on special testing topics
- Previously this year we've done series on Outdoor Testing, Corrosion, and Laboratory Weathering Testing

Date	Topic
02 Jun	Q-PANEL standard test substrates
09 Jun	UVC Testing

We'll take a summer hiatus and return in September with a series on performing Calibrations and running Standards.

Until then, all our content is free and on-demand at: [q-lab.com/webinars](https://q-lab.com/webinars)

# Administrative

You'll receive a follow-up email from [info@email.q-lab.com](mailto:info@email.q-lab.com) with links to a survey, registration for future webinars, and to download the slides

Use the Q&A feature in Zoom to ask us questions today!



We make testing simple.



**Thank you for attending our webinar!**

We hope you found our webinar on *UV Testing of Materials* to be helpful and insightful. The link below will give you access to the slides and recorded webinar.

You can help us continue to provide valuable and high quality content by completing our [3-question survey](#) about your webinar experience. Every piece of feedback is carefully reviewed by a member of our team.



# Topics

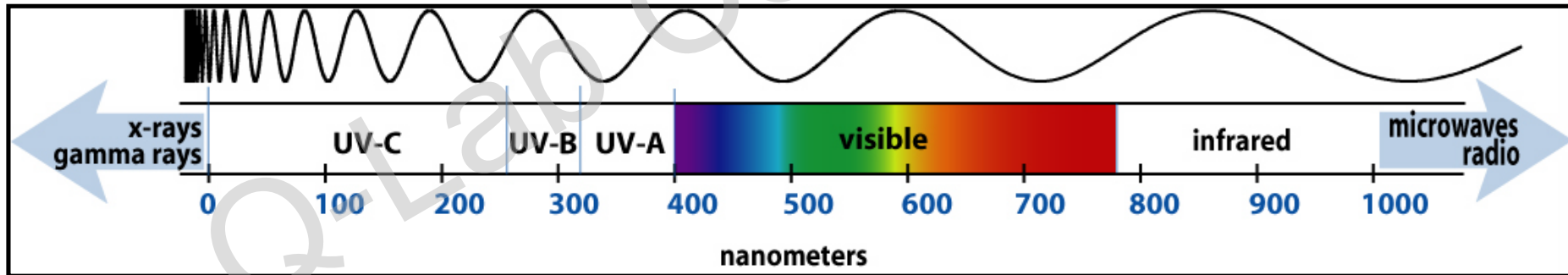
- Ultraviolet Germicidal Irradiance (UVGI)
- Durability of materials exposed to UVC light
- UVC exposure test results
- Standard test protocols for UVC testing



*Disclaimer: We aren't supporting use of our products for UVGI applications, just material testing.*

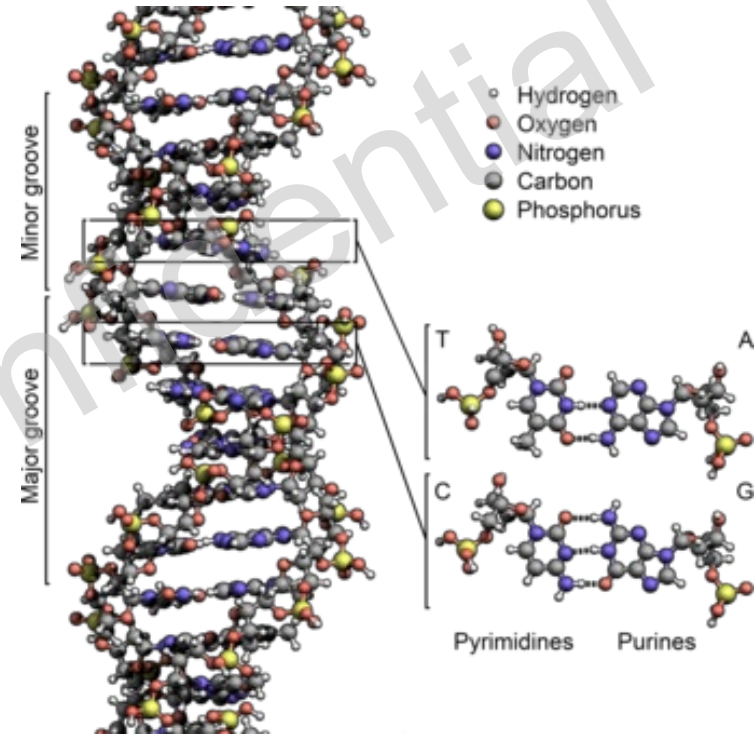
# Ultraviolet Germicidal Irradiation (UVGI)

- The use of ultraviolet (UV) wavelengths of light in the germicidal range (200–320) for the disinfection of air and surfaces. *Ultraviolet Germicidal Irradiation Handbook*
- Method for disinfection of air, water and surfaces that uses radiation with wavelength in the range 240 to 280 nm to kill or inactivate micro-organisms. *ISO 29464*



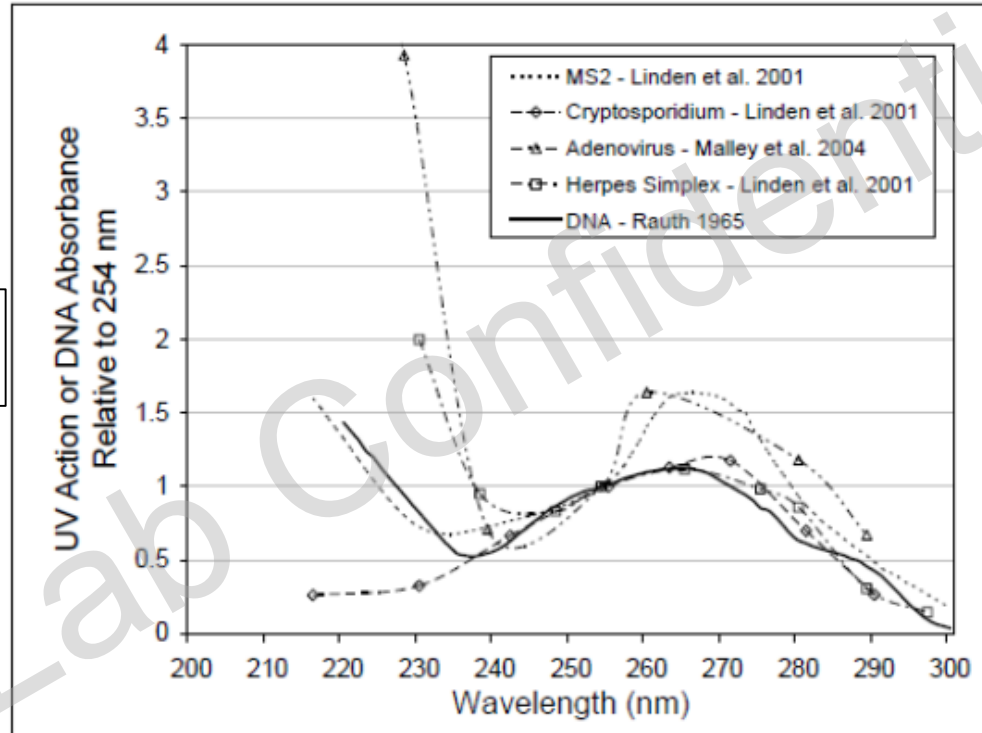
# How UVGI Works

- Ultraviolet light causes crosslinking of DNA or RNA strands
- Inactivates a cell's ability to replicate



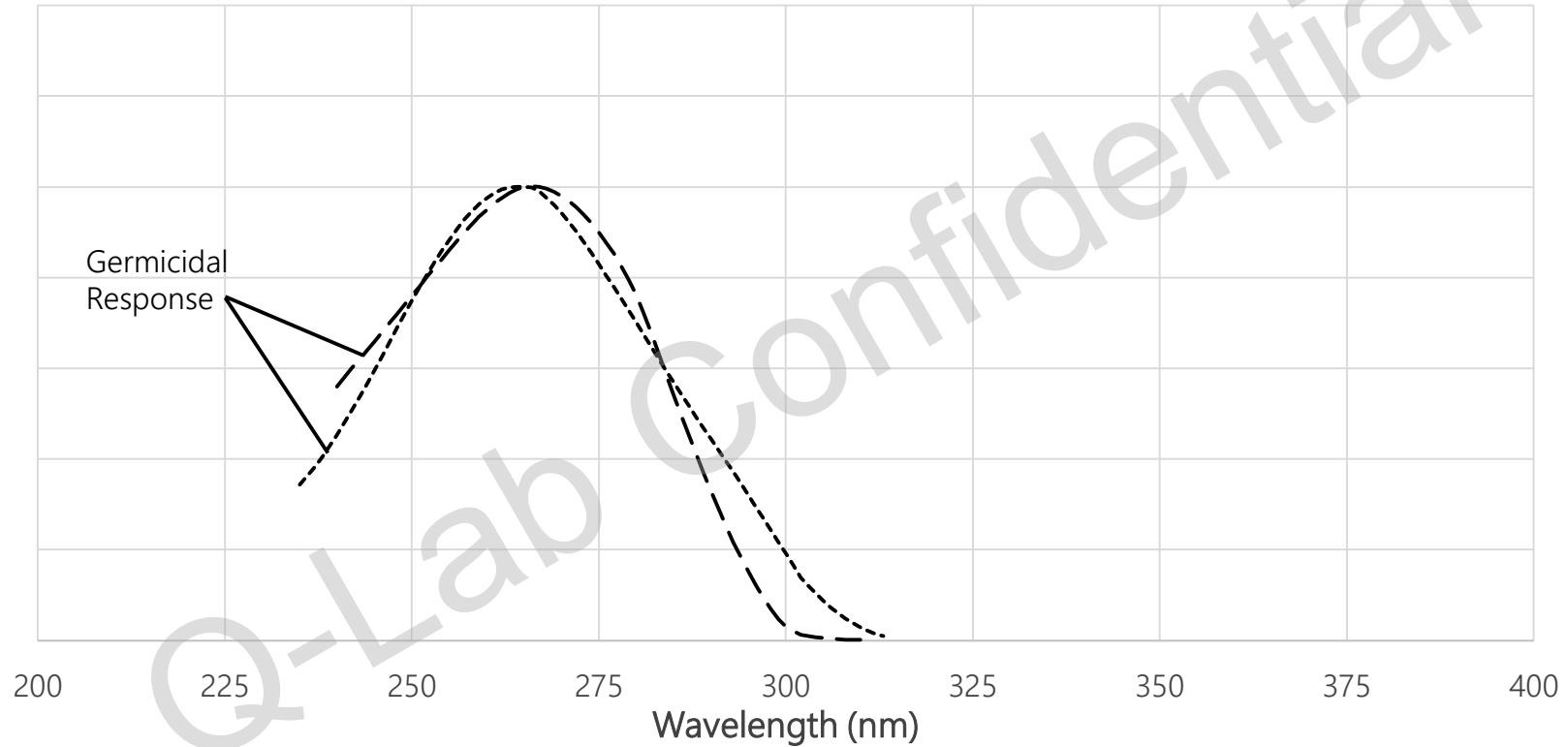
# Action Spectra of DNA & Select Microorganisms

USEPA UV Disinfection  
guidance manual, 2006



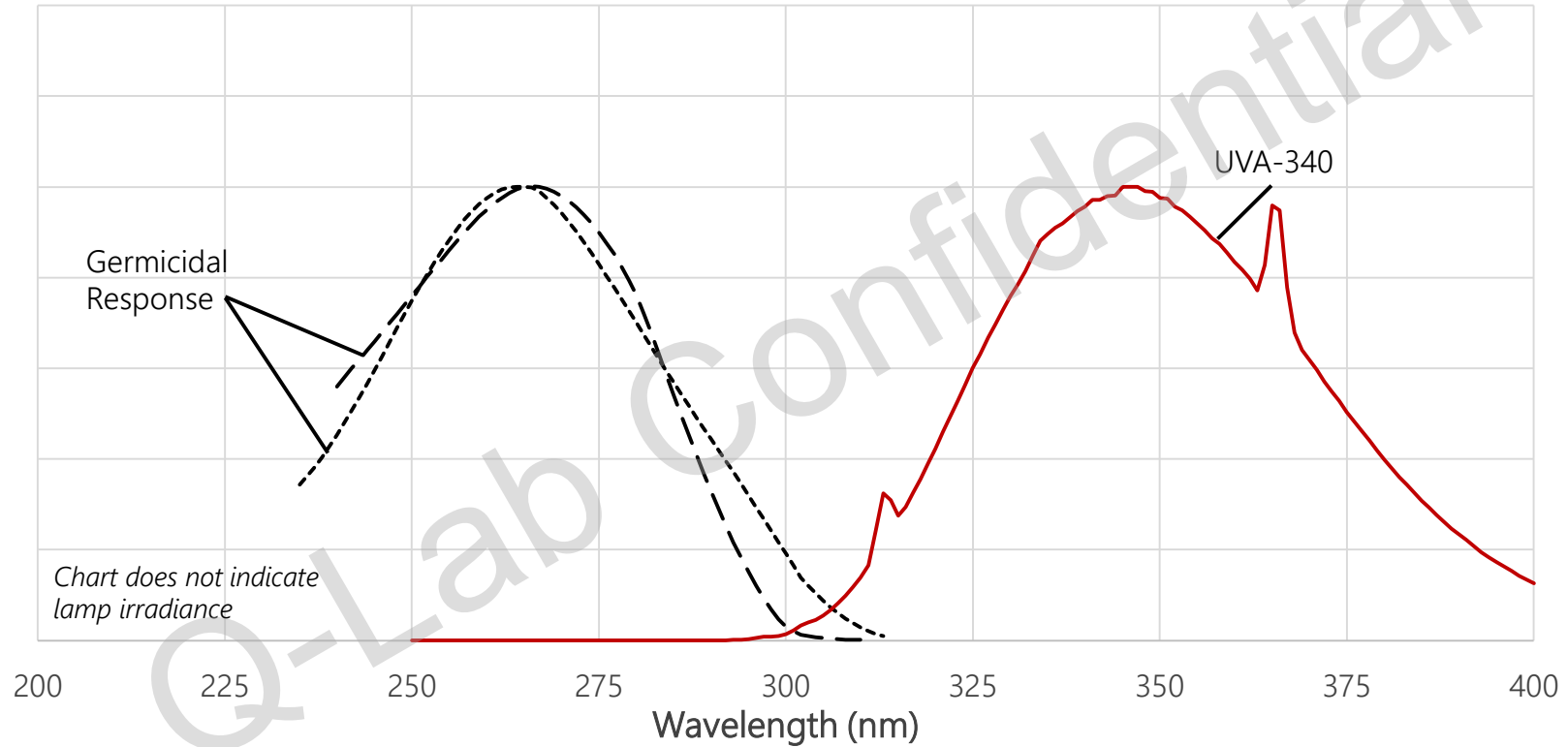
Source: Adapted from Rauth (1965), Linden et al. (2001), and Malley et al. (2004)

# Relative Spectral Irradiance and Germicidal Response

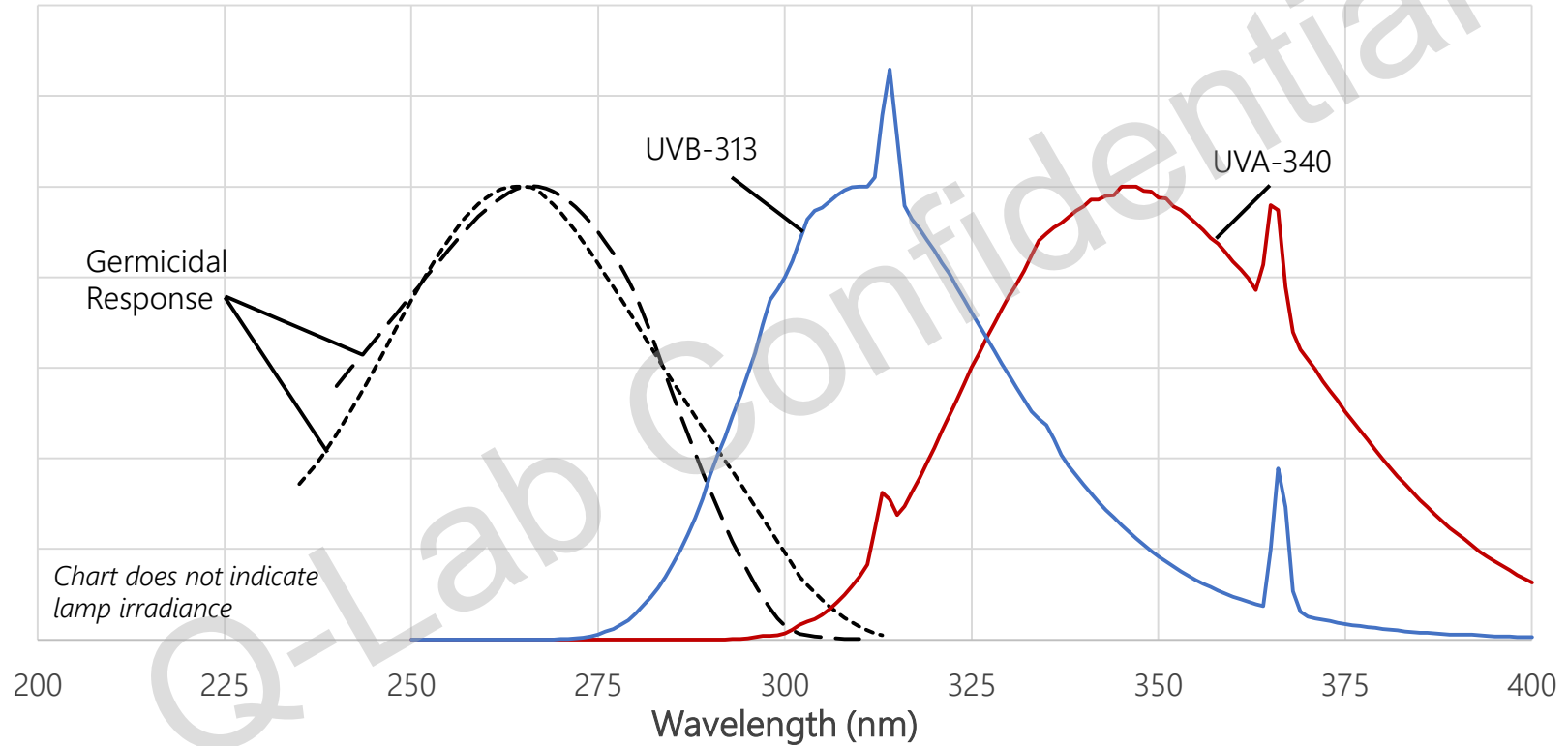




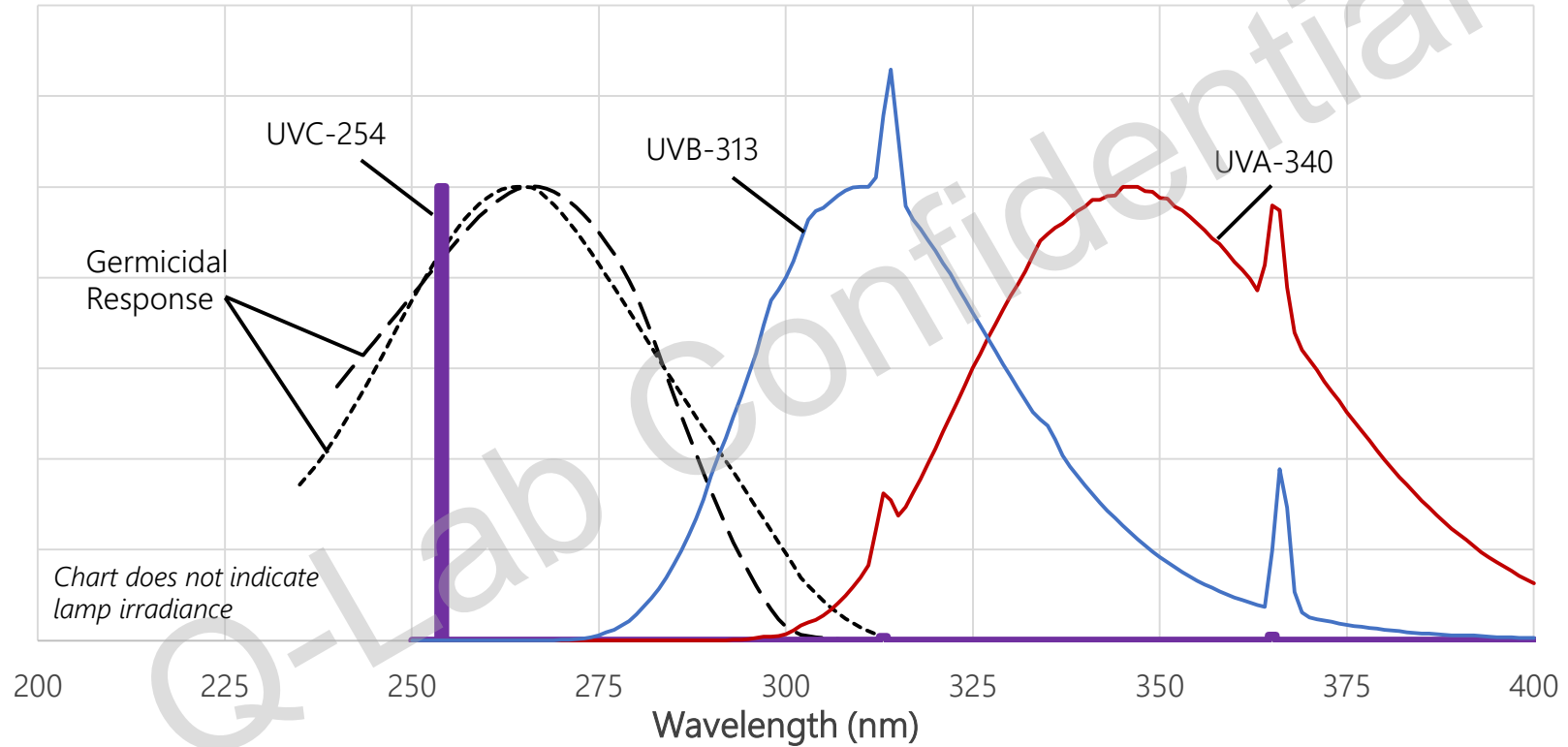
# Relative Spectral Irradiance and Germicidal Response



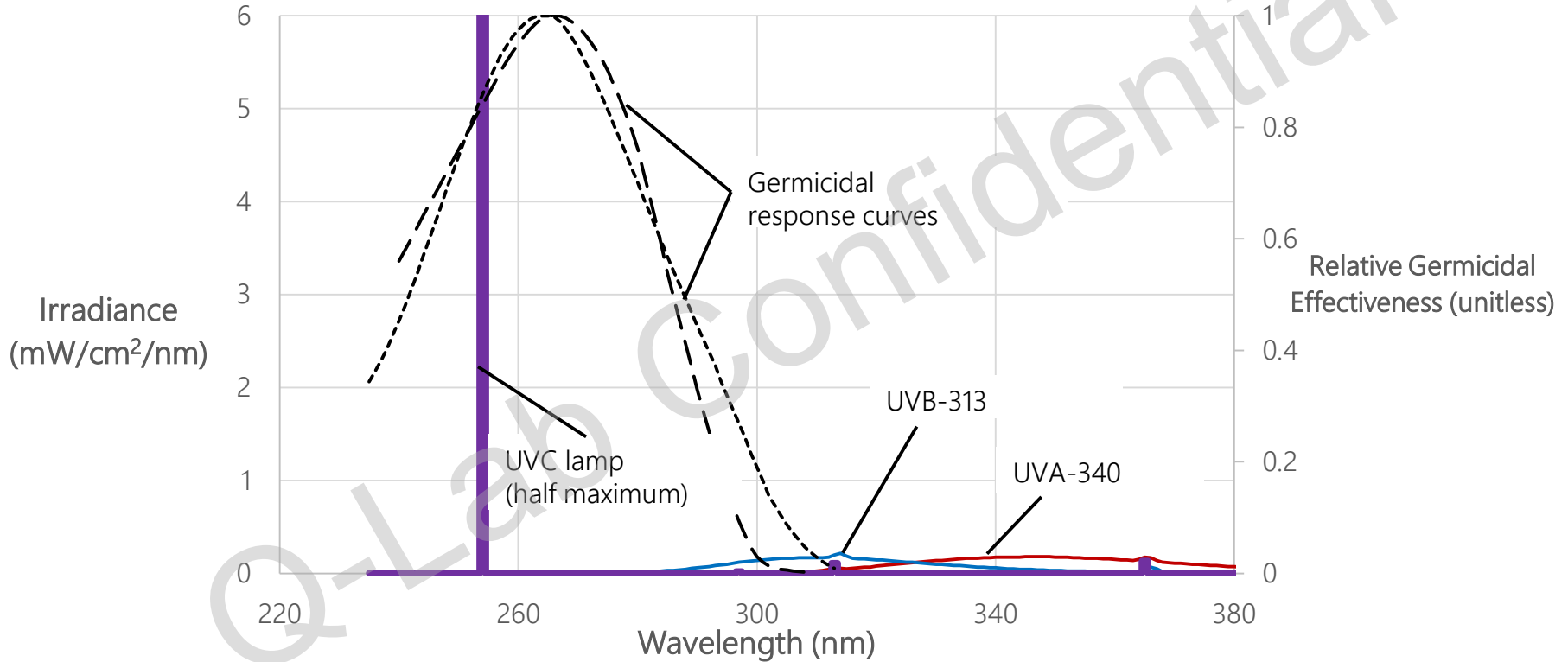
# Relative Spectral Irradiance and Germicidal Response



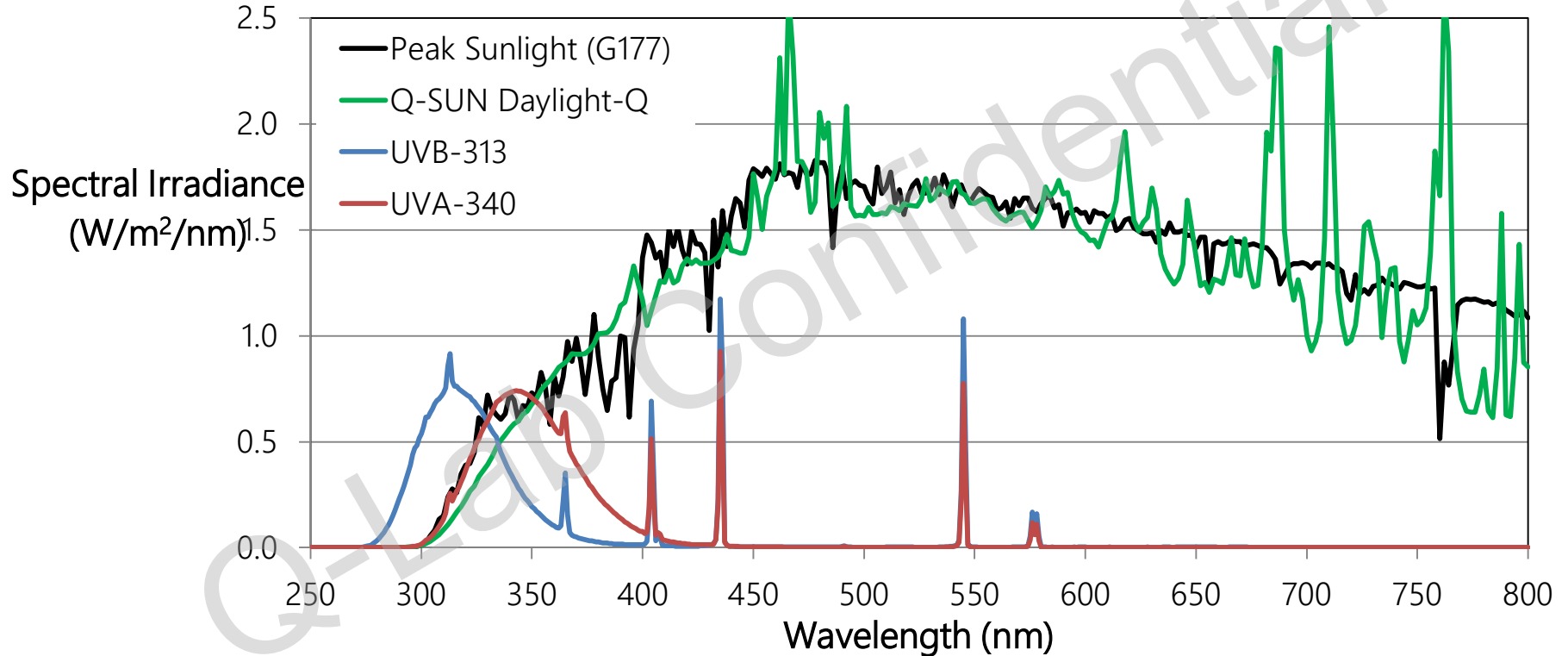
# Relative Spectral Irradiance and Germicidal Response



# Actual Spectral Irradiance and Germicidal Response



# Fluorescent UV, Xenon Arc, and Sunlight



# UVGI Applications



Medical facilities



HVAC



Emergency Vehicles

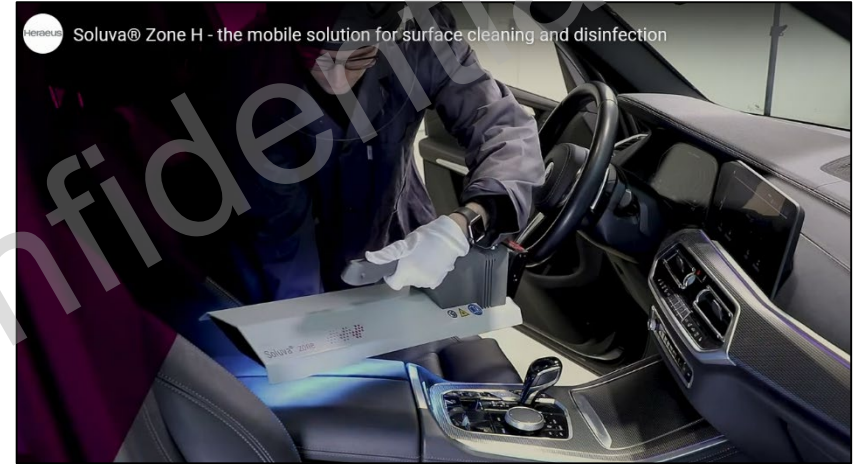


Airports



Schools

# UVGI Applications



Interior materials are not typically designed to withstand UV exposure, so UVC exposures are not often considered during material development

# UVC Light for UVGI Applications

- UVC light is effective at inactivating viruses and other microorganisms
- As a result, indoor materials are now being subjected to highly destructive UVC energy
- The actual UVC dose experienced is unpredictable in most applications
- Because UVC light is very damaging, UVC exposures will often be much faster than standard weathering tests for outdoor materials

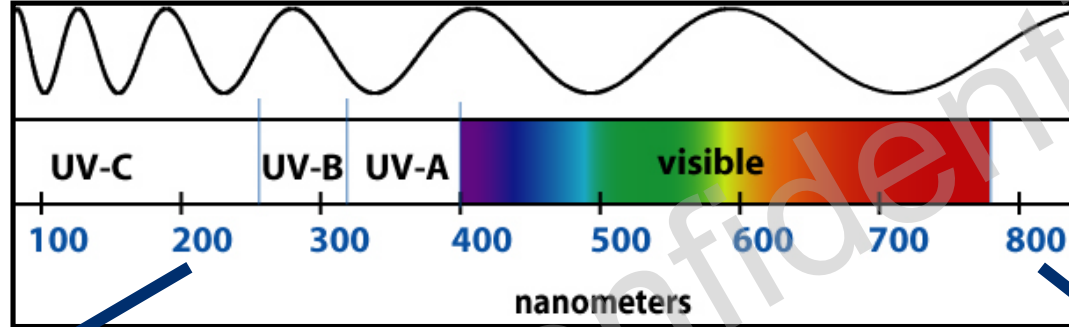
*Let's look at some UVC exposures of plastics and other materials*



# Units in UVC Exposure Testing

- Energy  $1 \text{ Joule} = 1 \text{ W}\cdot\text{s}$
- Irradiance (Power)  $1 \text{ mW/cm}^2 = 10 \text{ W/m}^2$
- Radiant Dosage (Energy) (Irradiance  $\times$  Time)  
 $1 \text{ mJ/cm}^2 = 10 \text{ J/m}^2$
- The energy of a photon is inversely proportional to its wavelength
- Short-wavelength light has more energy per photon and is more damaging than long-wavelength light

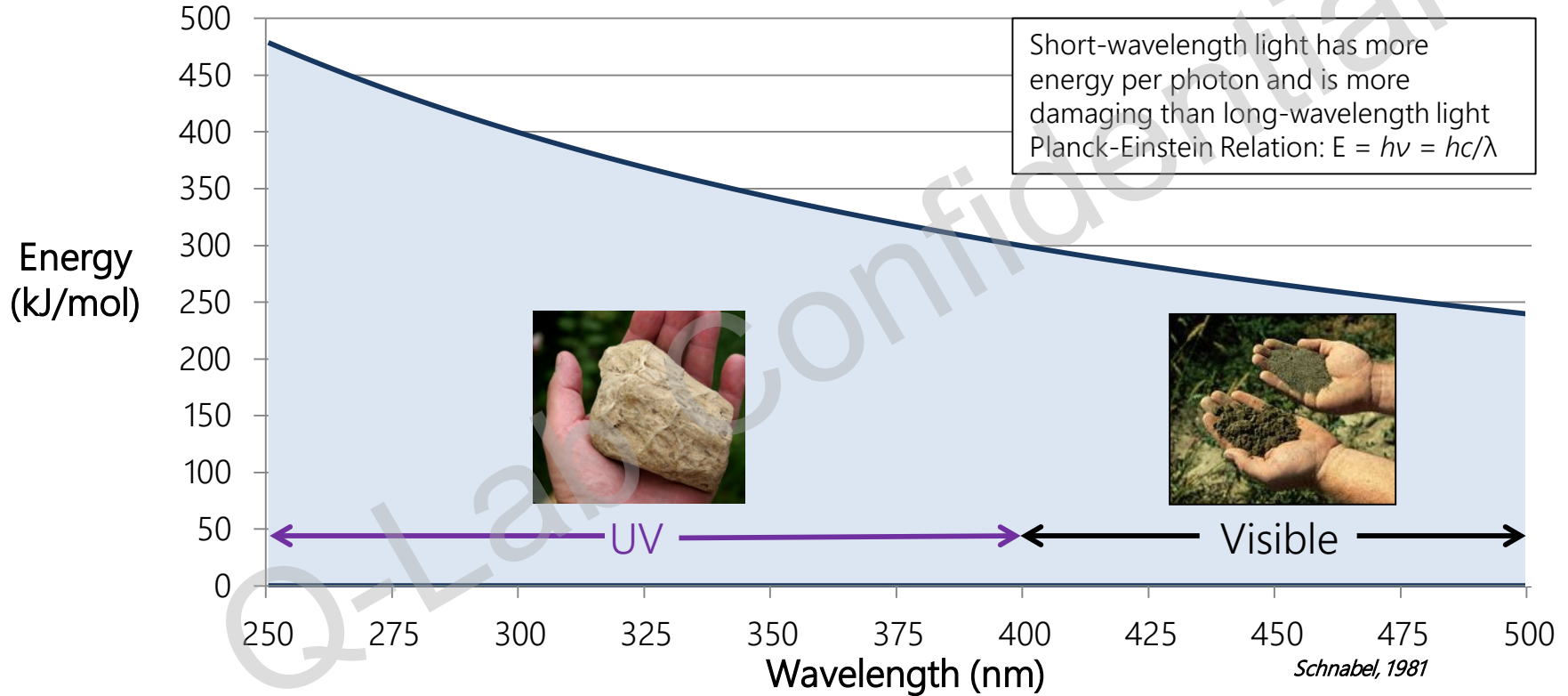
# Electromagnetic Spectrum



The energy of a photon is inversely proportional to its wavelength



# Energy per Photon (Quantum)



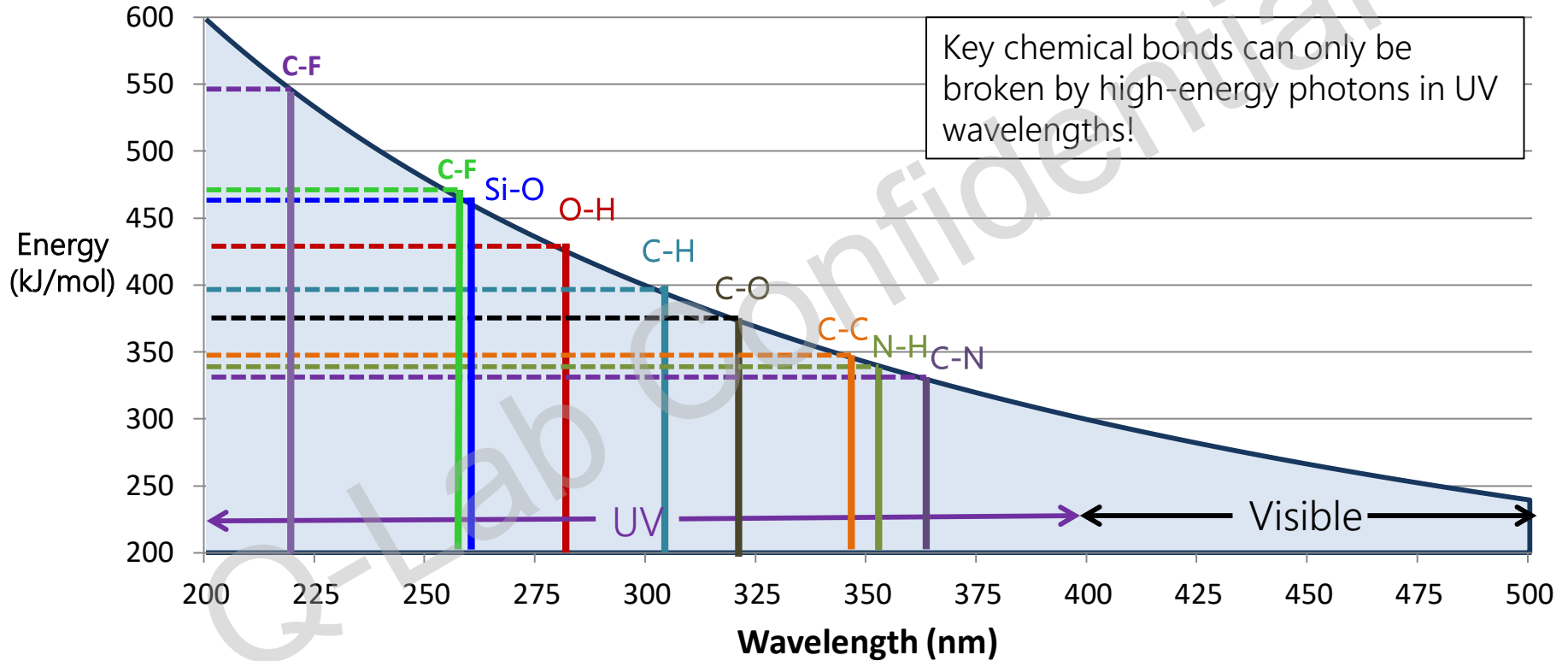
# UVC Light and Chemical Bond Breaking

Chemical Bond	Energy to break bond (kJ/mol)	Wavelength of photon with equivalent energy (nm)
C-N	330	363
N-H	339	353
C-C	348	344
C-O	372	321
C-H	393	304
O-H	426	281
Si-O	452	265
C-F (CH <sub>3</sub> F)	460	260
C-F (CF <sub>4</sub> )	544	220

Schnabel, 1981

Bonds can only be broken by photons with a wavelength **shorter than** the threshold value shown. UVC photons have the potential to be **very** damaging. *Are they, though?*

# Chemical Bond Energy & Photon Wavelength



# UVC Durability Testing

- Test instrument and cycle
- UVC-254 vs fluorescent UV lamps

# Laboratory UVC Testing

- Tests conducted in the QUV/uvc tester - a new model of the QUV tester
- Onboard UV sensor precisely controls irradiance at 254 nm
- Features light baffles and automatic safety shut-off features
- Water functions (condensation, spray) removed for simplicity



# UVC Exposure

- **Irradiance:** 3 mW/cm<sup>2</sup> (30 W/m<sup>2</sup>)  
(low- to mid-range of achievable set points)
- **Temperature:** 30°C black panel
- **Duration:** 200 hours (2.16 kJ/cm<sup>2</sup>)  
(evaluate color at 24, 100, 200 hours)





# UVC-254 Lamp



# UVC Test Results

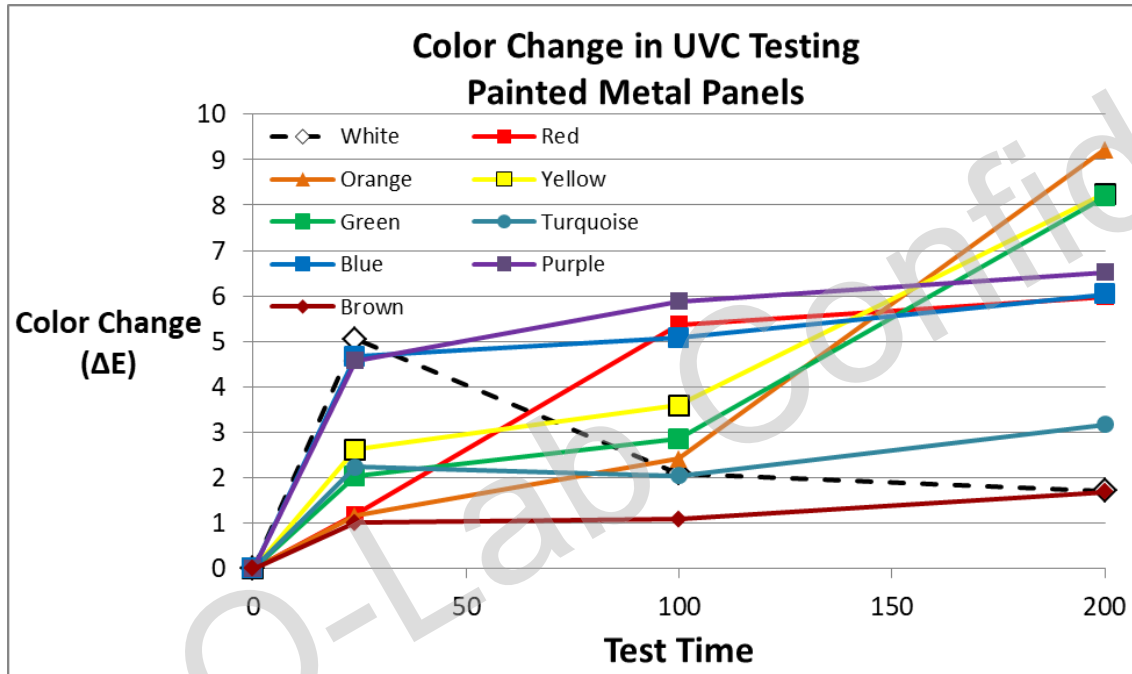
- Painted Panels
- Vinyl Flooring
- Fabrics
- Leathers
- Surface Materials

# Painted Panels: Visual Evaluation



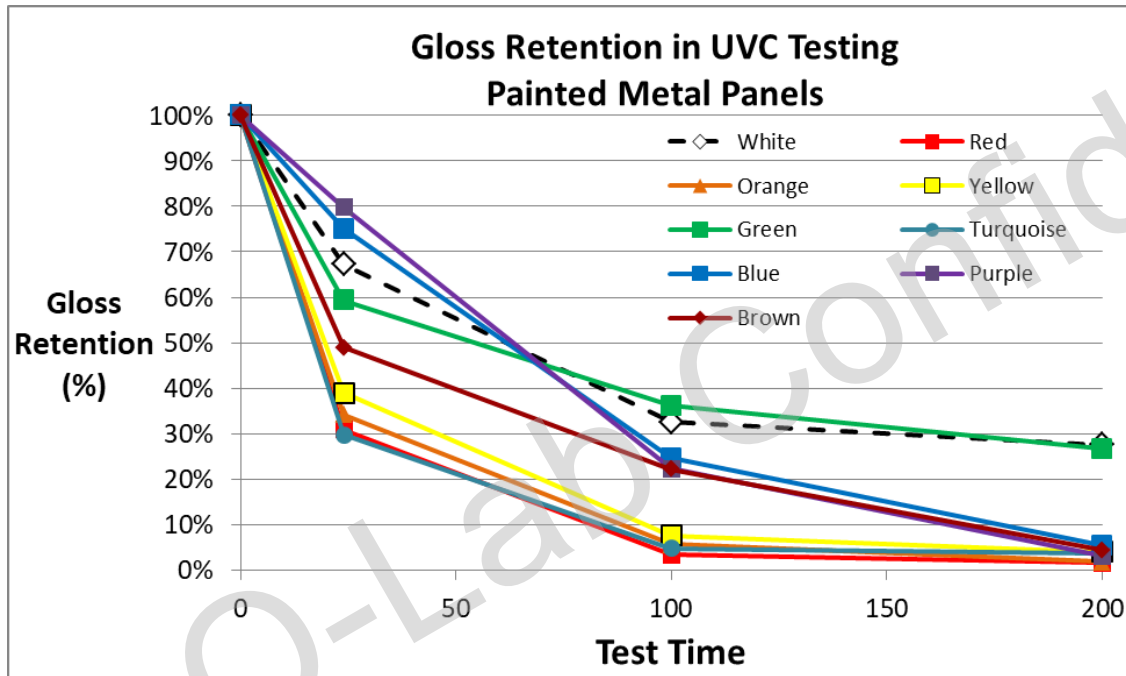
*Significant changes in gloss and color*

# Painted Panels: Color Change



- General-purpose acrylic modified alkyd spray paint
- Noticeable color change in only 100-200 hours

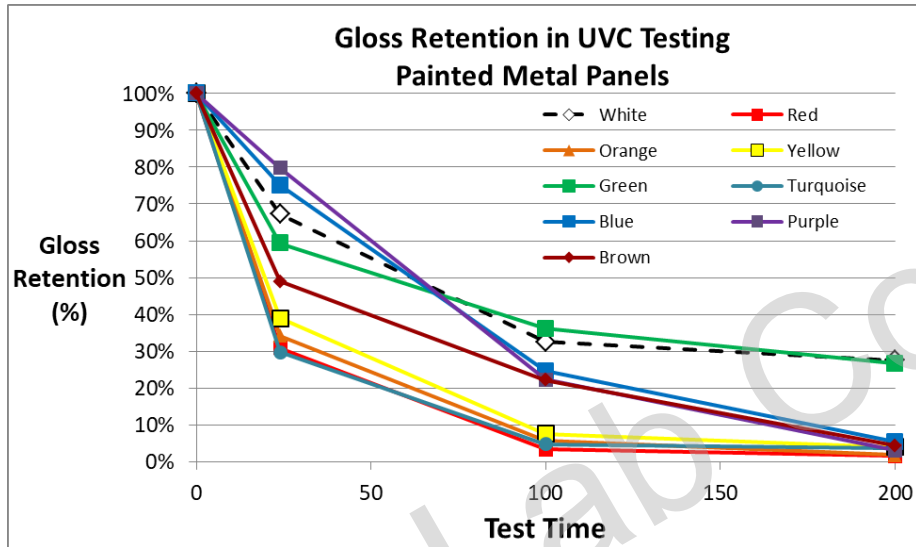
# Painted Panels: Gloss Retention



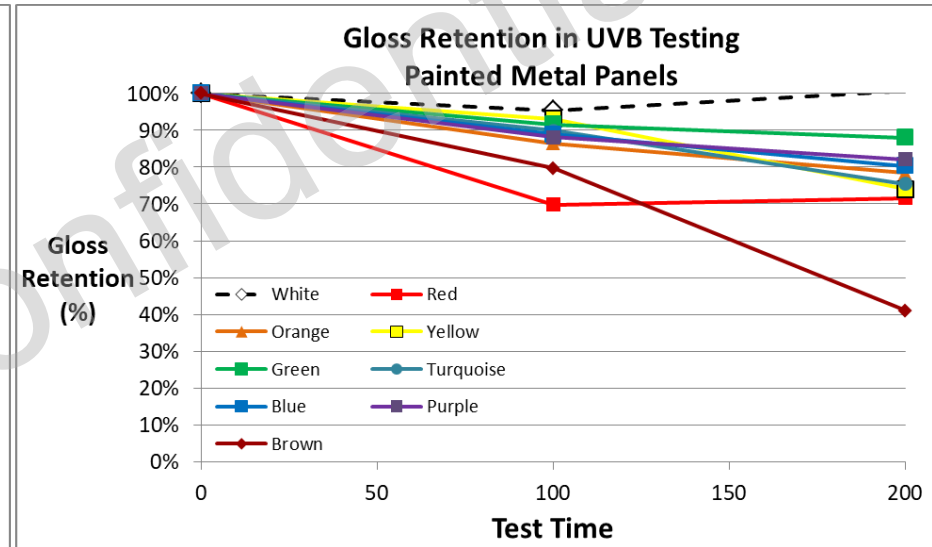
- General-purpose acrylic modified alkyd spray paint
- Major loss of gloss in only 100 hours

# Painted Panels: UVC and UVB Exposures

## UVC

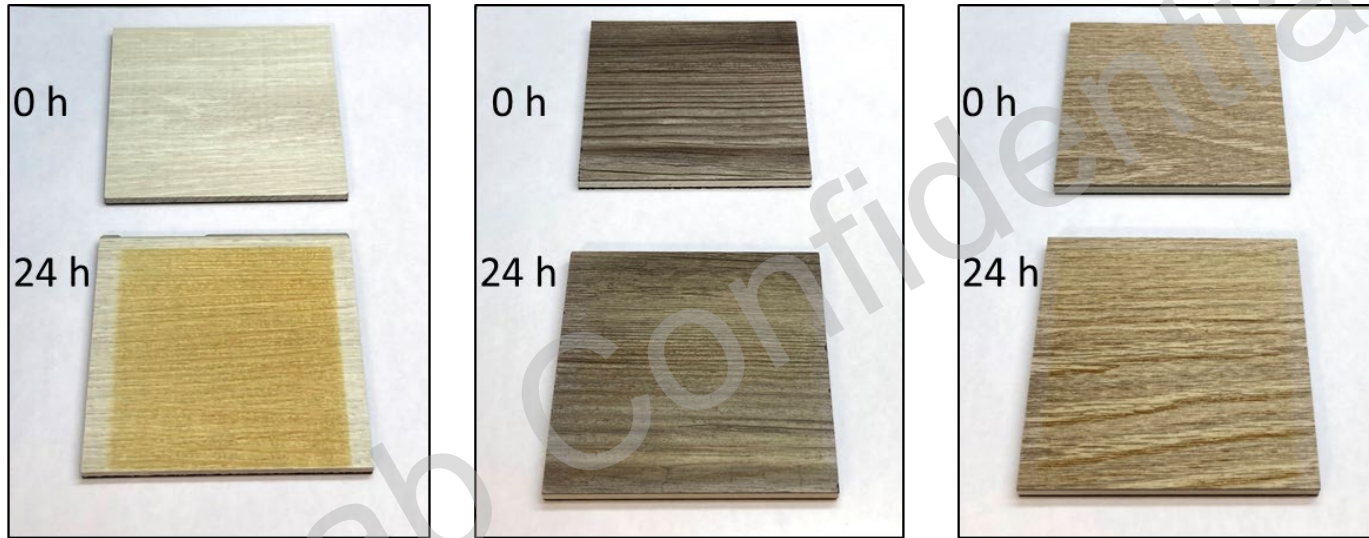


## UVB



UVC testing is very harsh even compared to UVB testing – which is also known to degrade materials quickly

# Vinyl Flooring: Visual Evaluation



- Commercially-available vinyl flooring material
- Major discoloration in just a day of testing!

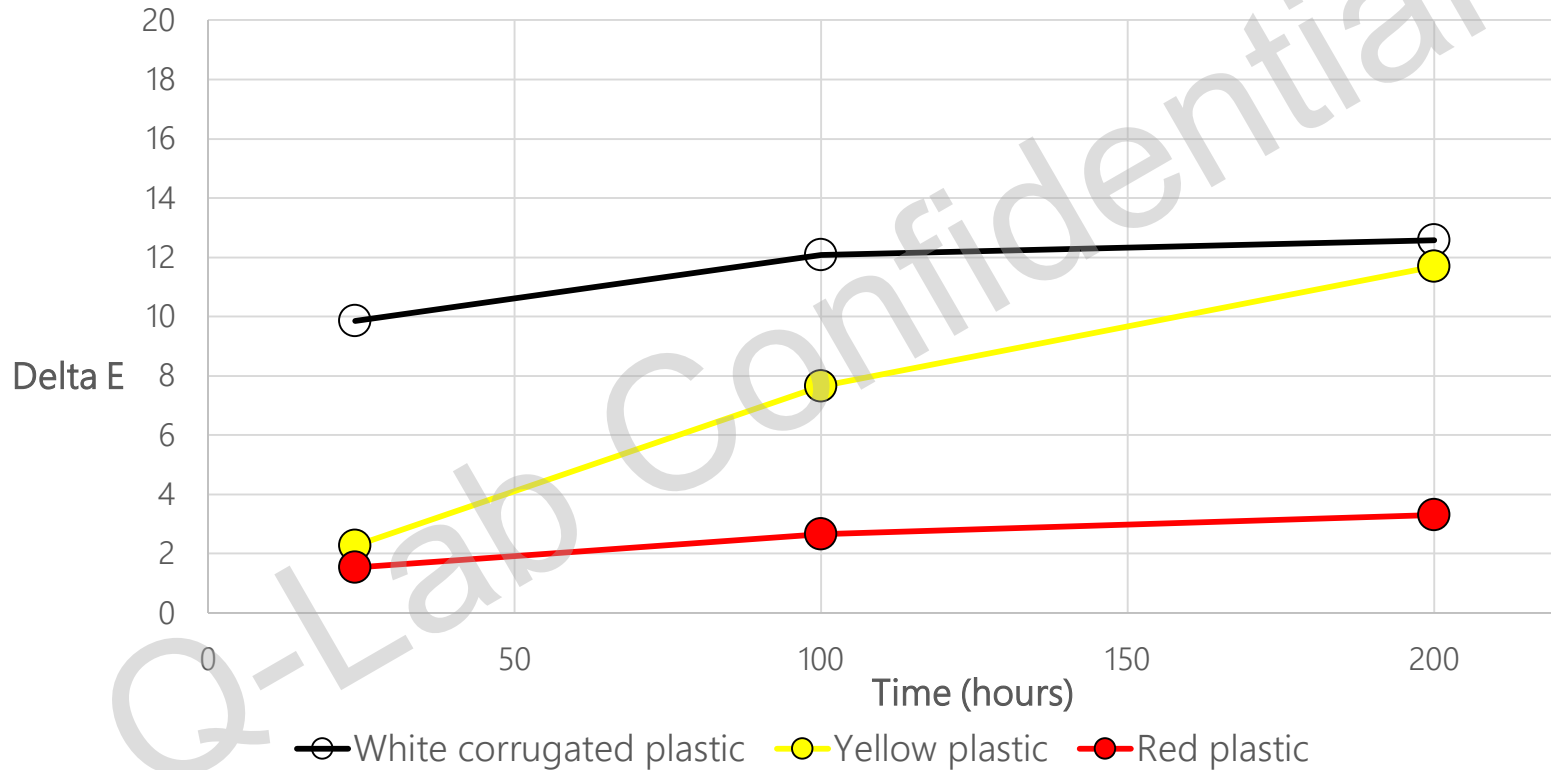
# Plastics: Visual Evaluation



- Significant degradation in clear and yellow plastics
- Degradation is yellowing/darkening, likely of base polymer
- Red plastic showed less color change and retained more gloss



# Plastics: Color Change

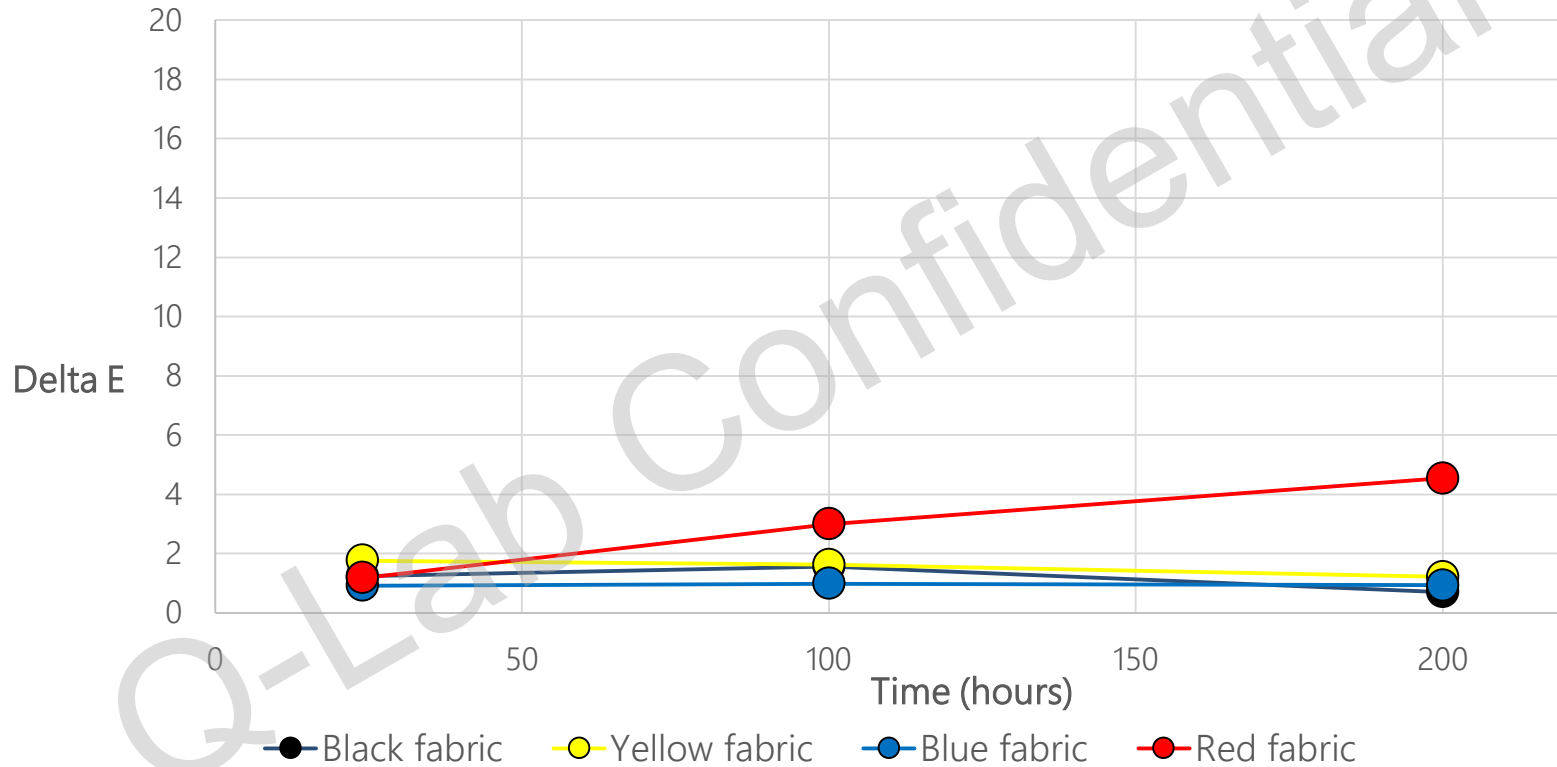


# Fabrics: Visual Evaluation



- Cheap synthetic fabrics are surprisingly UVC-resistant!
- The floral print at righties an exception

# Fabrics: Color Change

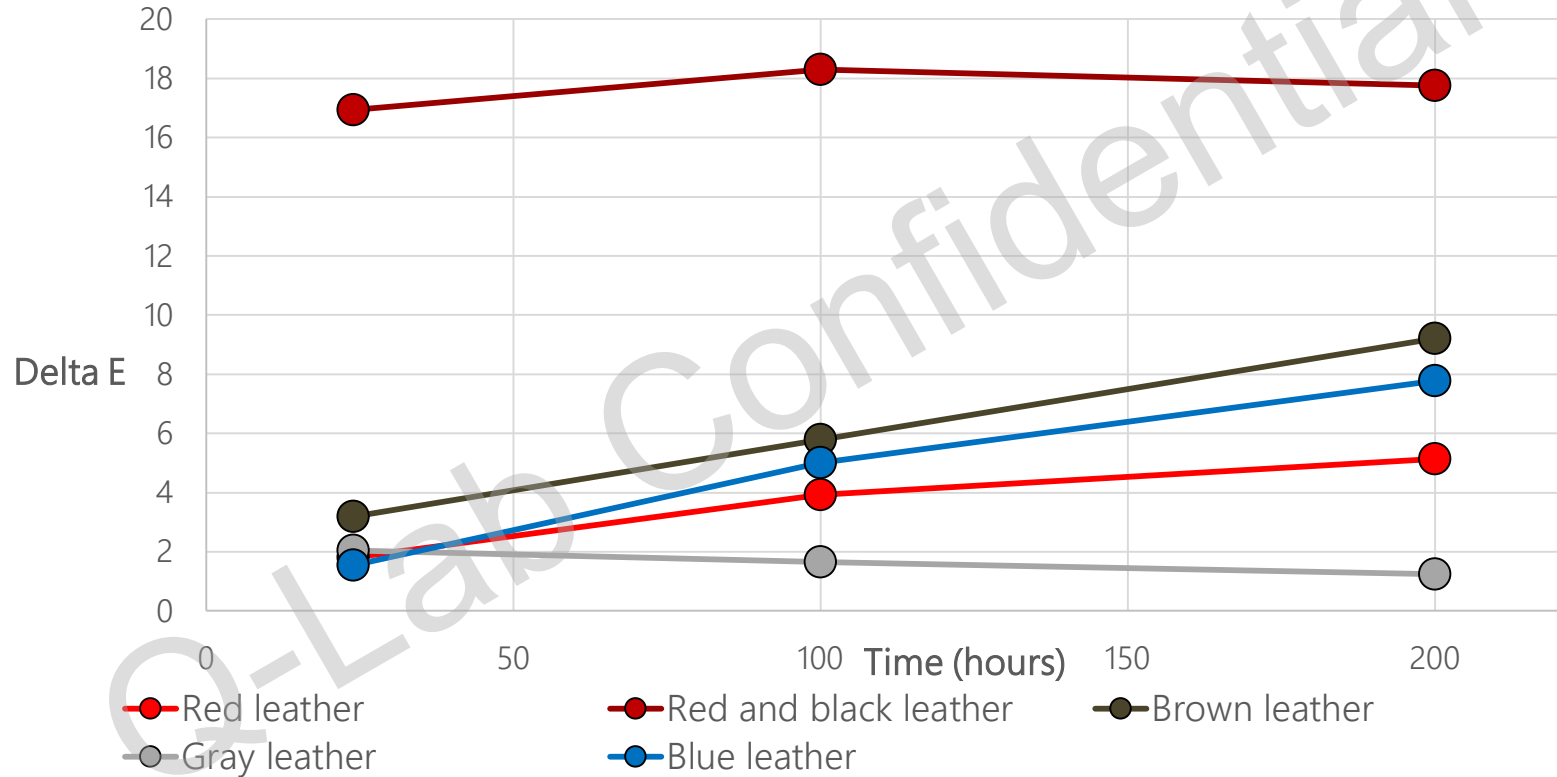


# Leathers: Visual Evaluation



- Wide variety in performance of synthetic leathers
- Red, blue, and gray very little change
- Brown and red/black degraded very quickly – color fade observed

# Leathers: Color Change



# Surface Materials: Visual Evaluation

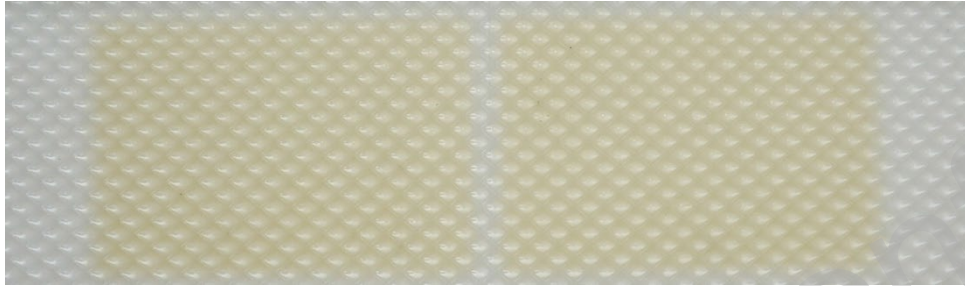


- Surface / tiling materials are fairly UVC resistant
- Some yellowing observed in lighter-colored specimens

# Laboratory and Real-World UVC Exposures

Q-Lab Confidential

# Lab and Real-World UVGI Exposures



- Even short UVC exposures caused significant damage to some materials
- *What do these tests correlate to in terms of real-world UVGI exposure?*



# Material Exposure to UVGI



*Many surfaces will be significantly over-exposed in an effort to ensure all areas receive sufficient dose; possibly 10 × the target dose*

# Disinfection Levels

Term	Kill/Deactivation Ratio	Comments
1-Log	90%	Also called D90 Disinfection; commonly-used benchmark
2-Log	99%	
3-Log	99.9%	
4-Log	99.99%	
5-Log	99.999%	Lowest level of "sterilization"
6-Log	99.9999%	Typically the lowest level measureable

*Dose vs kill ratio varies by microorganism and follows a logarithmic decay rate*

# What are typical UVGI exposure doses?

- 2 mJ/cm<sup>2</sup> to 1500 mJ/cm<sup>2</sup> have been cited for various microorganisms and disinfection levels (1-log to 6-log)
- 1 J/cm<sup>2</sup> has been suggested as a standard UVGI cycle

# UVC Radiant Dosage

Assume 1 “cycle” of UVGI is a dose of  $1 \text{ J/cm}^2$  (estimates for this value vary significantly!)

At irradiance of  $3 \text{ mW/cm}^2$ , a single dose is achieved in 334 seconds  
( $334 \text{ s} \times 3 \text{ mW/cm}^2 = 334 \text{ s} \times 3 \text{ mJ/s}\cdot\text{cm}^2 = 1000 \text{ mJ/cm}^2$ )

UVGI Cycle Frequency	Time to achieve one year of UVC dosage at 254 nm irradiance of $3 \text{ mW/cm}^2$ (hours)	100 hour test represents how many years of UVGI?
Daily	34	3.0
Weekly	4.8	20.8
Monthly	1.2	83.3

# Potential Standard Test Parameters

- Irradiance: 1-6 mW/cm<sup>2</sup> (10-60 W/m<sup>2</sup>)  
*Will reciprocity be valid for UVC testing?*
- Temperature: 30-63 °C BPT (Black Panel Temperature)  
*Are room temp values more practical? Does high temp accelerate?*
- Cycle: Continuous or Light/Dark cycling  
*Will dark periods affect results?*
- Duration: 200-1000 hours  
*Usually not specified in standard operating practice  
Short exposures acceptable, or longer tests required?*

# UVC Dose Reciprocity

- Will these exposures deliver the same result?

100 hours @ 1.5 mW/cm<sup>2</sup>

50 hours @ 3.0 mW/cm<sup>2</sup>

25 hours @ 6.0 mW/cm<sup>2</sup>

12.5 hours @ 12.0 mW/cm<sup>2</sup>

*All achieve 540 J/cm<sup>2</sup>*

- In the QUV/uvc tester you can run all of these tests to verify reciprocity (LIGHT/DARK cycling also possible)

# Conclusions

- Ultraviolet Germicidal Irradiation (UVGI) is growing quickly; any commercial space is a candidate
- Your materials may be exposed to more UVC energy than anyone can predict
- UVC laboratory testing shows significant degradation in a short timeframe to a variety of products
- Test protocols are in the process of being standardized

# Thank you for your attention!

## Questions?

Send your inquiry to:  
[info@q-lab.com](mailto:info@q-lab.com)