TECHNOLOGY

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CALiPER GUV Testing: Measuring and accurately reporting product performance

Germicidal ultraviolet (GUV) disinfection technology is among the most effective and energy efficient methods to reduce airborne disease transmission and meet new ASHRAE and CDC building design guidelines. GUV is a topic of great interest due to its potential role in creating a healthy workplace. The COVID-19 pandemic was a catalyst for many new GUV products to appear in the marketplace, raising questions about their effectiveness and the state of this technology in general.

Enter the U.S. Department of Energy (DOE) CALiPER testing program, which between 2006 and 2014 compared measured performance of emerging LED lighting products with manufacturer-claimed performance and the measured performance of incumbent technologies. Published CALiPER testing results helped encourage high-quality products and accurate performance claims while educating product developers, specifiers and buyers on how to evaluate the waves of new LEDs hitting the market. Early CALiPER testing also led to the development of new industry standard test methods to consistently measure and report on LED product performance.

The DOE reactivated CALiPER for GUV testing as part of the national imperative to reduce the spread of airborne disease and improve resilience to future pandemics. CALiPER is now evaluating and reporting on the performance and photobiological safety of available GUV technologies, the most common of which is the phosphorless low-pressure mercury (LPM) lamp, which has been used in health and institutional settings for decades. Emerging alternatives include products incorporating UV-emitting LEDs or krypton chloride (KrCl)-based excimer lamps.

In Round 1 of GUV product testing, CALiPER evaluated the performance of 13 products purchased between February and July 2022. They included three different product types, all of which were rated to generate UV-C:

- Seven portable, consumer-oriented GUV towers (**Figure 1**) designed to be placed on the floor or a desk of an unoccupied room to disinfect air and surfaces. Five of these products used LED sources and two products included LPM sources.
- One GUV whole-room luminaire (**Figure 2**) designed to be installed on a ceiling to disinfect air when a room is occupied. This product employed LED sources.
- Five GUV troffer or high-bay style whole-room luminaires (Figure 2) designed to be installed in or suspended from a ceiling to disinfect air and surfaces when a room is unoccupied. All five used LPM sources.

> The biggest takeaway from early CALiPER testing of GUV products is the robust learning opportunity that is present, one that will contribute to the development of new and revised industry-standard test methods

For this first round, GUV product testing followed past CALiPER practices: accredited, independent laboratories conducted the testing using industry-standard test methods and metrics wherever possible—recognizing that in some cases, these methods do not yet directly address UV-C measurements. For example, LPM products were tested to ANSI/IES LM-41-20 and LED products were tested to ANSI/IES LM-79-19. Initial performance was measured for all tested products; LED products were tested at 0 hours of operation (in accordance with IES LM-79), while lamps in LPM towers and whole-room luminaires were "seasoned" for 100 hours before testing (in accordance with IES LM-41 and ANSI/IES LM-54-20). Four products were additionally measured after 100 hours and 500 hours of operation.

Round 1, which is now complete, produced some interesting results reminiscent of the early days of LED testing—performance sometimes differed widely from product claims (**Table 1**) and some of the LED tower products emitted no UV-C at all. In addition, UV-C output from the two LED products

tested long-term showed a substantial drop-off over time. That said, the sample size was small and included several consumer-oriented products chosen from online retailers; therefore, the findings from Round 1 are not expected to reflect all GUV products on the market. Future rounds will focus more on commercial-oriented luminaires for occupied spaces.

The first round of CALiPER testing of GUV products revealed important needs within the industry. In some cases, incomplete, ambiguous, contradictory or untestable product performance claims were found, suggesting that some product developers and sellers may not understand GUV technology or how to measure and accurately report product performance—all of which indicates a need for further education, industry standards and accountability in the GUV product industry. To address this issue, the industry could prioritize the development of a standard set of recommended testing for each product type, with a standard set of associated performance data that should be reported for each product. In one such effort, NEMA's ANSI C137.12 working group has begun drafting a new standard that is partly aimed at presenting consistent and accurate information regarding GUV products. Once developed, product developers, sellers, specifiers and buyers could be educated about the use of such standards.

Figure 1. LED and LPM tower products.

As GUV technology continues to evolve, there is a need to evaluate different GUV product types, technologies, spectral distributions, radiant intensity distributions and design approaches to identify those that are most energy efficient and effective in specific applications. This would address the wide variation seen in radiometric performance among different GUV product types and technologies, with this round of testing showing LED products at orders of magnitude lower in UV-C radiant efficiency than LPM products (**Figure 3**). The safety, effectiveness and energy efficiency of GUV systems will vary by application and also depend on spectrum and radi-

Figure 2. LED and LPM whole-room luminaires, viewed from below and to one side. LED-22-06 had a 5-in. diameter and protruded 2.1 in. below ceiling. LPM-22-03 and LPM-22-04 were 2-ft by 2-ft troffers, measuring 2 ft on each side in plan. LPM-22-05 was a high-bay luminaire measuring 14-in. by 48-in. in plan. LPM-22-06 and LPM-22-07 were 2-ft by 2-ft troffers. Troffers are intended to be recessed into the ceiling, but are shown surface mounted.

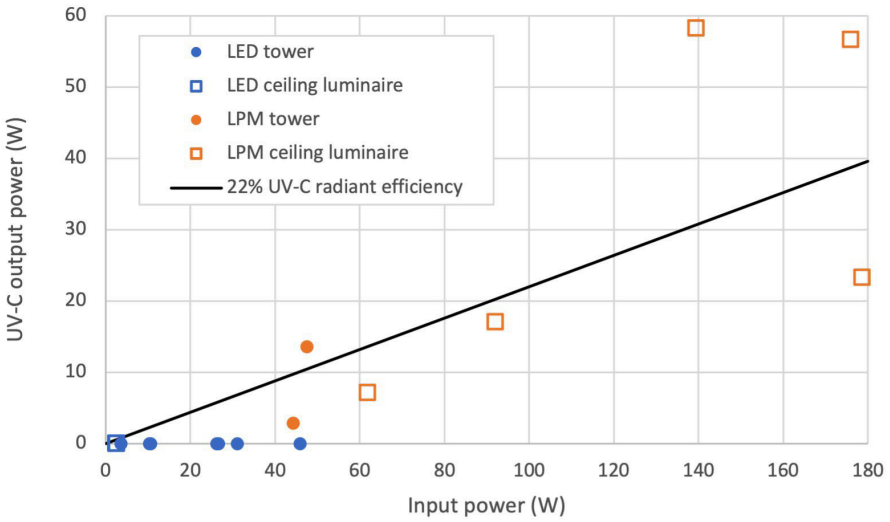


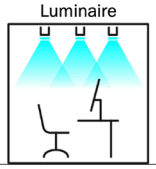
Figure 3. Measured electrical input power and UV-C output power for all tested products. The solid black line represents the average UV-C radiant efficiency for tested LPM products (22%).

ant intensity distribution.

The test results also illustrate the work needed to address testing limitations and improve testing laboratory infrastructure and capabilities to support the accurate testing of GUV products. In particular, the ability to test larger-dimension GUV products is essential to enable the accurate use of GUV application design software using electronic files that contain far-field UV-C radiant intensity data. Efforts are also needed to evaluate and understand discrepancies identified between results from integrating hemisphere and gonioradiometer testing.

The biggest takeaway from early CALiPER testing of GUV products is the robust learning opportunity that is present, one that will contribute to the development of new and revised industry-standard test methods. The CALiPER Round 1 reports can serve as a starting point as they assemble data from several product tests and provide comparative analyses. Future rounds of testing will focus on one or more types of products and/or particular performance aspects. For example, Round 2 will emphasize upper-room luminaires (which use LED or LPM to treat the portion of the room above occupants), and Round 3 will concentrate on whole-room luminaires using KrCl excimer (Far UV-C) to treat occupied spaces. Round-robin testing is also planned to gauge reproducibility between test laboratories.

Both the summary[1] and full[2] reports are available for download and include more details about the tested products, methods and results.

Product type	Product	Input power	UV-C output power	Peak UV wavelength	UV-C irradiance	IEC 62471 Risk Group
Tower 	LED-22-01	-48%	none detected	140 nm		
	LED-22-02	-49%	none detected	140 nm		
	LED-22-03		none detected	145 nm		
	LED-22-04	-12%		20 nm		
	LED-22-05	-71%		1 nm		2
	LPM-22-01	-14%		0		
	LPM-22-02	-26%		0		
Occupied-room Luminaire 	LED-22-06	-31%	-52%	5 nm		0
Vacant-room Luminaire 	LPM-22-03	3%	-47%	0		
	LPM-22-04	-16%		0	6%	
	LPM-22-05	1%	24%	0	-15%	
	LPM-22-06	-13%		0	88%	
	LPM-22-07	12%	-71%	0		

Values shown are differences from claim (e.g., -1% means measured value was 1% less than claim).

- Yellow shading indicates test result differed substantially from claim but would not necessarily be problematic (e.g., input power lower than rated)
- Red shading indicates test result differed substantially from claim and would likely be problematic (e.g., output power lower than rated)
- Green shading indicates test result did not differ substantially from claim (e.g., less than 10% difference)
- Empty fields indicate no claim was made or tested

Table 1: Test results relative to claims. Shading is explained in the table footnotes. Notably, whereas LPM-22-04 and LPM-22-06 had claims pertaining to minimum irradiance, the claim for LPM-22-05 pertained to maximum irradiance.

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References:

1 U.S. Department of Energy, "Radiometric Testing of Germicidal UV Products, Round 1: UV-C Towers and Whole-Room Luminaires CALiPER Summary Report," Sept. 2023. Available: https://www.energy.gov/sites/default/files/2023-09/ssl_caliper-guv-rd1-summary.pdf

2 U.S. Department of Energy, "Radiometric Testing of Germicidal UV Products, Round 1: UV-C Towers and Whole-Room Luminaires CALiPER Full Report," Sept. 2023. Available: https://www.energy.gov/sites/default/files/2023-09/ssl_caliper-guv-rd1-full.pdf