



**Pacific
Northwest**
NATIONAL LABORATORY

Preliminary Findings from Rounds 3 and 4 of CALiPER GUV Product Testing

Joint CORM & CIE-USNC Conference

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U.S. DEPARTMENT OF
ENERGY **BATTELLE**

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CALiPER background

- Program launched by DOE in 2006 to provide objective test data on solid-state (LED) and benchmark lighting products
- Expanded scope to include germicidal ultraviolet (GUV) disinfection products in response to the COVID-19 pandemic

At least one vendor says the lamp contains mercury, but another vendor says “no need of ballast” ...


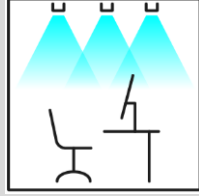

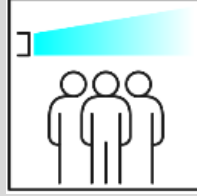


“Short-wave radiation with a peak at 253.7 nm”
“density of 254nm”
“more than 30 Wicm2”
“classified to-ozone and without-ozone”

CALiPER GUV product testing

- Round 1
 - Published on DOE website in 2023 (<https://www.energy.gov/eere/ssl/caliper>)
 - Test lab: Intertek
- Round 2
 - Published on DOE website in October 2024
 - Test lab: LightLab

- Round 3
 - In final review
 - Test lab: LightLab
- Round 4
 - First draft complete
 - Test labs
 - Intertek
 - LightLab
 - UL

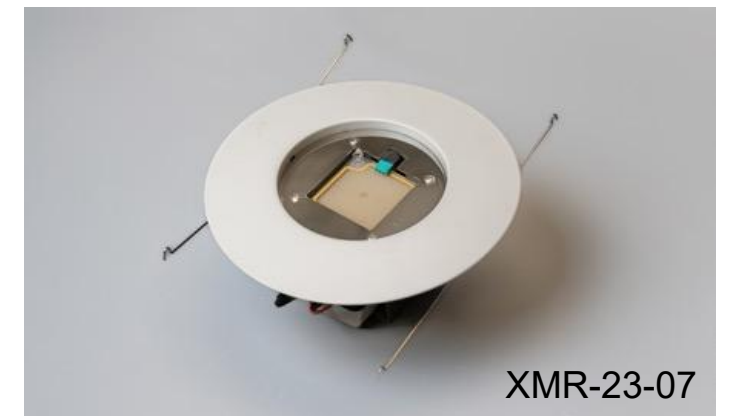
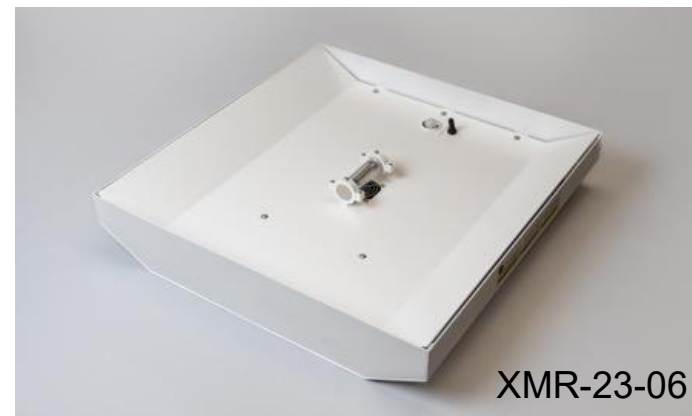
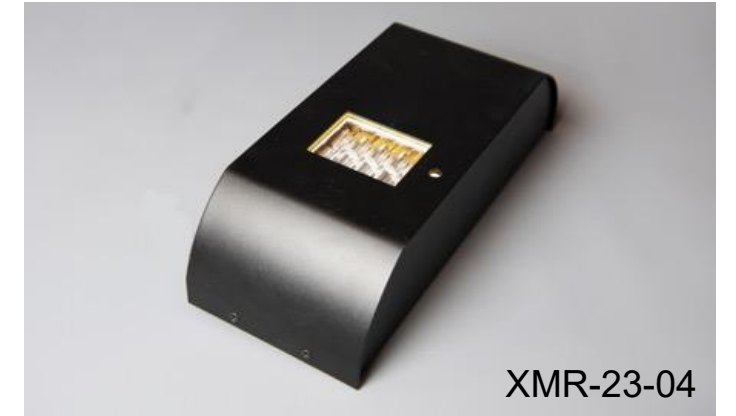
	Towers	Whole-room luminaires for vacant rooms	Whole-room luminaires for occupied rooms	Upper-room luminaires
KrCl excimer • Peak λ = 222 nm				
Low-pressure mercury (LPM) • Peak λ = 254 nm	Round 1	Round 1	Round 3	Round 2
UV LED • Peak λ = 255-280 nm	Round 1		Round 1	Round 2

CALiPER GUV Round 3 KrCl excimer products tested

XMR-23-02 was the only tested product that had lamps which could be tilted without tilting the whole luminaire, and was tested two ways

- All 3 lamps aimed at nadir
- All 3 lamps aimed 45° from nadir

XMR-23-04 was customized by the manufacturer for continuous UV emission (100% duty cycle) to enable goniometer testing

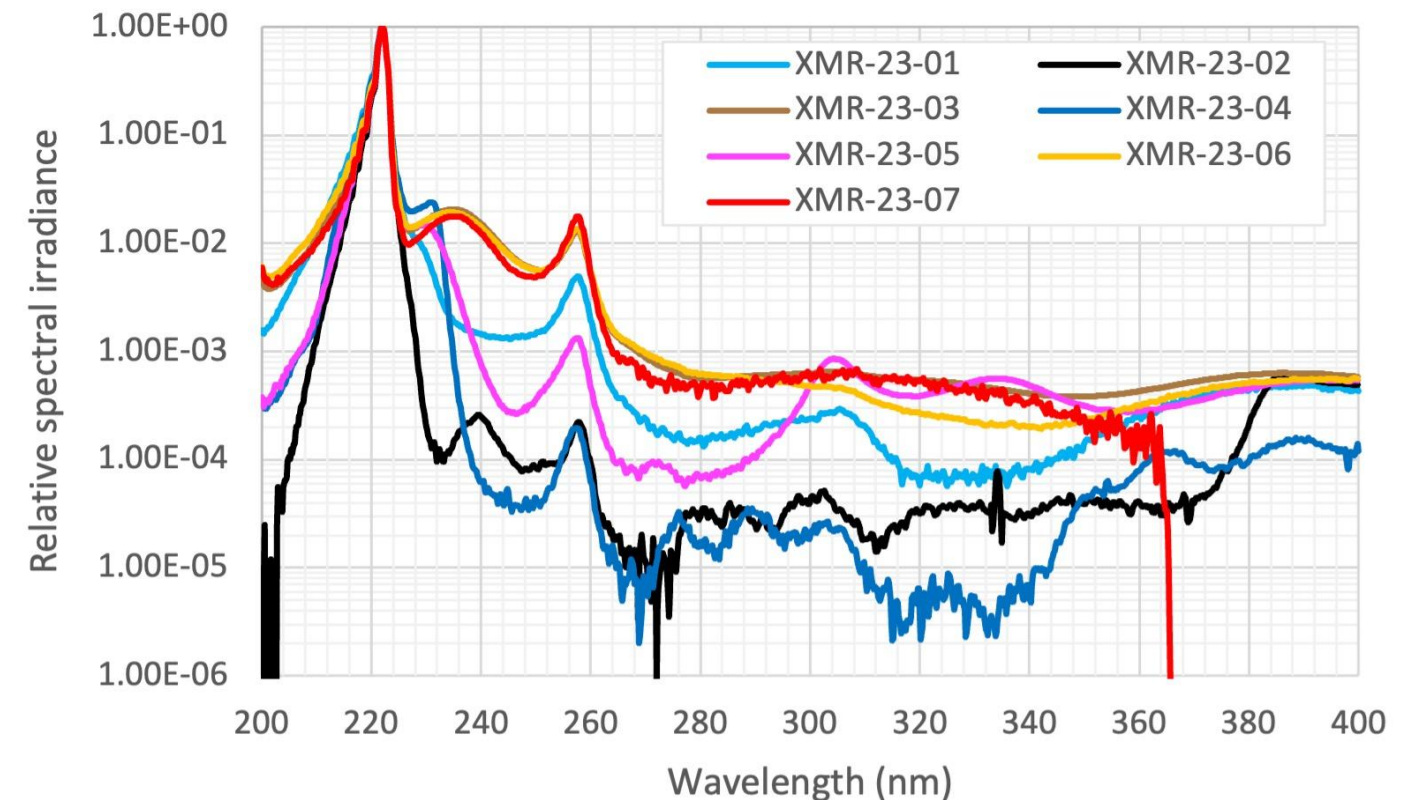


CALiPER GUV Round 3 spectral distribution

Compare with findings from
Eadie and others (2024)
<https://doi.org/10.1111/php.14005>

- ANSI/IES/IUVA LM-93-22 specifies measurement across 200–300 nm wavelength range
 - Partially covers UV-B (280–315 nm) and actinic weighting function (200–400 nm) ranges
 - Relatively little emission 300–400 nm, and relatively low sensitivity there for eyes and skin
- The 3 products on shaded rows in the table appeared to be unfiltered
 - The 4 filtered products could irradiate spaces to levels 2–3 times higher without exceeding safety limits

GUV product	Irradiance limit for luminaire relative to limit for monochromatic 222 nm radiation	
	Eyes	Skin
XMR-23-01	71%	62%
XMR-23-02	102%	100%
XMR-23-03	34%	28%
XMR-23-04	94%	95%
XMR-23-05	81%	75%
XMR-23-06	35%	29%
XMR-23-07	34%	27%



CALiPER GUV Round 3 photobiological safety

- CALiPER used spectral distribution data to predict results of photobiological safety testing for 5 products with far-field radiant intensity distribution data
 - The 3 products in the table clearly had far-field data in all directions
 - Irradiance was calculated at eye with 80° full-angle FOV detector aimed horizontally per RP-27.1
 - UL 8802 states that tested GUV products shall be oriented and operated to produce the most severe test result permitted by its construction and installation instructions
 - XMR-23-01 was predicted to **exceed** its irradiance limit for skin
 - Data for 2 other products could be considered far-field in vertical plane of lamp axis
 - XMR-23-03 and XMR-23-06 were predicted to **exceed** their irradiance limits for eyes and skin by > 2x

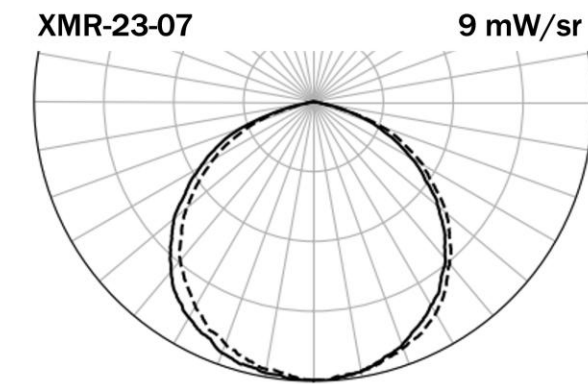
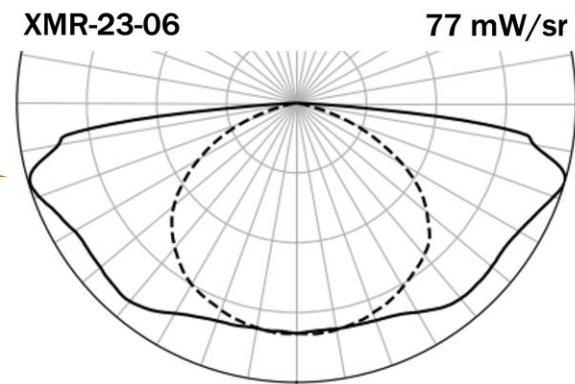
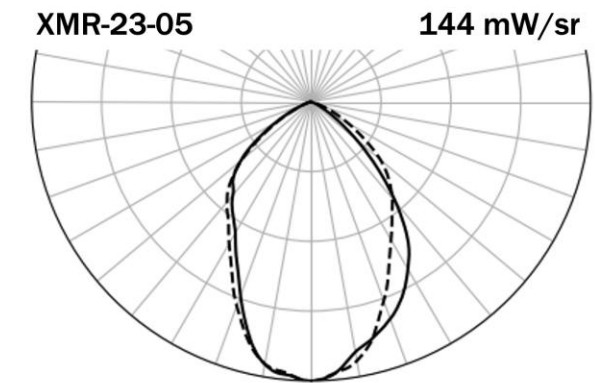
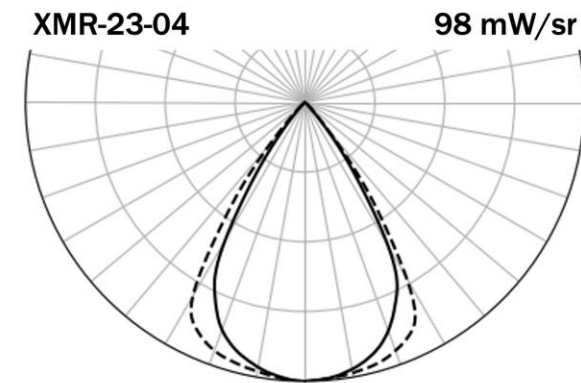
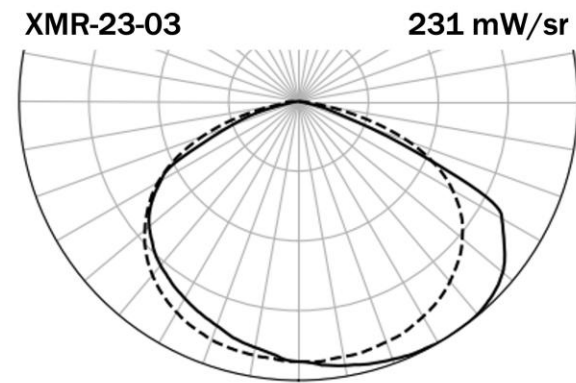
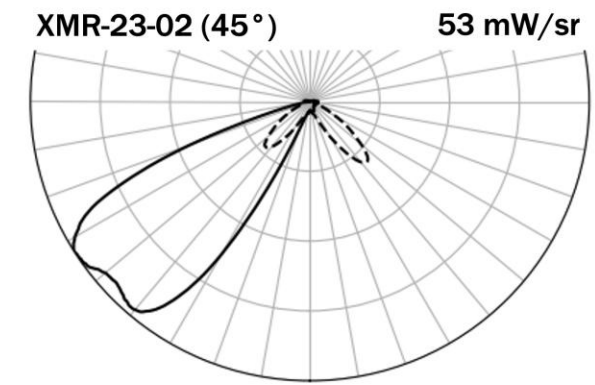
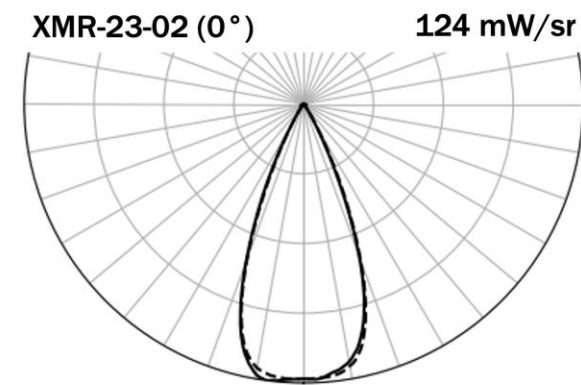
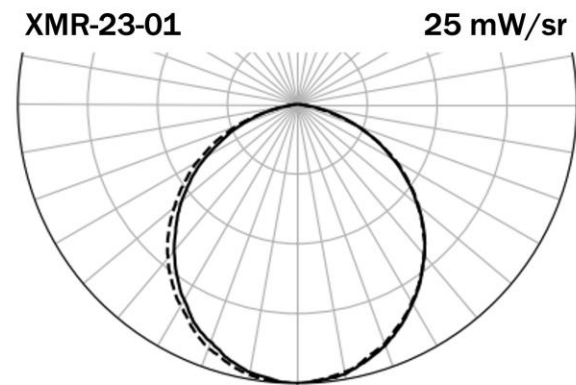
Standard versions of XMR-23-04 are configured for 10–50 s of UV emission out of every 12-minute cycle, depending on ceiling height

GUV product	Ceiling height (ft)	UV-C irradiance at eye (μW/cm ²)		UV-C irradiance on skin (μW/cm ²)	
		UL 8802 limit	Maximum calculated value	UL 8802 limit	Maximum calculated value
XMR-23-01	8	3.95	3.43	10.13	10.85
XMR-23-04 (10 s)	9	378.72	5.48	1134.72	16.93
XMR-23-04 (50 s)	11	75.74	1.69	226.94	5.22
XMR-23-07	8	1.86	1.11	4.50	3.25

CALiPER GUV Round 3 photobiological safety

The direction of maximum radiant intensity for XMR-23-02 was 57.5° from nadir when its lamps were aimed 45° from nadir

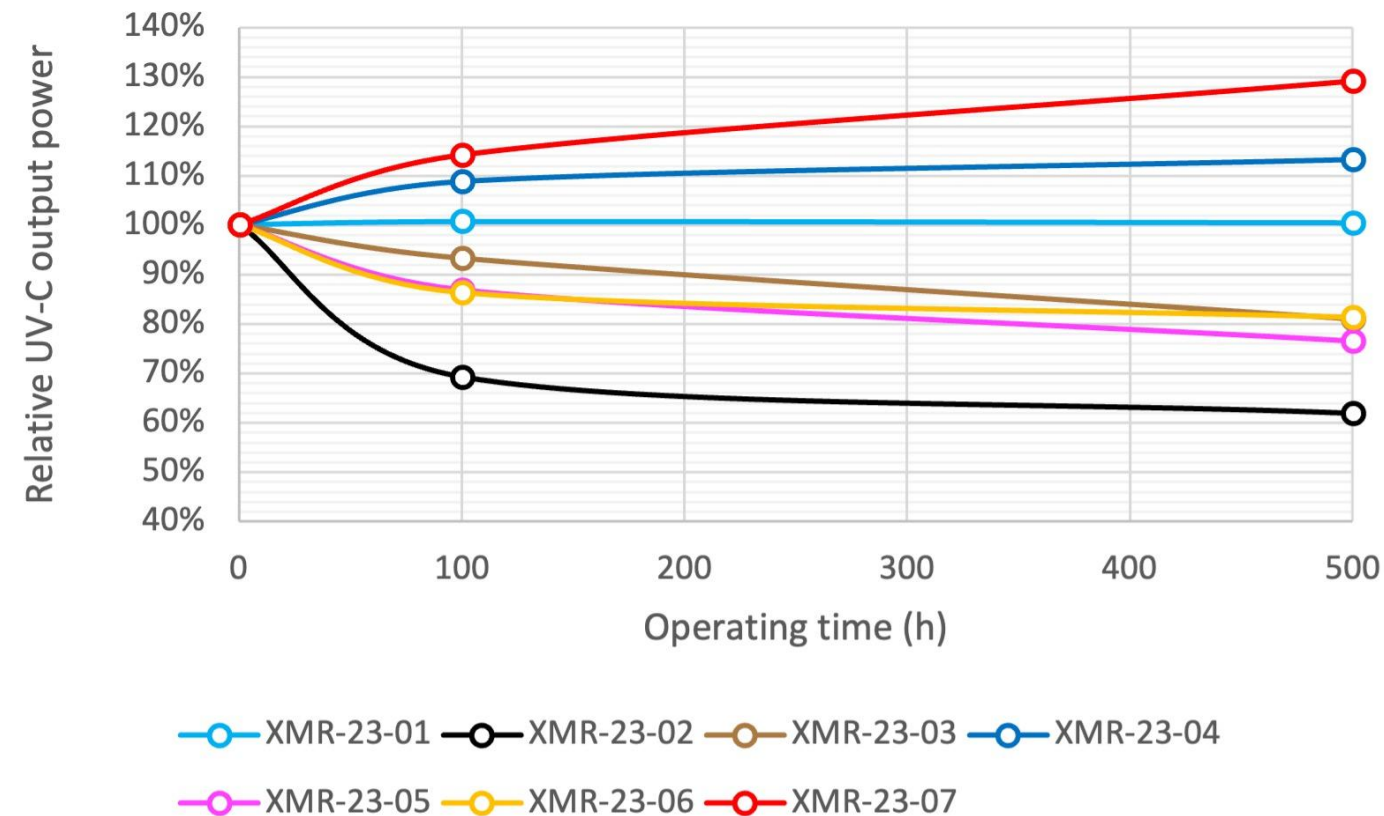
- ANSI/IES RP-27.1-22 assumes minimal emission at angles $\geq 50^\circ$ from nadir
 - Some products were rated/ marketed for ceiling or wall mounting



The direction of maximum radiant intensity for XMR-23-06 was 73.5° from nadir

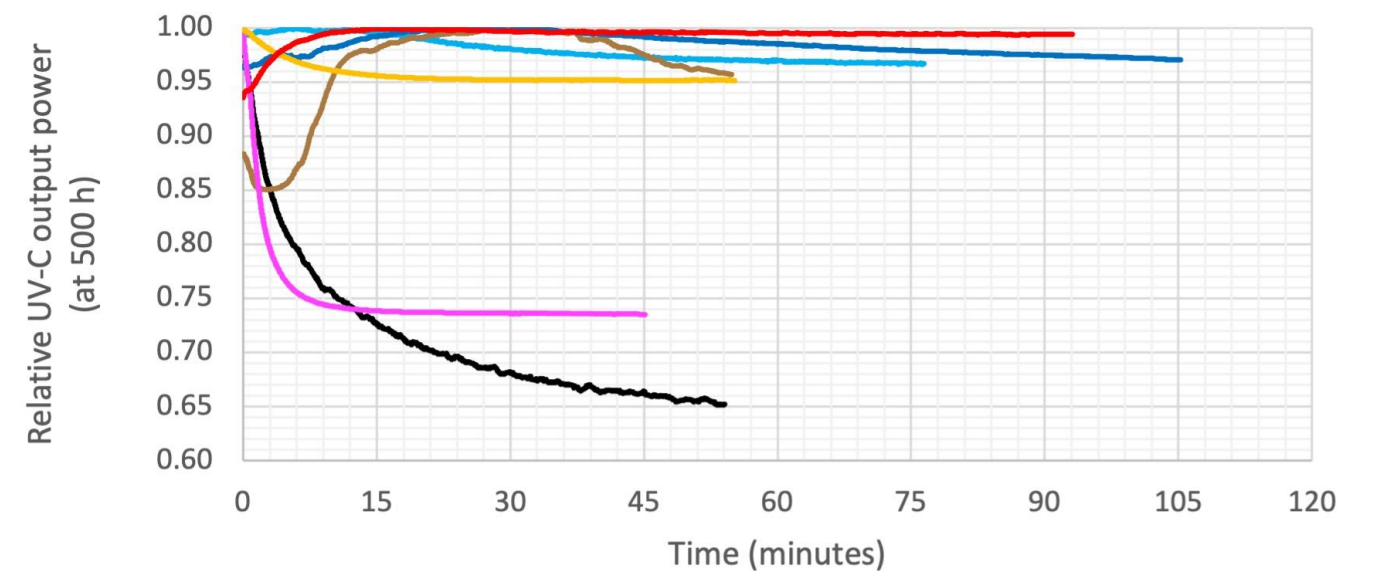
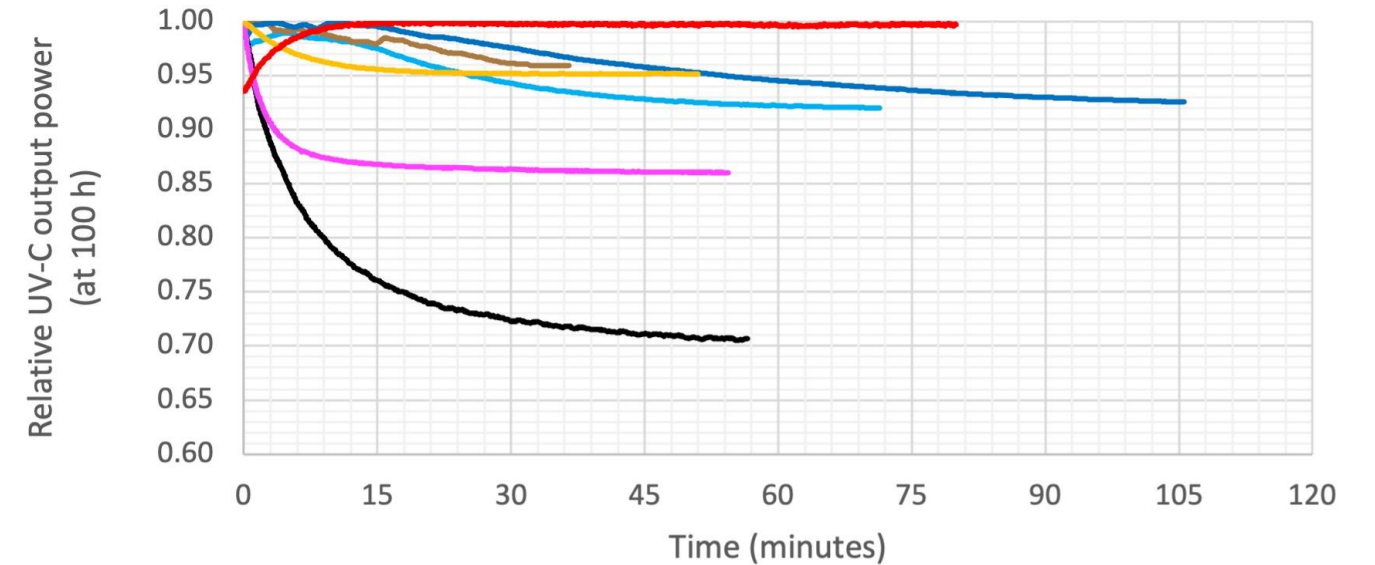
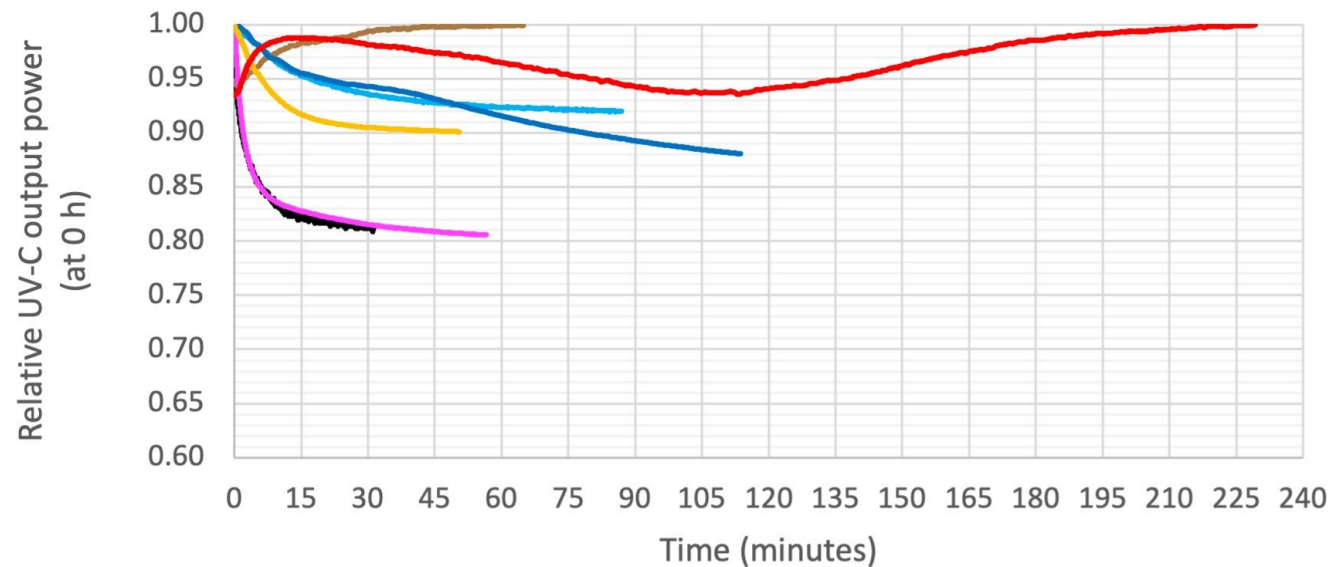
CALiPER GUV Round 3 long-term testing

- Curve slope for most products was greatest for the first 100 h of operation
 - Suggests a seasoning period of ~100 h might be appropriate
 - All products had been seasoned 2 h per LM-93
 - XMR-23-03 had an hour meter that indicated 126.6 h upon receipt



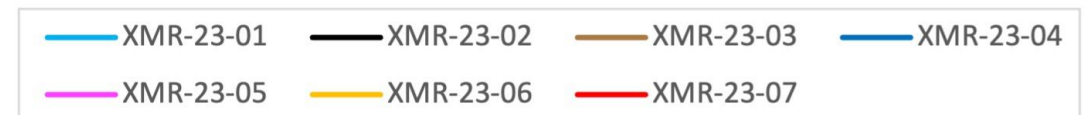
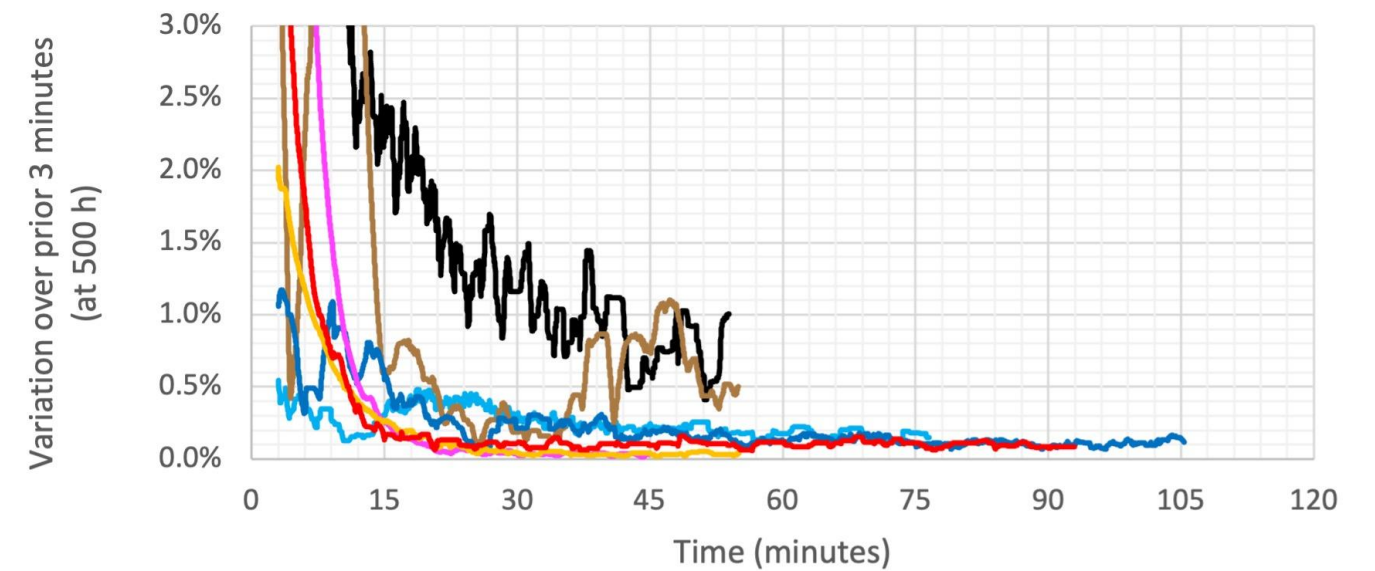
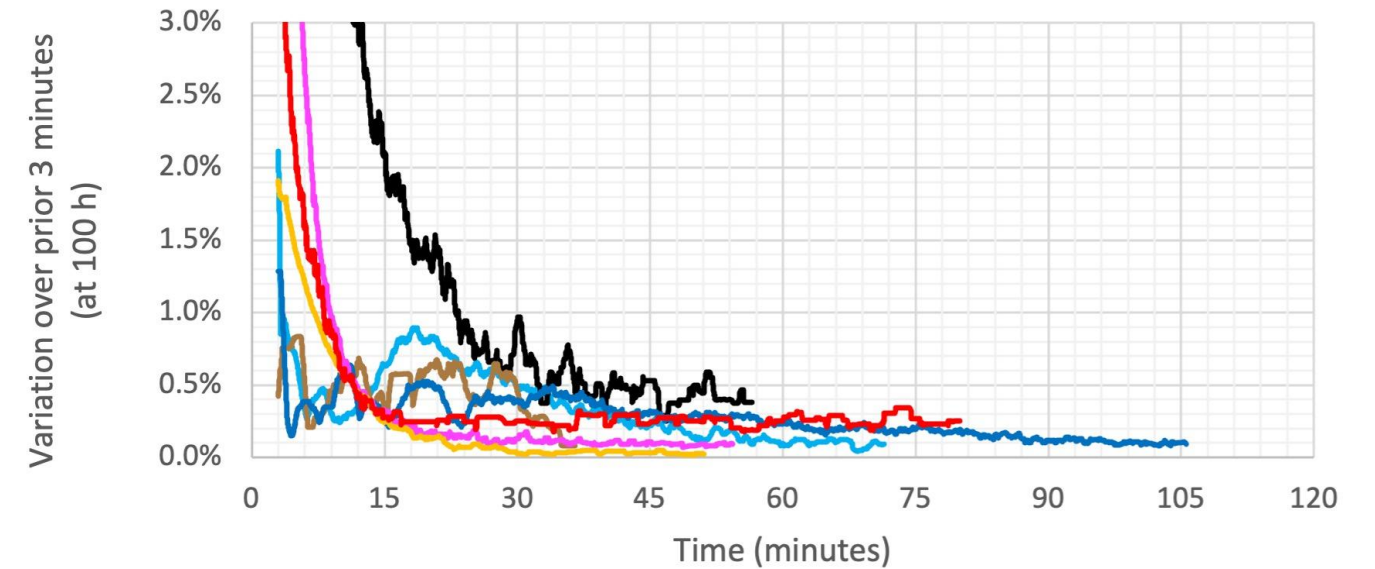
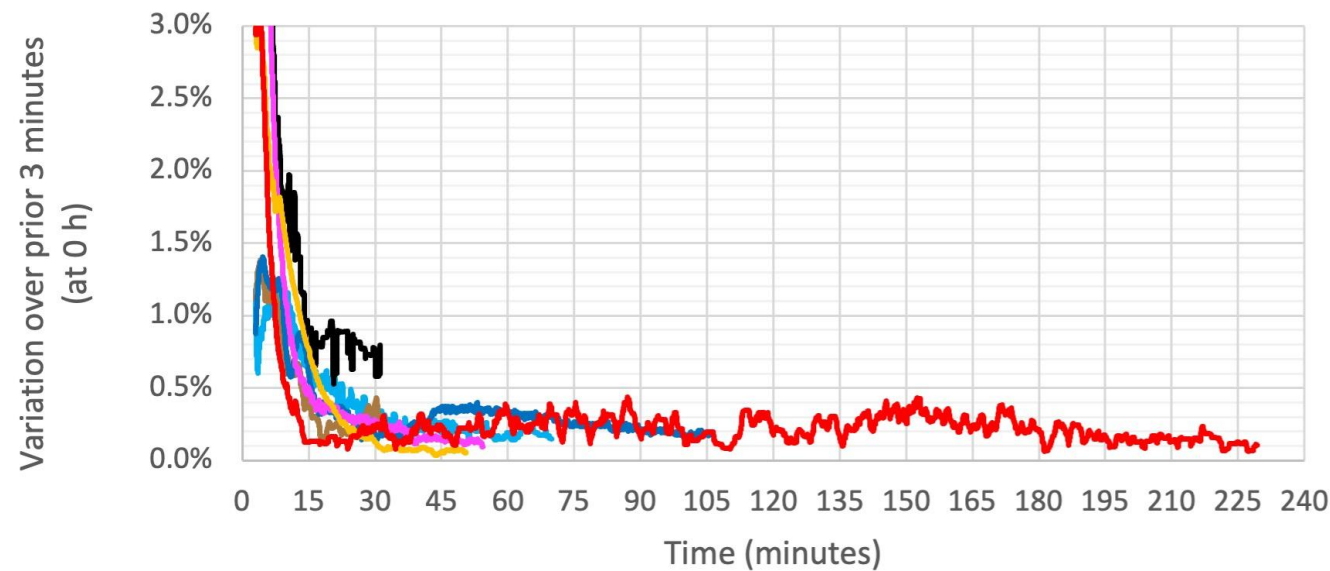
CALiPER GUV Round 3 product stabilization

- LM-93 specifies $\leq 1\%$ variation for 3 minutes
 - We deviated from the criteria, suspecting they were too lenient
 - Products needed at least 30 minutes to stabilize at nominal 0 h mark



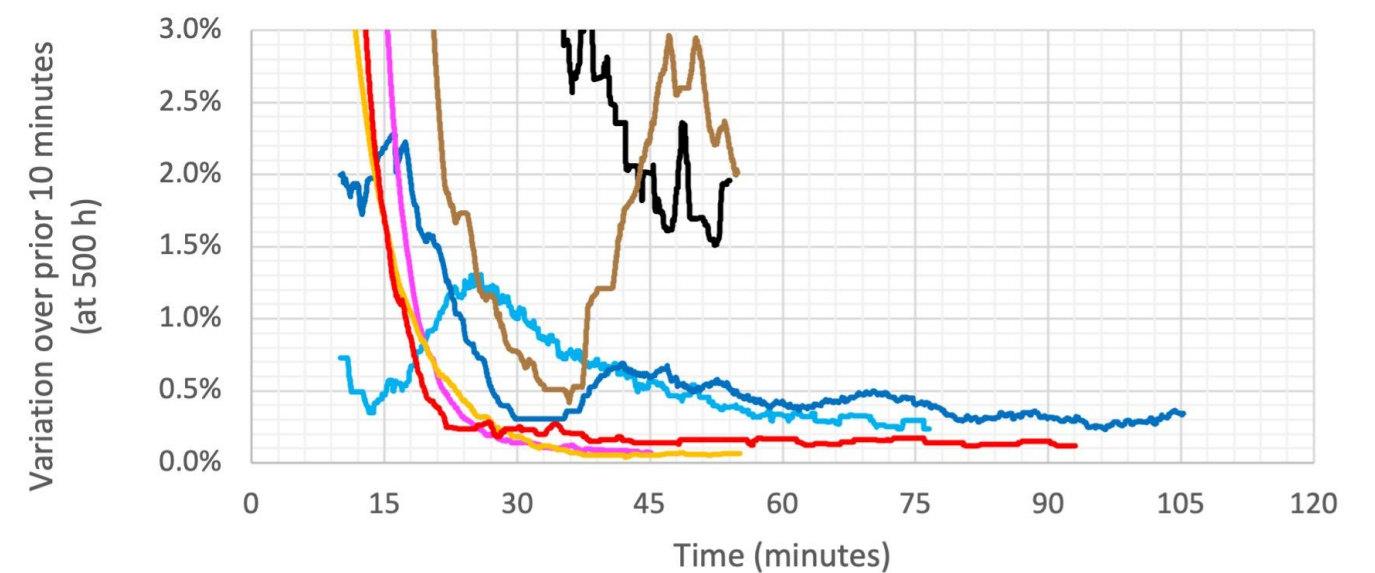
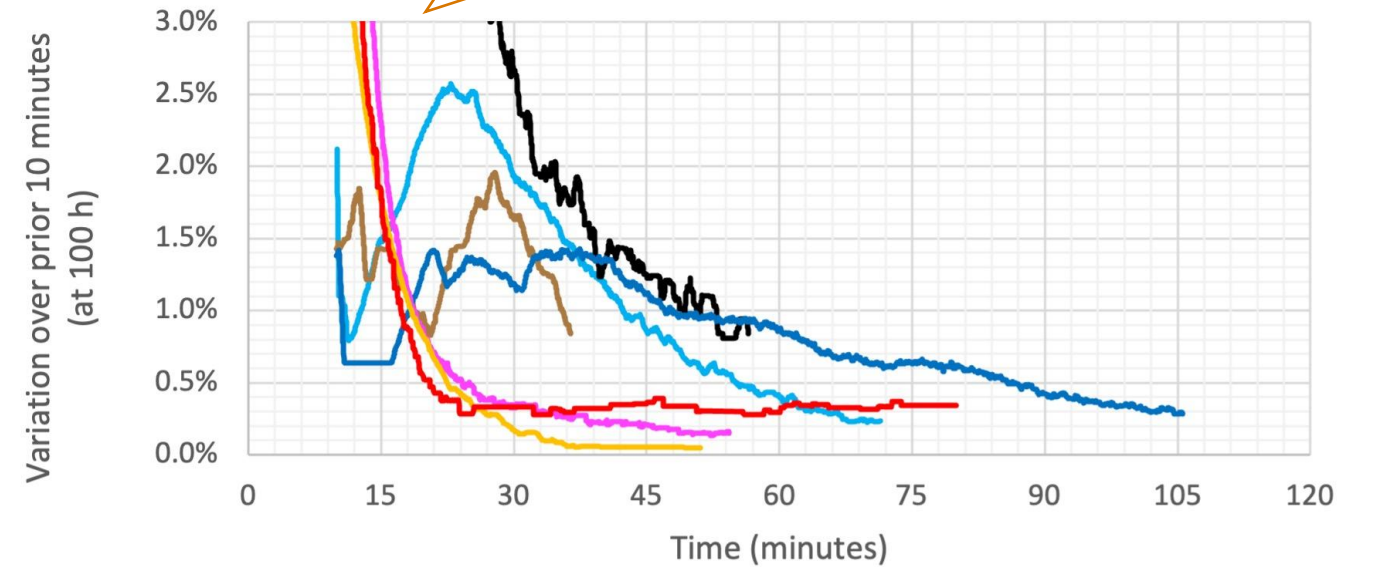
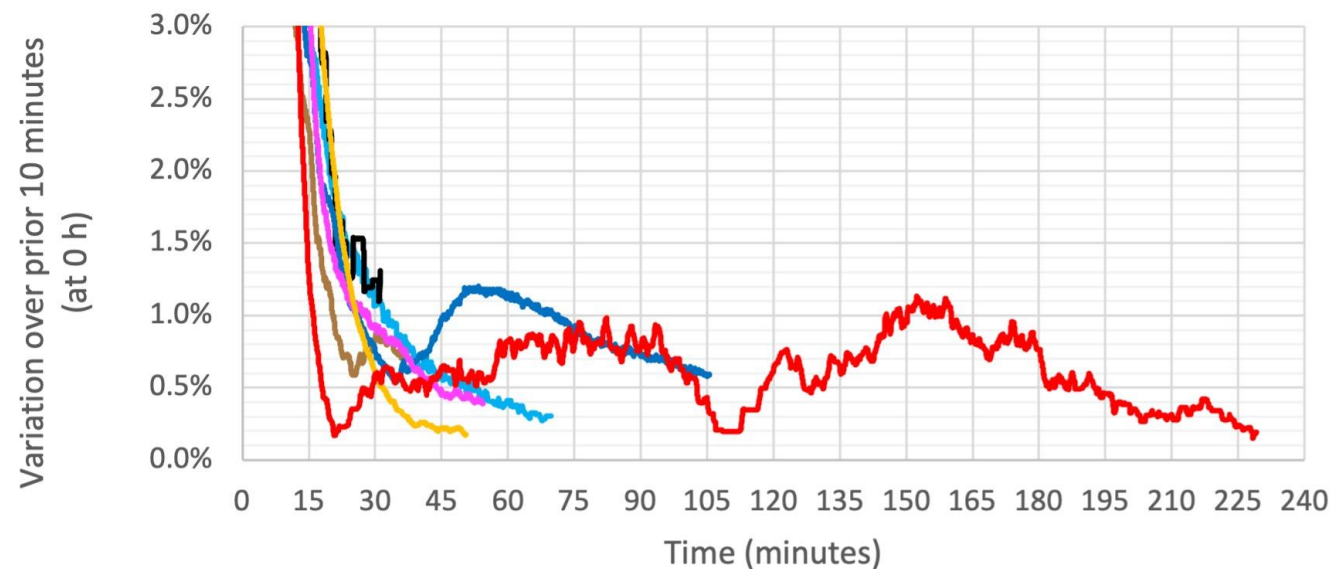
CALiPER GUV Round 3 product stabilization

- LM-93 specifies $\leq 1\%$ variation for 3 minutes
 - All products would have met the criteria within 15 minutes at nominal 0 h mark
 - Output power values would be overstated by 1–12% for five products and understated by 2–3% for the other two products



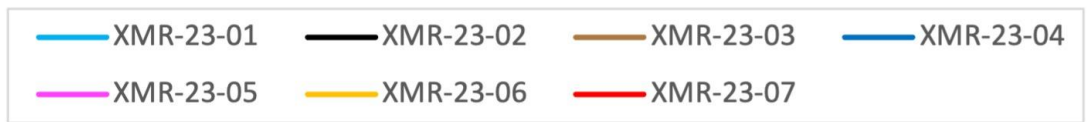
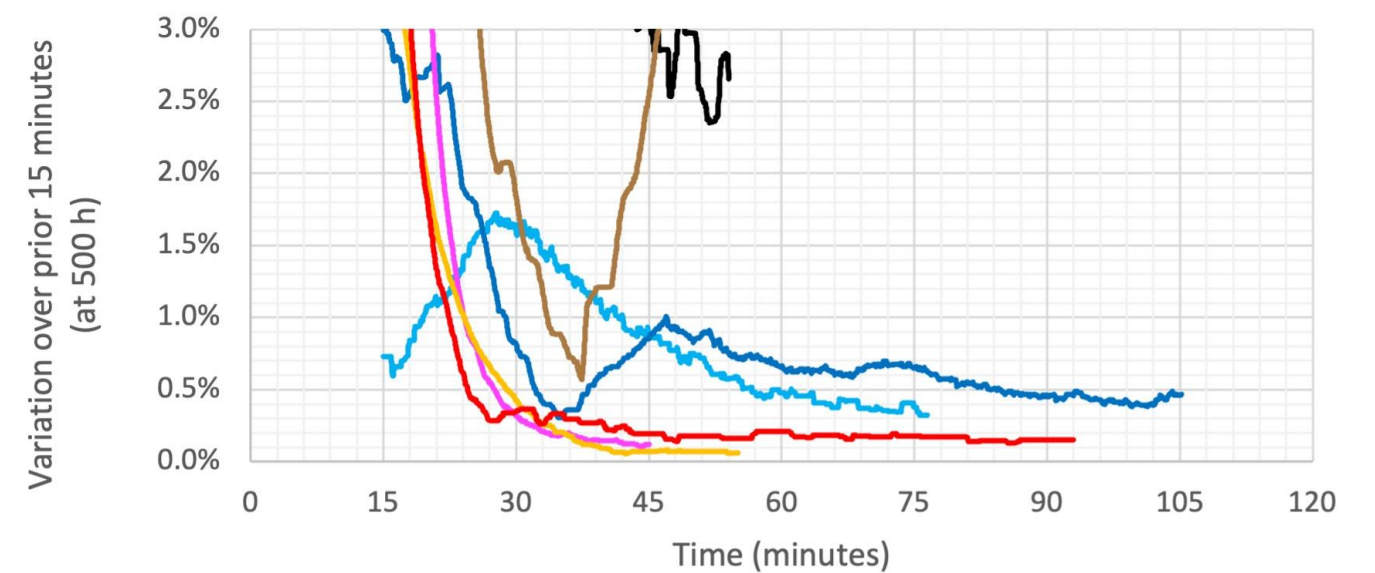
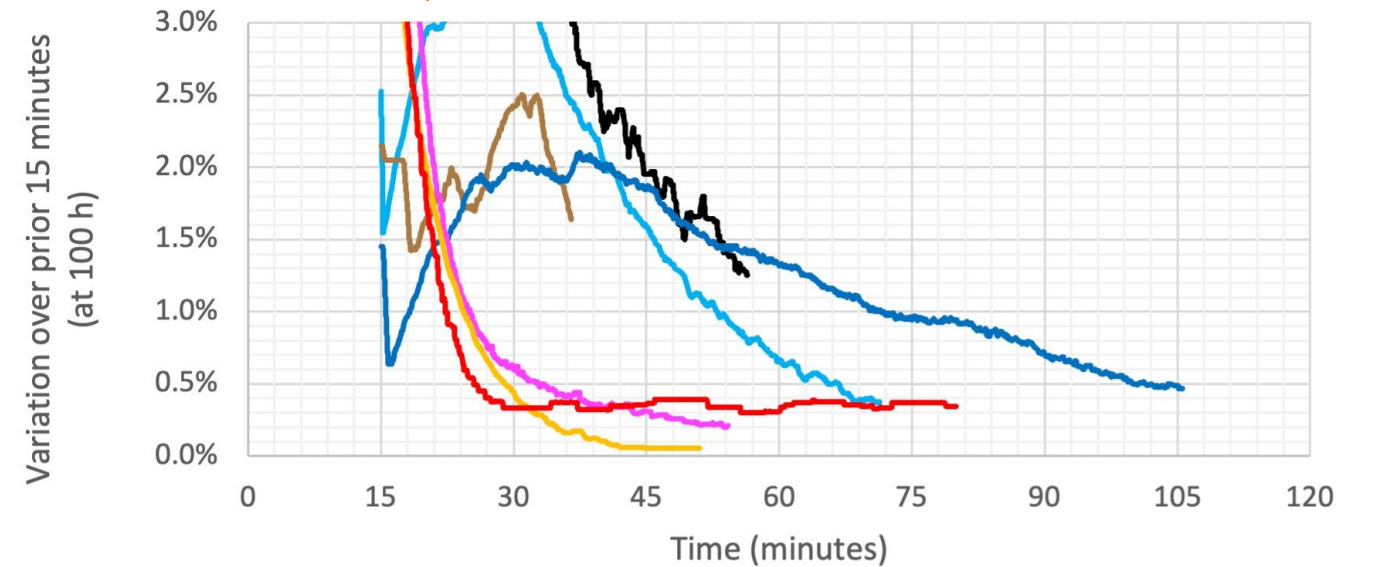
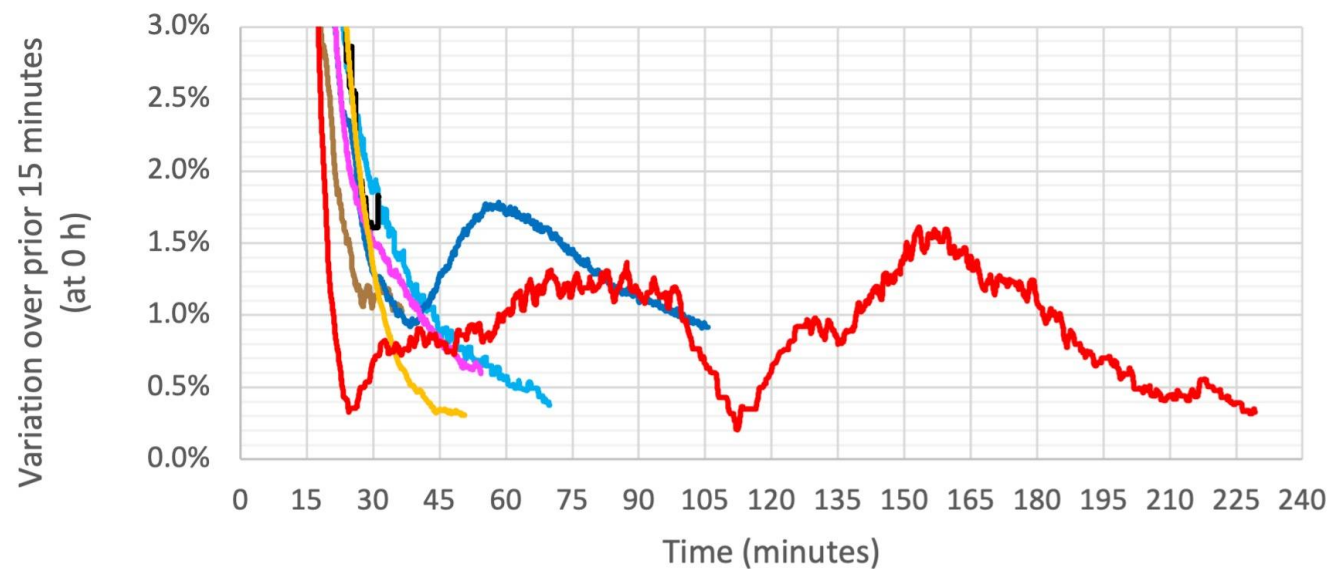
CALiPER GUV Round 3 product stabilization

- LM-93 specifies $\leq 1\%$ variation for 3 minutes
 - A 10-minute window might suffice, especially if supplemented with a minimum stabilization period of 20–30 minutes and ~100 h of seasoning
 - Pre-burning might shorten stabilization time



CALiPER GUV Round 3 product stabilization

- LM-93 specifies $\leq 1\%$ variation for 3 minutes
 - A 15-minute window appears stringent, especially if supplemented with a minimum stabilization period of 20–30 minutes and ~100 h of seasoning
 - Pre-burning might shorten stabilization time



CALiPER GUV Round 4 scope

- "Round-robin" interlaboratory comparison testing using products from Rounds 1–3
 - Only Intertek offered measurement via integrating sphere (specifically a hemisphere)
 - Only Intertek and LightLab offered measurement via gonioradiometer
 - All 3 test labs offered ANSI/IES LM-91-22 application-distance measurements



GUV product	Sphere	Gonio	Application -distance
LED-22-05C	Intertek	Intertek LightLab	-
LED-23-02	-	Intertek LightLab	Intertek LightLab UL
LPM-22-03A	-	Intertek LightLab	Intertek LightLab UL
LPM-23-01	-	Intertek LightLab	-
XMR-23-01	Intertek	Intertek LightLab	Intertek LightLab UL

Maximum nominal dimension

CALiPER GUV Round 4 preliminary findings

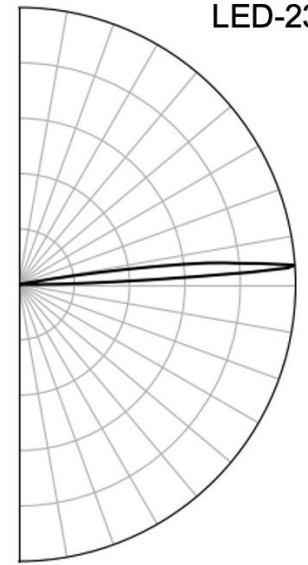
- Good agreement for electrical input power
 - Maximum relative range of 3.7%
- Greater variation for UV-C output power
 - Test sequence was LightLab, then UL, then Intertek gonio, then Intertek sphere
 - Variation for LED-22-05C would likely have been mitigated if it had been seasoned 100 h
 - LightLab used gonio mirror for LED-23-02, LPM-22-03A, and LPM-23-01
 - Intertek did not (resulting in near-field data)

GUV product	UV-C output power (mW)			Relative range
	LightLab (gonio)	Intertek (gonio)	Intertek (sphere)	
LED-22-05C	8.3	6.4	6.2	30.1%
LED-23-02	434.5	526.2	-	19.1%
LPM-22-03A	5,464.2	6,608.9	-	19.0%
LPM-23-01	548.7	661.8	-	18.7%
XMR-23-01	65.0	63.1	60.1	7.7%

Product preparation

- LPM-22-03A and LPM-23-01 were seasoned 100 h in prior rounds
- LED-23-02, LPM-23-01, and XMR-23-01 were operated 500 h in prior rounds
- No seasoning was performed for Round 4
- LightLab pre-burned LED-23-02 for 90 minutes, UL pre-burned all products for one hour, and Intertek pre-burned the two LPM products overnight

CALiPER GUV Round 4 preliminary findings



- Good agreement for application-distance testing
 - LED-23-02 was tilted 90° downward
 - Its tight beam was expected to be relatively sensitive to error in tilt angle

LED-23-02 data from Intertek

- Y direction is up, and
- X direction is right (per LM-91)

GUV product	Application distance (inches)	Grid resolution (inches)	
		Y direction	X direction
LED-23-02	60	4	2
LPM-22-03A	60	4	4
XMR-23-01	30	2	2

GUV product	Average UV-C irradiance (μW/cm ²)			Relative range
	LightLab	UL	Intertek	
LED-23-02	67.03	69.84	74.85	11.1%
LPM-22-03A	85.94	93.19	90.00	8.1%
XMR-23-01	3.40	3.36	3.32	2.5%

distance from radiometric center out from luminaire (inches)	12	1.19	1.27	1.27	1.55	1.65	1.74	1.74
	10	17.68	14.84	24.85	27.19	23.12	16.15	19.17
	8	95.36	83.80	107.08	89.44	80.21	65.20	56.26
	6	213.06	203.10	186.66	173.44	150.61	134.14	114.53
	4	232.72	205.09	208.46	194.97	164.49	135.62	116.09
	2	90.90	83.88	70.98	76.12	57.07	49.08	38.34
	0	7.07	7.25	6.29	6.63	4.57	3.48	2.42
			0	4	8	12	16	20
distance from radiometric center along luminaire (inches)								

In closing

- Next steps

- Targeting publication of Round 3 report in early 2025
 - Findings are already informing revision of LM-93
- Working with the test labs to identify/mitigate sources of disagreement in Round 4 results
- Launching Round 5

	Round 3	Round 4
PNNL report coauthors	Jason Tuenge Gabe Arnold Margaret Axelson Eduardo Rodriguez-Feo Bermudez	Jason Tuenge Gabe Arnold Margaret Axelson
Test laboratories	LightLab International Allentown	Intertek Testing Services LightLab International Allentown UL Solutions