Why ASHRAE Standard 185.2 is Important to the Success of Germicidal Ultraviolet Projects

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UV devices have been incorporated into HVAC systems as part of decarbonization efforts and to maintain coil efficiency. They are also in ASHRAE Standard 241-2023, *Control of Infectious Aerosols*. It is important to understand how the installation environment may affect the performance of a UV-C system. ANSI/ASHRAE Standard 185.2-2020, *Method of Testing Ultraviolet Lamps for Use in HVAC&R Units or Air Ducts to Inactivate Microorganisms on Irradiated Surfaces*, is a test method designed specifically to determine UV device performance when under HVAC-induced windchill conditions based on temperature, humidity and airflow.[1]

Low pressure UV lamps are the most commonly used UV-C source for microbial reductions in air, water and wastewater. UV was originally used for bacterial control by Niels Ryberg Finsen to treat tuberculosis of the skin, for which he received the Nobel Prize in 1903. Commercial production of UV lamps began in the early 1900s. A Cooper Hewitt lamp[2] is shown here.

Cooper Hewitt UV Lamp.[2]

The performance of early, modern UV-C lamps has been shown to be impacted by the temperature of its surrounding environment, with an ideal operating temperature between 75°F–80°F (24°C–27°C).[3,4] These lamps rely on gaseous mercury to produce the UV-C wavelengths and use a combination of temperature and pressure to generate their UV-C output by creating an internal environment for the optimum mercury vapor pressure. When the surrounding environment is colder or hotter than the ideal operating temperature, it will impact the mercury vapor pressure and subsequent lamp performance.

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Although it is known that the emitted light intensity of UV devices changes with temperature, little information exists on whether it is significant and how the windchill effects of an HVAC system might further alter performance. In this article we use a modified Standard 185.2-2020 apparatus to test four 254 nm non-ozone lamps; two 42 in. (107 cm) UV-C stick lamps, an induction lamp, a parallel (PLL) lamp and a 265 nm LED device to determine the significance of any change and to also develop an emission curve for each lamp/device. A radiometer was used for measuring the UV-C intensity at 254 nm. *Table 1* provides a description of the UV sources. Manufacturer's specifications were all noted to be at room temperature: 72°F–75°F (22°C–24°C).

The two 42 in. (107 cm) stick lamps were selected to determine if the lamp design differences, particularly filaments, would impact their performance (*Figures 1* and *2*). The most convenient way to describe these lamps is as "short filament" (100 Watt) (*Figure 1*) and "long filament" (105 Watt) (*Figure 2*); this refers to the filament position in relation to the base or end cap of the lamp. The long filament lamp is a more traditional high output stick lamp, and the short filament lamp is a high output lamp that has been manufactured for colder environments. The induction and PLL lamps (*Figures 3* and *4*, respectively) were selected for their unique configuration. Induction lamps do not use a filament, and "parallel lamps" are connected via a small cylindrical connection at the end of each.

Each UV lamp and LED device was tested per Standard 185.2-2020 at a constant airflow of 500 fpm (2.5 m/s), ±10 fpm (0.05 m/s); 50% relative humidity (±10%); the temperature varied from 55°F–120°F (13°C–49°C) in 5°F or 10°F (2.8°C or 5.6°C) degree increments to develop a temperature/intensity curve. The devices were allowed to stabilize at each measurement point. The intensity was measured at 1 m (approximately 39.37 in.). Readings were collected over a range of ±3°F (±1.7°C) of the target temperature, at the center position of the UV source using a radiometer, with a 254 nm peak sensor/detector for the lamps and peak 265 nm–270 nm) sensor/detector for the 265 nm LED device. It was determined that the center of the UV source was

TABLE 1 UV devices.

	DESCRIPTION OF TESTED UV SOURCES	MANFACTURER SPECIFIED INTENSITY @ 1 m (μW/cm²)	LAMP WATTAGE
1.	42 in. T5 HO Stick Lamp with "Short Filaments" (Figure 1)	290	100
2.	42 in. T5 HO Lamp with "Long Filaments" (Figure 2)	285	105
3.	Induction Lamp (Figure 3)	1300	300
4.	95 Watt PLL (Figure 4)	NA	95
5.	265 nm LED Device 12 × 30 mW (Figure 5)	360,000 (360 mW)*	NA

*Calculated 12 × 30 mW

FIGURE 1 Short filament lamp intensity.

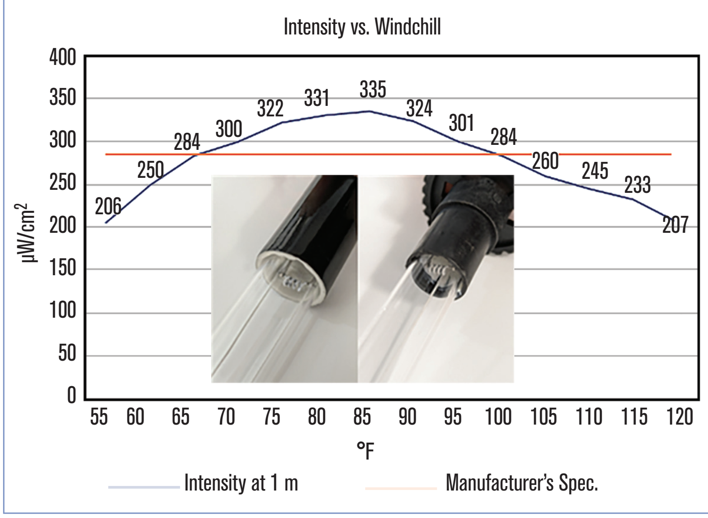
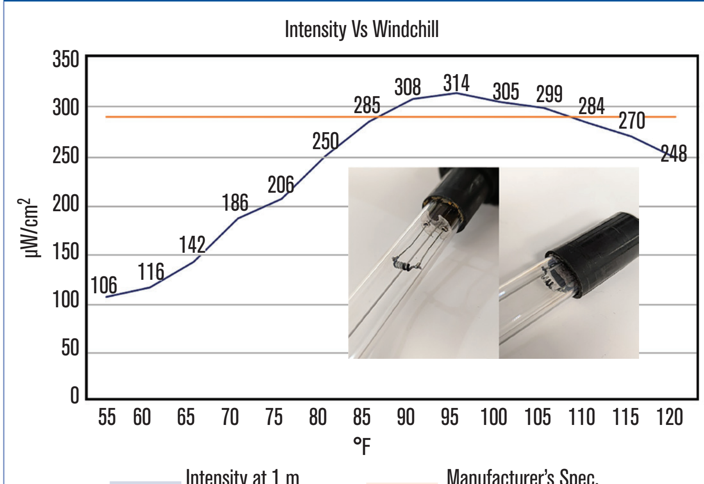


FIGURE 2 Long filament lamp.



consistently the highest measured intensity.

Table 2 provides the measured intensities at each of the Standard 185.2-2020 testing temperatures: 55°F (13°C), 75°F (24°C) and 120°F (49°C). All of the UV lamps had lower intensities at 55°F (13°C). Losses ranged from 27% to more than 70% from the manufacturer's specification. Only one of the lamps achieved the manufacturer's specification at 75°F (24°C), the short filament lamp, which exceeds the manufacturer's specification from 65°F–100°F (18.3°C–37.7°C) by as much as 18%.

The short filament 100 W lamp had the lowest intensity loss at 55°F (13°C) at –27% (*Figure 1*). Intensity losses were also seen at elevated temperatures from 105°F–120°F (41°C–49°C). The greatest loss was observed at 120°F (49°C) at –36%.

The long filament 105 W lamp did not meet manufacturer's specification at 75°F (24°C); however, at 90°F–105°F (32.2°C–40.6°C), it exceeded it (*Figure 2*). The lamp did not perform well at lower temperatures; at 55°F (13°C) the intensity dropped by 63% from the manufacturer's specification. It performed well at elevated temperatures with only a 14% loss at 120°F (49°C).

Induction lamps are known for having very high UV-C intensity. We were never able to achieve the manufacturer's specification of 1,300 $\mu W/cm^2$ at any temperature for the 300 W lamp. The intensity curve was close to linear and did not exhibit significant curvature in the testing range. The Standard 185.2-2020 test chamber temperature was taken up to 135°F (57°C) during the test to see if the UV intensity would begin to show curvature, which it did at 125°F (51.6°C). Temperatures above 120°F (49°C) were not part of this study. At the colder temperatures the induction lamps had the highest intensity losses, at greater than 70%.

The PLL lamps' unique design is intended to provide high UV-C intensity at a shorter total length. This lamp performed well at elevated temperatures as seen in *Figure 4* and achieved the manufacturer's specification at 95°F (35°C). At 55°F (13°C) the PLL also exhibited significant intensity losses of approximately 67%.

For comparison, a 265 nm LED device was also tested. UVC LEDs can reach temperatures in excess of 400°F (204°C) within one second of being turned on, requiring a significant heat sink (*Figure 5*). The device has 12 mW–30 mW, 265 nm LEDs equally spaced and attached to the heat sink; they were not directly exposed to the conditioned air. The LED device was tested for about one hour and performed better at cooler temperatures. Intensity

FIGURE 3 Induction lamp.

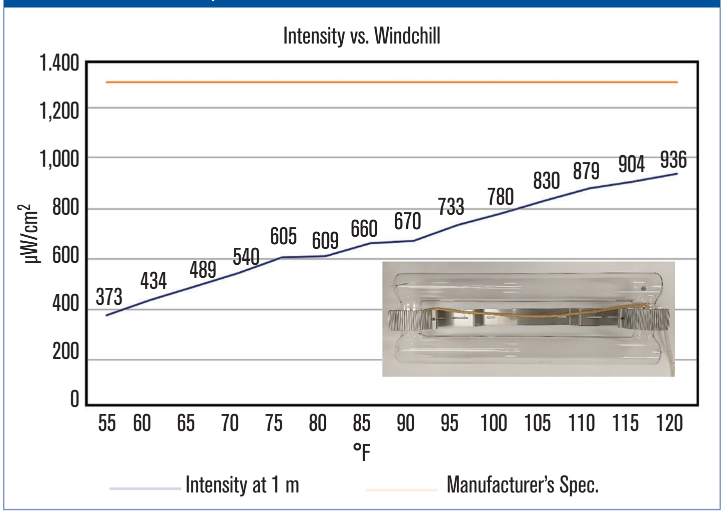


FIGURE 4 PLL lamp.

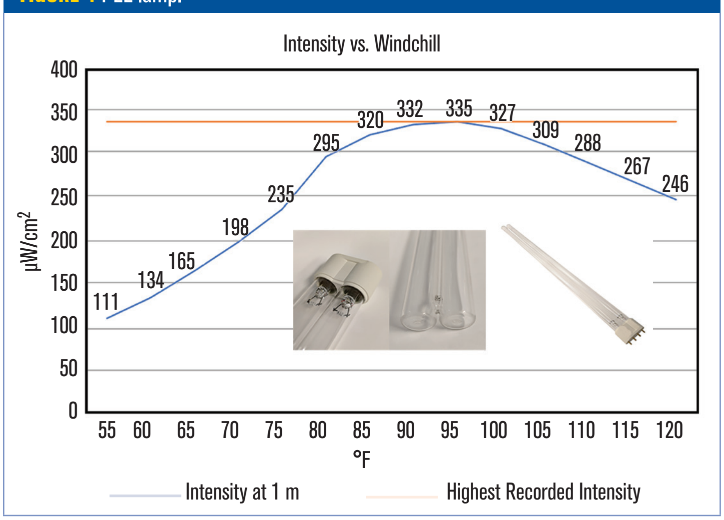


TABLE 2 Measured intensity.

	DESCRIPTION OF TESTED UV SOURCES	MEASURED INTENSITY ($\mu W/cm^2$)		
		55°F	75°F	120°F
1.	42 in. T5 HO Stick Lamp with "Short Filaments" (290 $\mu W/cm^2$)	206	322	207
2.	42 in. T5 HO Lamp with "Long Filaments" (285 $\mu W/cm^2$)	106	206	248
3.	Induction Lamp (1,300 $\mu W/cm^2$)	373	605	936
4.	95 Watt PLL (NA)	111	235	246
5.	265 nm LED device 12 × 30 mW (360 mW total)	49	48	40

measurements from 55°F–85°F (13°C–29°C) exhibited little to no change. Surprisingly, at elevated temperatures the measured intensity declined by as much as 18% at 120°F (409°C). The LED device had the highest specified UV intensity. However, it generated the lowest intensity at 39.37 in. (1 m) at all of the temperatures.

Standard 185.2-2020 testing is imperative to a successful system design. *Table 3* provides the estimated exposure time required to achieve a D90, 90% microbe reduction for influenza A, using 1900 μW/cm^2·s as the inactivation rate constant with a single lamp located at a distance of 12 in. (0.3 m). The inverse squares law was used to estimate the UV intensity at 12 in. (0.3 m) to represent a more real-world application. When comparing the two 42 in. (107 cm) HO lamps at 55°F (13°C), approximately a 2x difference exists in the time required to achieve the D90, 90% reduction of influenza A.

Table 4 provides the estimated UV-C dose at different air velocities using measured intensities for the 42 in. (107 cm) short filament lamp. The inverse squares law was again used to estimate UV intensity at 12 in. (0.3 m) to represent a more real-world application.

Source manufacturer specifications are used to design many systems. They are performed at 72°F–75°F (22°C–24°C) and no airflow. *Tables 3* and *4* illustrate that seasonal variation in the surrounding environment (heating versus cooling), in addition to accelerated and/or variable air velocities, may cause a system to not perform as intended. These scenarios highlight the importance of Standard 185.2-2020 when specifying UV devices. Knowing the UV source intensities at various temperatures with airflow and humidity (found using Standard 185.2-2020), combined with the maximum designed air velocity for the installation location provide engineers and specifiers needed information for successful use of UV systems for decarbonization (coil sanitation) and pathogen control.

FIGURE 5 265 nm LED device.

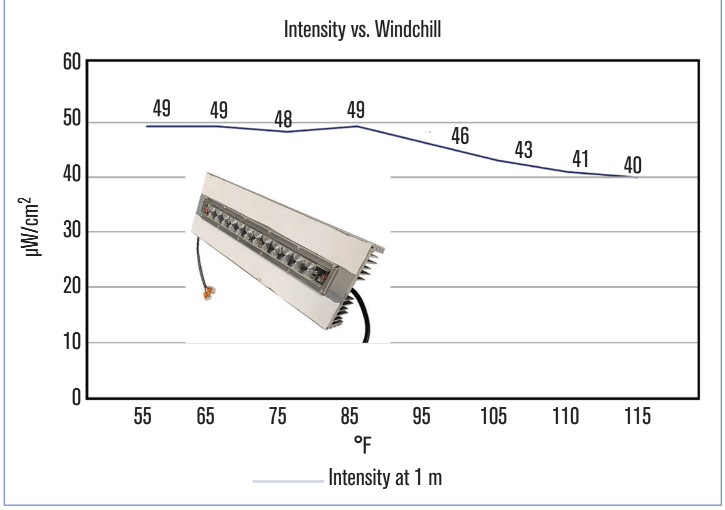


TABLE 3 D90 exposure times for influenza A (1900 μW/cm^2·s) at Standard 185.2 temperatures.

	DESCRIPTION OF TESTED UV SOURCES	ESTIMATED TIME TO ACHIEVE D90 FOR INFLUENZA A (SECONDS) @ 12 in.		
		55°F	75°F	120°F
1.	42 in. T5 HO Stick Lamp with "Short Filaments" (290 μW/cm^2)	0.86	0.55	0.85
2.	42 in. T5 HO Lamp with "Long Filaments" (285 μW/cm^2)	1.67	0.86	0.71
3.	Induction Lamp (1,300 μW/cm^2)	0.47	0.29	0.19
4.	95 Watt PLL (NA)	1.58	0.75	0.72
5.	265 nm LED device 12 × 30 mW (360 mW total)	3.60	3.68	4.41

TABLE 4 Single lamp, estimated UV-C dose, 42 in. HO stick lamps at 12 in. and different velocities.

	LAMP FILAMENT DESIGN	SHORT FILAMENT	LONG FILAMENT	SHORT FILAMENT	LONG FILAMENT	SHORT FILAMENT	LONG FILAMENT	SHORT FILAMENT	LONG FILAMENT
Est. Delivered Dose	Duct Velocity (ft/min)	500	500	1,000	1,000	1,500	1,500	2,000	2,000
	Assumed UV Zone (ft)	6	6	6	6	6	6	6	6
	55°F	1,598	821	799	410	533	274	398	205
	75°F	2,498	1,598	1,249	799	828	533	621	641
	120°F	1,606	1,922	803	961	533	641	400	481

References

1. ANSI/ASHRAE Standard 185.2-2020, *Method of Testing Ultraviolet Lamps for Use in HVAC&R Units or Air Ducts to Inactivate Microorganisms on Irradiated Surfaces.*

2. Electrotherapy Museum. Working Example of One of the First Commercially Available UV Lamps. Electrotherapy Museum. www.electrotherapymuseum.org

3. Lau, J., W. Bahnfleth, J. Freihaut. 2009. "Estimating the effects of ambient conditions on the performance of UVGI air cleaners." *Building and Environment* 44(7):1362–1370.

4. Lau, J., W. Bahnfleth, R.Mistrick, D. Kompare. 2012. "Ultraviolet irradiance measurement and modeling for evaluating the effectiveness of in-duct ultraviolet germicidal irradiation devices," *HVAC&R Research* 18(4):626–642. ■