Effective Ultraviolet Sanitizing

Using

STERILE-BRIGHT™

OVERVIEW –

Ultraviolet light in the proper wavelengths destroys pathogens like bacteria, viruses, and fungi. Sterile-Bright™ technology uses a unique combination of germicidal wavelengths in conjunction with ozone generation to provide a holistic, comprehensive and reliable sanitizing process. Although UV sanitizing has been well-established for more than 100 years, actual practices (protocols) for using UV for large areas and multiple surfaces is relatively new and often misunderstood. For example, some potential users are concerned about possible adverse effects upon people, pets, plants, and materials. These common questions and concerns will be addressed to provide an understanding of how and why Sterile-Bright™ technology works safely and more effectively than other UV products.

HOW UV WORKS –

All light is electromagnetic radiation and is commonly defined by its wavelength in nanometers ("nm") and photon energy measured in electron volts ("eV") or joules ("aJ"). We don't normally think of visible light as radiation because we take for granted it is safe and a natural part of our environment. Yet, even visible light can be dangerous if it is too intense or inappropriately stimulates our hormonal system. For example, visible and near-visible blue light can disrupt our circadian rhythms. UV light, by nature, has a higher energy level than visual wavelengths which is why it can destroy viruses, bacteria, and fungi. UV is also used to activate chemical processes and alter chemical structures. It stands to reason that materials, surfaces, and people can be negatively impacted by excessive UV exposure. This does not automatically mean that all UV is dangerous. Short-term exposure to "black lights" has been commonplace in entertainment venues like dance clubs, bars, and theaters as well as museums to create a "fluorescing" effect. Short exposures to most UV is relatively safe, even to the naked eye and bare skin. There are several ranges within the UV category spanning from 10 nano meters ("nm") to 457nm. Sanitizing UV usually holds between 457nm down to 180nm, spanning the most common categories as follows:

UV-A is the longest wavelength defined as ultraviolet spanning from 457nm to 315nm. While it has a lower energy than shorter wavelengths, it has greater penetrating power for skin and eyes. It is associated with sunburn, skin aging, and altering DNA in the dermis, epidermis, and even the hypodermis. Higher frequencies of UV-A from 425nm to 457nm usually require special lasers to be generated. UV-A travels well through the atmosphere and is associated with modest germicidal potency. Some UV-A wavelengths can be generated by light emitting diodes (LEDs) and there are several sanitizing systems based upon this wavelength. All such systems require very long exposure periods that can be harmful to certain materials; in particular, polymers like plastics.

UV-B falls between 280nm and 315nm. It is associated with sunburn and skin cancers. It penetrates the dermis and can reach the epidermis. Although UV-B has a higher energy than UV-A, some doctors and scientists believe it is more harmful for longer exposures. Modest exposure of about 15 to 20 minutes of summertime UV-B has the benefit of generating vitamin D3 through a chemical reaction in the skin. Most UV-B is filtered out at sea level by the atmosphere. Sun blocking lotions use waxes or metalized compounds like zinc oxide paste to prevent UV-B from penetrating the skin.

UV-C is blocked from reaching the lower atmosphere by the ozone layer. Ranging from 200nm to 260nm, some UV-C at above 260nm to 280nm can reach very high altitudes, but is not naturally occurring from sunlight at sea level. Within UV-C there are several categories, but the most common distinctions are between the germicidal frequency of 254nm and "far UV-C" falling between 207nm and 222nm. UV-C at 254/257nm is the most commonly used germicidal frequency (wavelength) due to its higher energy and proven efficacy. In general, light emitting diodes (LEDs) cannot generate germicidal wavelengths with sufficient intensity to sanitize wide areas. There are some LEDs being used to "clean air" with a circulation system, but surfaces must still be addressed using other methods.

FAR UV-C references the 207nm to 222nm range and is highly effective in destroying viruses, bacteria, and fungi. Its higher energy is associated with germicidal power while the shorter wavelength is believed to be safe for human exposure because it does not penetrate the skin or eye cornea (lens). It is important to note that assumed safety associated with the lack of penetration is based upon laboratory experiments. Since this frequency band is *not naturally occurring* in our environment, there is no way to determine with certainty that long-term exposure is not harmful. Still, claims are being made that continuous exposure to 207nm~222nm can be tolerated. UV-C is absorbed by the atmosphere and does not travel well or far at sea level under normal humidity. This implies the far UV-C source must be relatively close to the intended target.

VACUUM UV is often placed in the UV-C category, but it is significantly different because it is powerful enough to ionize substances/elements like oxygen (O_2), turning it into ozone (O_3). Vacuum UV ranges from 10nm to 200nm, but is usually confined between 180nm and 200nm which can be produced from special UV bulbs. It has very potent germicidal efficacy, but does not travel well through the atmosphere because it is absorbed and blocked when reacting to the atmosphere, creating ozone and other reactions. Because of the ozone effect, vacuum UV-can be effective in controlling dust mites, bed bugs, and certain insect larvae. Ozone is, itself, an effective germicide that destroys viruses, bacteria, fungi, and living organisms. Ozone fumigation is used in extermination and deodorization. In fact, ozone is perhaps the only effective means for removing odors as potent as skunk.

Professor Anne Rammelsberg of Millikan University explains that UV energy initiates a reaction between two thymine molecules within DNA. Although bacteria can normally repair damaged DNA, when the damage is extensive the cell ceases to function. This same response can be engendered in viruses and fungi relative to the wavelength used and the light intensity. There are actually four criteria that determine the germicidal "kill rate:" (https://www.scientificamerican.com/article/how-does-ultraviolet-ligh/)

1) UV spectrum/wavelength (UV-A, UV-B, UV-C, Vacuum UV)

2) Light intensity – power

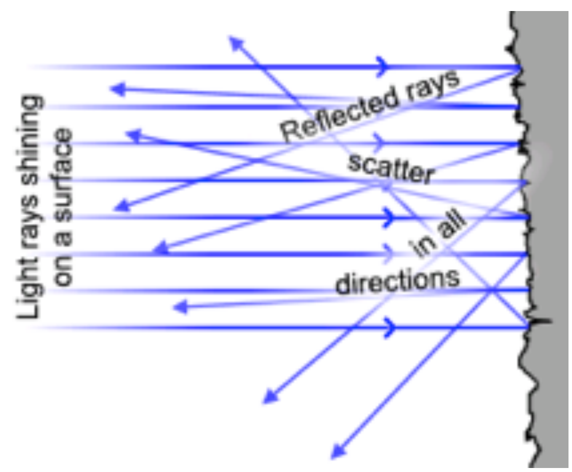
3) Proximity to intended surface and/or space volume

4) Duration (exposure time)

In practice, effective sanitizing is a function of these four components taken proportionately. This means that a longer exposure can offset distance from the intended target and wavelength can determine exposure time as can intensity. The objective is to maximize efficiency and effectiveness in the shortest, least disruptive application. Since UV radiation can adversely affect plastics and materials, care must be taken to minimize possible damage. Here, the science is clear… short exposure is better because reactions occur over time.

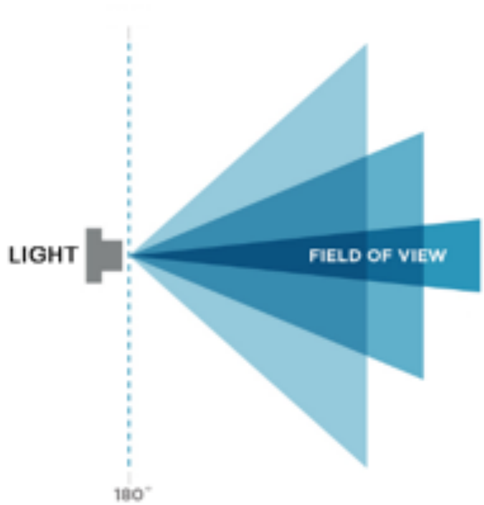
UV IS DIFFERENT –

Unlike visible light, UV is more directional. Consider that sunlight diffuses through a reflective process. That is why there is daylight in shaded areas. Natural light is distributed through reflection from surface to surface. The pattern of light distribution depends upon reflective surfaces. As previously mentioned, UV radiation is absorbed by materials. Generally, it does not reflect well. Moreover, when UV bounces off a surface, it can change wavelengths as well as lose energy. This is why reflectors are not effective for most UV applications.



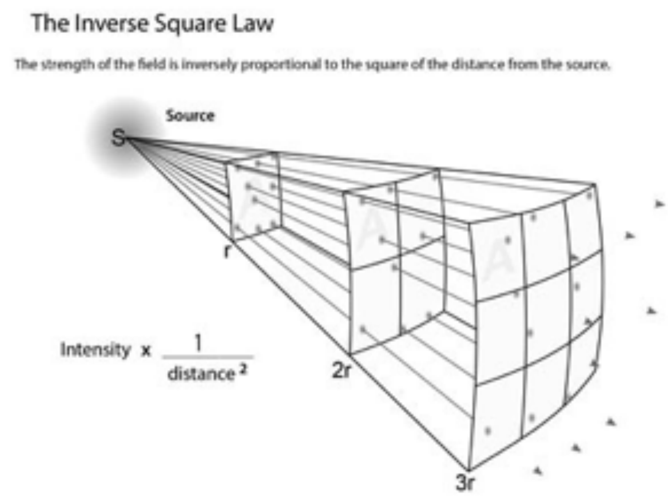
Artificially generated visible light is usually directional, involving a symmetrical light source and a reflector. Consider a flashlight that sends a beam of light to a target. The reflector geometry directs the light beam.

Light fixtures are designed to spread light at a desired intensity within the "field of view." Sanitizing spaces like rooms or vehicles usually requires a different approach because the objective is to spread radiation in all directions rather than pointed or focused energy. This is because you couldn't sanitize behind the light source. However, if the objective is to direct energy in a specific direction without other exposures, a focused approach makes sense. Examples include directing UV toward a food preparation table or a conveyer. Distributing UV from a central ceiling location can be effective if the energy distribution pattern is appropriate for the space and the particular surfaces within the space.



All light, including UV, loses intensity with distance. This is in accordance with the "inverse square law." This is a critical consideration for UV because weaker light requires more exposure time. At some point, the sanitizing process is not feasible. Since each wavelength has a different energy level and propagates differently through air, the UV source must generate the most effective radiation using the least amount of energy and distribute that energy in accordance with the defined application. A stadium poses a different challenge than a hospital room or a vehicle. Spaces with high ceilings like convention centers and exhibition halls are not the same as hotel rooms.

When scientific studies are aggregated, it appears that each UV wavelength contributes to the overall effectiveness of any sanitizing process. For example, UV-B wavelengths and higher are the only radiation that penetrate the Earth's atmosphere to reach sea level. Yet, most UV sanitizers have, until recently, concentrated on UV-C at 254nm as the primary wavelength. Right behind this frequency is far UV-C from 207nm to 222nm, which some studies demonstrate better potency against some pathogens. (Kowalski, W. J. Ultraviolet Germicidal Irradiation Handbook: UVGI for Air and Surface Disinfection. New York: Springer, (2009)) The drawback is that the very nature that allegedly makes far UV-C safe when people are present, i.e. it does not travel as well as UV-B through the atmosphere, renders it ineffective in reaching modest distances from the source. Higher power levels can compensate for this deficiency; however, it is very difficult to produce high-power far UV-C radiation within the narrow bandwidth from 207nm to 222nm. Thus, most lamps claiming to produce this range have other radiation "leakage." This adds an element of exposure risk. We know this because UV in that range is totally invisible, yet lamps that claim only this range still appear blue to the naked eye.



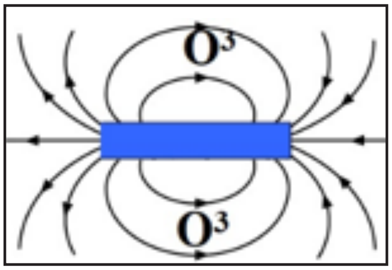
The two most common UV bulbs are fluorescent tubes and mercury vapor. Due to mercury's toxic nature and environmental hazard, vapor bulbs were banned in the U.S. in 2008, leaving fluorescent. Although fluorescent and even magnetic induction bulbs contain mercury, levels are significantly lower than with mercury vapor lamps. Sterile-Bright™ bulbs use magnetic induction technology originally invented by Nikola Tesla in 1891.

OZONE IS DIFFERENT –

Ozone is an unstable form of oxygen that is created when ionizing energy combines a third molecule to oxygen's natural two-molecule state; O_2 becomes O_3. By nature, oxygen is a reactive element that "oxidizes" other elements. Ozone is often called "active oxygen" because it more rapidly oxidizes as it returns to its more stable O_2 state. This is why ozone is such a good germicide, fungicide and deodorizer.

Sterile Bright™ units generate ozone as a consequence of ionizing vacuum UV. Unlike "ozonators" that make ozone using an electrostatic charge, Sterile Bright™ tubes create ozone from ionizing UV energy that radiates several feet away from the unit. Since Sterile-Bright™

fixtures are designed to provide radial 360-degree omnidirectional UV dispersion, ozone distribution does not require a fan. Still, fans or ventilation systems can be used to spread this germicidal gas.

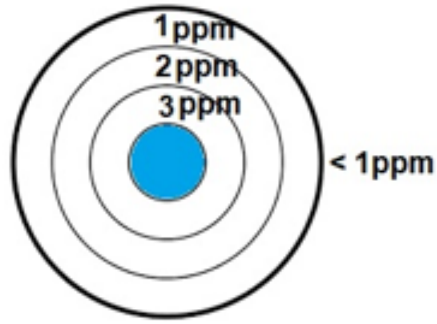


Ozone has been used for sterilization for many decades because it is extremely effective at small concentrations. As little as 0.5 parts per million (ppm) of ozone can deactivate bacteria and viruses. Like most chemical treatments, the higher the concentration, the faster the process. Academic and technical papers suggest germicidal effects can require up to 25ppm for longer periods, however, ozone has the advantage of being an absolute gas, meaning it does not exist as a solid or liquid at room temperature. ("Ozone gas is an effective and practical antibacterial agent;" Sharma and JB Hudson, AJIC Applied epidemiology in health care settings and the community, October, 2008, Vol. 36, No. 8) Thus, when ozone dissipates, its effect is completely gone. This is why ozone has been used instead of liquid and evaporative chemical treatments for sanitizing, deodorizing, and exterminating. For example, many hospitals and medical facilities have used, and continue using formaldehyde vaporization, peracetic acid, and/or chlorhexidine for sanitizing. These chemicals are caustic and toxic; they can cause many adverse reactions in humans and animals as well as damage surfaces and materials.

Ozone has the added advantage of being an irritant to insects and even deadly to bed bugs, dust mites, fleas, and lice. Insects and rodents instinctively flee from small ozone concentrations as little as 1ppm to 3ppm. This means that regular low-level ozone treatments can control pests which, themselves, can be disease carriers. In outdoor applications, ozone bonds to human odor molecules that would attract gnats and mosquitos.

Ozone air purification is debatable science. The Environmental Protection Agency (EPA) has labeled outdoor ozone as a pollutant, while acknowledging that "ozone high" is environmentally necessary, meaning our ozone layer protects us from harmful UV radiation. Ozone is routinely used to sanitize medical devices like ventilators, C-Pap and Bi-Pap sleep devices, and hospital ventilation systems. Ozone is also used to clear ductwork of mold and mildew as well as bacteria. A hot summer day can generate outdoor ozone levels that exceed EPA standards, making the entire effort to regulate ozone questionable. Although the EPA associates ground-level ozone with man-made pollution, natural events like sunlight and lightening create this gas which has been linked to general outdoor microbial reduction.

Ozone is an irritant that can cause burning eyes and air passages. Excessive exposure can be harmful and cause reactions for people with compromised breathing like COPD and asthma. This is why Sterile-Bright™ exposure times are brief and the amount of ozone generated throughout a space does not exceed 1ppm during a customary treatment. Ozone creation declines as distance increases from the Sterile-Bright™ unit. At increments of three feet, ozone generation declines proportionally, depending upon the Sterile-Bright™ power which can range from 250 watts to 2,000 watts. Proper ozone protocols are achieved by following the appropriate exposure times required for each space. It is inevitably up to the operator to determine what levels of ozone are needed for the particular task. For example, if the objective is to discourage insect and rodent infestation in a food preparation or storage environment, higher levels of ozone may be desirable; i.e. kitchens, pantries, and refrigeration lockers.



Ozone is an extraordinarily effective deodorizer. As little as 0.01ppm can freshen air. The Occupational Safety and Health Administration (OSHA) guidelines call for no more than 0.1ppm exposure for 8 hours on a "time-weighted" average. (http://www.osha.gov/dts/chemicalsampling/data/CH_259300.html) This means that at 0.2ppm the acceptable exposure time is 4 hours and at 0.3ppm, 2 hours. Keep in mind that these are workplace exposure limits, meaning that an individual would be physically working in spaces where atmospheric ozone concentrations were at such levels. Ozone in excess of 5.0ppm is considered dangerous for any form of physical exertion.

Ozone Level	Exposure Time	Dissipation Time 20' x 20' x 9' < 0.05ppm
0.1ppm	**8 hours**	**10 seconds**
0.2ppm	**4 hours**	**20 seconds**
0.3ppm	**2 hours**	**40 seconds**
0.4ppm	**1 hour**	**1 minute 20 seconds**
0.5ppm	**30 minutes**	**2 minutes 40 seconds**

The larger the room volume, the faster the dissipation. If a room is ventilated, the times drop geometrically;

i.e. HVAC is running, windows are open, etc. Sterile-Bright™ units should be deployed with targeted UV and ozone parameters in mind. For example, a 20' x 20' x 9' space can be sanitized at median exposure of 50J/cm2 in less than 7 minutes based upon a typical dosimeter. Within 7 minutes, median ozone would not exceed 1ppm. Dosimeter cards typically register only germicidal UV-C at ~256nm. Since Sterile-Bright™ generates a more comprehensive range of UV energy, the actual time to reduce pathogen loads to safe levels can be much less. An average rental automobile can be sanitized and deodorized in less than 60 seconds.

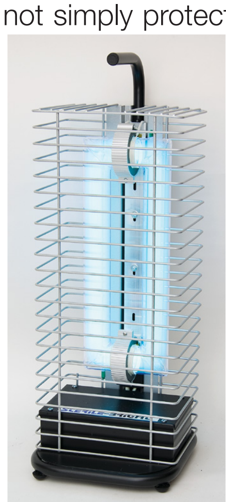
Sterile-Bright™ technology is designed to balance ionizing light with UV wavelengths that actually neutralize ozone by speeding conversion from O3 back to O2. This process occurs with wavelengths from 250nm to 300nm; most effectively in water. Sterile-Bright™ output is tuned to balance ozone-destructive UV with vacuum UV production to ensure dispersed ozone will not reach critically harmful levels or concentrations that cannot be reasonably reduced within relatively short periods. The Sterile-Bright™ proprietary wavelength formula is a unique feature that provides benefits of ozone while protecting against misuse. Sterile-Bright™ units will never generate fumigation ozone concentrations that reach above 25ppm.

SAFETY EQUIPMENT CONSIDERATIONS –

Excessive exposure to UV can be dangerous. Just as overexposure to sunlight UV causes sunburn and can damage eyes, artificially generated UV can have the same effect. Thus, remaining in a room while certain UV radiation is being generated can cause skin burns and eye damage similar to sun exposure. Any direct view of the sun can damage the eye. Thus, looking directly at a UV bulb should be avoided. Although it is dangerous to look directly at the sun even through glass, artificial UV light is generally blocked by glass. Deploying Sterile-Bright™ units in a glass enclosed room does not require full shades since the glass will block the invisible and harmful rays. A quick glance at a UV source is not considered dangerous. UV protective eyewear is readily available and inexpensive for use by staff that deploy or physically monitor Sterile-Bright™ units. The most common UV eye protection is amber over-wear goggles that can be used over glasses. Skin should be protected with tightly woven fabric clothing. A protective shield can prevent facial exposure. A high SPF sunblock can also be applied for an additional measure of safety. Protective equipment is only necessary if proximity to operating units is probable. Most often, this is not the case.

Protection against excessive ozone exposure can have several components. First, and most obvious is to run Sterile-Bright™ in accordance with appropriate protocols. Workers who may be more consistently in the vicinity of operating units can wear ozone dosimeter badges that change color to indicate various exposure levels. Due to "chain of custody" guidelines, Ultra-Tech™ Lighting does not supply measurement and safety equipment. Ozone "badges" are easily sourced through the internet. Employees who are likely to be frequently exposed to sanitized spaces within short times between Sterile-Bright™ operations can wear ozone dosimeter cards.

Workers who may need to operate within an ozone environment should use ozone mitigation masks that are readily available. These are not simply protective face masks. They have an active ozone neutralizing cartridge that must be replaced when saturated. Although not generally recommended, Sterile-Bright™ hand-portable units can be carried while operating if proper precautions are taken that include full skin protection with a suitable safety material, UV protective eyewear, and an ozone mitigation mask. This



same protective gear should be used when operating mobile Sterile-Bright™ equipment like the STRL-MU-250WUV up through the 1,600-watt model.

Charcoal filters and chemical agents like sodium permanganate or magnesium dioxide can be used for proactive ozone reduction. Since Sterile-Bright™ technology already uses a balancing mechanism to prevent ozone overproduction, such methods would only be necessary if extremely rapid turnover was required for a space such as an emergency room situation. However, emergency rooms usually have sufficient air recirculation to mitigate residual ozone. Sanitizing applications can be specific for each situation. Safety standards are not the same under all circumstances.

Protecting surfaces, furnishings, and equipment is important for all sanitizing practices. Notably, chemical foggers and sanitizing agents can be caustic to wood finishes, plastics, and fabrics. As previously mentioned, long exposures to UV-A within certain wavelengths can degrade plastics and synthetic fibers. This is why Sterile-Bright™ relies upon short bursts of powerful UV within specific proven intensities and wavelengths to destroy pathogens while not harming finishes, furnishings, and equipment.

Particular applications such as emergency medical response, police deployment, fire departments, and military facilities use specialized equipment that cannot be exposed to any degradation. Ambulances carry sensitive medical devices and plastic pieces. The hand portable STRL-PU-250WUV can sanitize and deodorize the patient compartment in less than 60 seconds without impacting any equipment or supplies. A police car and SUV can be sanitized in approximately 30 to 45 seconds. Fire departments have more diverse Sterile-Bright™ applications because units can deodorize smoke tainted spaces, vehicles, and even Bunker gear (also called turnout gear). Although there are ozonating boot racks that are specific to footwear, clothing, and sports gear, Sterile-Bright™ can sanitize outside surfaces with UV while deodorizing with low-level ozone. This process will not adversely impact materials such as Kevlar®, Nomex®, Nylon®, polycarbonate, canvas, or other commonly used Bunker gear materials.

Referencing the Dupont™ Nomex® manual, it requires very long-term UV exposure to cause damage. The manual recommends avoiding leaving gear in direct sunlight for long periods; however, sunlight at sea level does not include UV-C. As mentioned above, UV-C does not impact polymers to the extent of UV-A and UV-B. Ozone does not oxidize or degrade flame resistant materials at levels generated by Sterile-Bright™ technologies.

STERILE-BRIGHT™ UV/ OZONE VERSUS CHEMICAL TREATMENTS –

The COVID-19 pandemic has generated many approaches to sanitizing. Chemical foggers and wipe-downs have been employed at great expense in time, labor, and materials to control exposure to the virus. Popular chemicals include Lysol®, Clorox®, hydrogen peroxide, Max Quat® and other branded disinfecting chemicals. With the exception of hydrogen peroxide, all chemicals leave residues that require substantial time under various humidity and temperature conditions to dissipate. While many disinfectants are labeled USDA “food grade.” This refers to ingestion toxicity, but does not address potential allergic reactions. With the surge in chemical wipe-downs and fogger deployments has come an increase in complaints, workman’s compensation claims, and other unanticipated problems. Issues include eye irritation, nose/throat/lung irritation, loss of taste and smell, nausea, dizziness, contact dermatitis, hair loss, hair color changes, skin burning and itching. A large number of people cannot tolerate the off-gassing (smell) of chemical sanitizers.

By comparison, all UV treatments end when the light is turned off. There is no residue. Most UV lamps do not generate a full spectrum of UV wavelengths and do not generate consequential ozone. By comparison, Sterile-Bright™ delivers a complete range of UV from 181nm to over 400nm in various wavelength concentrations. The addition of ozone covers areas and surfaces that may be shaded from UV exposure. This ensures a more thorough sanitizing process and effective result. Because Sterile-Bright™ fixtures are designed to balance ozone and UV, the entire approach is significantly safer than using chemical treatments. Just as UV sanitizing stops when the units are turned off, ozone dissipates to safe levels quickly and completely.

In practice, Sterile-Bright™ is more accurate than chemical applications that rely upon wipe-downs or spray applications. This is because UV light is not subject to human error in application and distribution. There is an issue if workers fail to administer chemicals properly. By comparison, when Sterile-Bright™ is deployed, its use, date, time, operator, and duration can be recorded.

THE STERILE-BRIGHT™ EDGE –

There are many UV technologies currently available, and many more will be introduced. This is because UV is proven to destroy pathogens like COVID-19. Units that use fluorescent or mercury vapor UV bulbs have limited power and wavelengths. Newer technologies use xenon flash bulbs that can generate very high intensity UV-C in the 254nm~257nm wavelength. These units are usually very expensive, large, and require high maintenance because xenon bulbs do not have a long lifecycle. These technologies have been mainly used in hospitals with price tags starting above $100,000 per unit. Absent vacuum UV, xenon technology cannot generate ozone and does not have the penetrating power of UV-A and UV-B, or the effectiveness of far UV-C from 207nm~222nm.

Compare Technologies:

FEATURES	STERILE-BRIGHT	FLUORESCENT	MERCURY VAPOR	LED	XENON	EXICIMER LASER
UV-A	YES	NO	NO	SOME	NO	NO
UV-B	YES	NO	NO	NO	NO	NO
UV-C GERMICIDAL	YES	YES	YES	NO	YES	NO
FAR UV-C 207nm~222nm	YES	NO	NO	NO	NO	YES
VACUUM UV 181nm~200nm	YES	NO	SOME	NO	NO	NO
OZONE	YES	NO	NO	NO	NO	NO
100,000-HOUR LIFECYCLE	YES	NO	NO	NO	NO	NO
SINGLE BULB 200W AND MORE	YES	NO	NO	NO	NO	NO
360° RADIAL UV DISTRIBUTION	YES	NO	NO	NO	NO	NO
SINGLE BULB UP TO 500W	YES	NO	NO	NO	NO	NO
SELF-REGULATING OZONE	YES	NO	NO	NO	NO	NO

Equally important, Sterile-Bright™ technology provides the most diversified model lineup from the versatile and popular hand-portable STRL-PU-250WUV at under 20 pounds to the powerful chandelier STRL-DD-400WUV. Vehicles to stadiums, STERILE-BRIGHT™ has it covered.

ULTRA-TECH™ LIGHTING

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