ULTRAVIOLET
THE SCIENCE BEHIND THE MEDICINE

2.1 Molecular Structure

All gases, liquids, and solids are made up of elements. The fundamental building blocks of elements are atoms, which in turn are made of electrons, neutrons and protons...all held together by electronic attraction. This is referred to as polarity, the principle that positive and negative poles attract and remain bound together based upon the strength of that attraction.

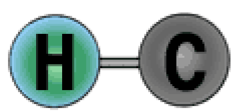
There are over 100 elements known in our universe. It is the elements that form compounds. Elements combine to form gases, liquids or solids. For example, water is made of two molecules of hydrogen and one molecule of oxygen. Carbon dioxide is one molecule of carbon and two molecules of oxygen. These and all other combinations of elements are bound together by the force of attraction or polarity at the level of the atoms.

2.2 Organic compounds

2.2.1 The compounds of our focus are those structures that are organic in nature. Primarily it is the organic molecules that are the basis of indoor contamination. We need to understand these compounds so we know how to clean and purify the home.

2.2.2 Organic compounds are carbon based. Life is determined by carbon based DNA and amino acid chains. Carbon is not only found in "life," but a whole range of chemicals. A number of useful organic compounds are made up of carbon, nitrogen, hydrogen, oxygen and traces of other elements.

The most recognizable organic compound is based upon the carbon and hydrogen combination, or hydrocarbons. Plastics, petroleum products and gasoline are hydrocarbons.



Picture 4A: hydrocarbon

Organic compounds tend to break down or decay faster than non-organic. The decaying process means hydrogen and carbon molecules separate. For example, if the plastic (organic) in milk bottle is left in the sun for a couple of years, much of it will decay. Skin, hair, tissue (all organic) decays rather rapidly.

The toxic VOC gases in our homes such as *formaldehydes* and *benzenes* are hydrocarbons. Airborne indoor dust particles, like dander, hair, dust mite feces, etc. are based upon organic compounds generally associated with the *lipid* group. And, of course, bacteria, molds and viruses are based upon carbon.

2.2.3 Here is the thread that runs through all indoor contaminates; those things that pollute our homes are almost entirely based upon organic or carbon based compounds.

With that understanding, we now focus on the forces that will break down organic and carbon based contaminate molecules. In short, a photochemical process, initiated by short-wave ultraviolet can do this.

2.3 Short-Wave Ultraviolet

We all accept but don't understand the damaging effects of x-ray and gamma ray radiation. Why isn't visible light as destructive on human cells or bacteria as x-ray and short wave UV have been shown to be?

2.3.1 X-ray, gamma, ultraviolet, infrared and visible light energy all fit in a category called "electromagnetic" energy. They all have the same characteristic "lazy S" energy wave, as seen in Figure #1, that travel at the speed of light. The light ray energy is called ***photons*** that oscillate, resulting in wave *frequency*.

2.3.2 The difference in each type of wave energy is the ***wavelength****,* ***the distance across this wave***. By definition, the shorter the distance across the wave, ***the*** *more powerful the wave will be*. The ***difference in the wavelength determines how the wave affects its surroundings***.

It is this wavelength difference that allows short-wave x-ray to pass through walls, while longer-wave visible light cannot pass though the same material; short-wave ultraviolet and x-ray can destroy DNA in living microorganisms and breakdown organic material while visible light will not.

2.3.3 Nanometers: Measuring Light Energy All light energy is measured on a "nanometer" (nm) scale as outlined in Table #2. Nanometer means one-billionth of a meter. The lower end of the scale has the shortest wavelength, and the upper the longest. Cosmic, gamma, x-rays and "C" band UV are all classified short-wave energy. Visible light is at middle ground, at 400-700 NM on the scale. Infrared light is in the upper end of the spectrum, running from about 800 to 1400 NM, and radio waves are longer yet in the 1400 to 2200 NM range.

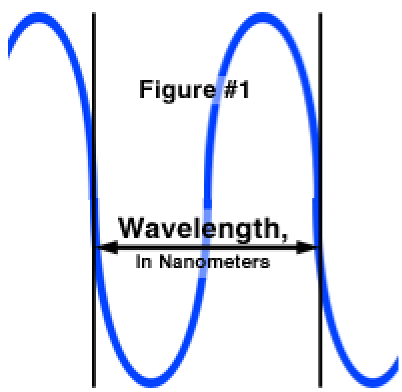
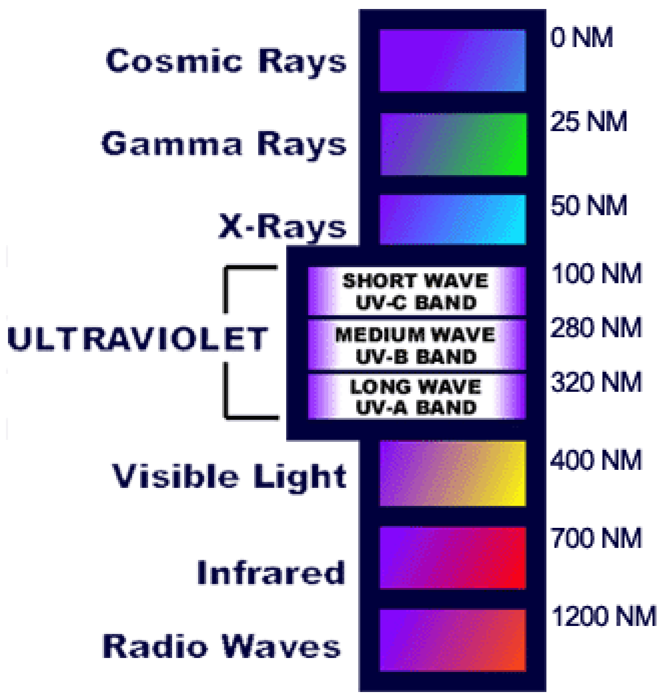


Table #2 Spectrograph: Charting Light Energy in Nanometers

2.3.4 What is Ultraviolet Light?



2.3.4.1 *Ultraviolet light* is toward the low end of this scale, from about ***100 to 400 NM,*** with three categories, "A," "B" and "C." UV is beyond the range of visible light and cannot be seen. We only see evidence of its presence.

Short-wave UV, called "C" band (100 – 280 NM) is known as UVC. Most C band radiation is screened from the sun before reaching the earth by the production of ozone in the upper atmosphere. Useful UVC is entirely manmade, found in today's low-pressure UVC lamps.

The most effective sterilizing range for UV is within the C bandwidth. This range is called the germicidal bandwidth. The ideal germicidal curve is considered 240 NM to 280 NM, with the most effective at 265 NM (Figure #3).

2.3.4.2 With the initial exposure, UVC has properties that alter the cells of living tissue, particularly microbes. UVC radiation triggers the formation of peptide bonds between certain amino acids in the microbe's DNA molecules. This renders bacteria, viruses and molds harmless by robbing them of the ability to reproduce. If the germ cells are exposed for longer periods, they start breaking down to the molecular level (carbon, oxygen, hydrogen, nitrogen ions, etc.).

UVC Germicidal Effectiveness	
Wave length, NM	**Relative germicidal effectiveness**
240	.62
245	.72
250	.90
255	1.03
260	1.12
265	1.15
270	1.08
257	.98
280	.87
285	.73
290	.60

Figure #3
It has been determined that the optimal wavelength for germicidal effectiveness is 265 NM

2.4 Targeting Microorganisms

Germicidal effectiveness is based upon UV intensity. Intensity is measured in microwatts per square centimeter (µw/cm²). The energy required to destroy a microorganism has one more element, time. It is ***microwatt-seconds per square centimeter*** (µw x sec/cm²), with "seconds" in the formula meaning the energy in seconds (time) necessary to kill the microorganism. Table #4 is based upon an energy output of µw-sec/cm² at ***253.7 NM to destroy 90 percent of the organisms at 1 meter:***

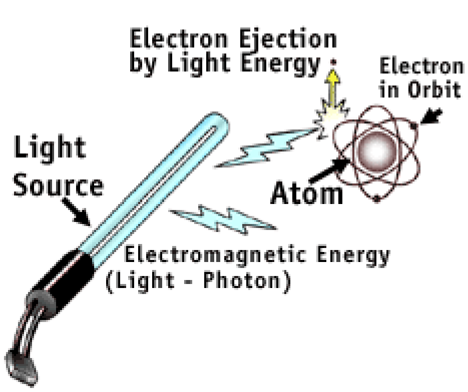
Germicidal energy required to destroy common microorganisms.

Microorganism	Energy: µW-sec/cm	Microorganism	Energy: µW-sec/cm
Bacteria Bacillus anthracis Bacillus megaterium Bacillus megaterium spores Bacillus subtilis Bacillus subtilis spores Corynebacterium diphtheriae Escherichia coli Micrococcus lutea Micrococcus shperoides Neisseria Catarrhalis Proteus vulgaris Pseudomonas aeruginosa Pseudomonas fluorescens Salmonella enteritidis Salmonella typhimurium Serratia marcescens Shigells paradysenteriae Spirllum rubrum Staphylococcus albus Staphylococcus aureus Streptococcus hemolyticus Streptococcus lactis Streptococcus viridans	4,520 1,300 2,700 7,100 12,000 3,370 3,000 19,700 10,000 4,400 2,600 3,500 8,000 4,000 8,000 2,420 1,680 4,400 1,840 2,600 2,160 6,150 2,000	Yeast Saccharomyces cerevisiae Saccharomyces ellipsoides Brewer's yeast Baker's yeast Mold Spores Aspergillus flavus Aspergillus glaucus Aspergillus niger Mucor racemosus Oospora lactis Penicillium digitatum Penicillium expansum Penicillium roqueforti Rhizopus nigricans	6,000 6,000 3,300 3,900 60,000 44,000 132,000 17,000 6,000 44,000 13,000 13,000 111,000

Table #4

2.5 Photochemical Process, the Mechanics of Ultraviolet There are a number of reactions going on when UV irradiates germs and organic compounds. As seen in the nanometer chart, UVC is near the x-ray group and has similar characteristics, i.e., both have very short wavelength energy. This short wave energy stimulates other secondary processes when UV irradiates organic material.

2.5.1 A photon is light ray energy. The science of UV is essentially the science of ***photochemistry***, or photon-chemistry. ***Photochemistry*** is defined as a ***chemical reaction or change in a material induced by the radiation of light energy***. Sunburn is a photochemical process that alters the chemistry of the skin, causing a breakdown.



2.5.2 The photochemical process is essentially a photoionization process where ***electrons of a molecule are ejected or changed by the irradiation of light energy, leaving an incomplete molecule (ion***). With an absence of an electron, a compound becomes unstable and "falls apart."

2.5.3 The ***first rule*** of this photo energy process is that each type of compound has a ***sensitivity level*** to photon energy; there is a given wavelength of light energy at which each type of material will react. It is at this given wavelength that electrons are stripped (or altered) from the target molecule, breaking bonds and causing a chemical alteration.

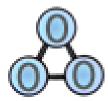
2.5.4 The ***second rule*** in this degradation process is the higher the frequency of a wave, ***the shorter the wavelength, the more energy a wave*** has in breaking chemical bonds of a material.

All organic material is photodegradable, at some point within the 100 to 320 NM bandwidths. And within this range, each compound has a characteristic sensitivity where peak chemical alteration will occur.

2.6 Ultraviolet and Ozone

UV at the 100 – 280 NM bandwidth not only breaks down electron bonding (primary process) of an organic molecule, but also instigates an oxidation process (secondary process).

2.6.1 The first example is ozone. The stable oxygen (O_2) molecule readily absorbs ultraviolet light at 184 nanometers (NM). This absorption of ultraviolet light in the atmosphere breaks the molecular bond between a two-oxygen molecule (O_2), resulting in an O_1 free radical (atomic oxygen). A single atom (O_1) of oxygen will immediately search for a stable molecular combination, often O_2. This new combination forms ozone (O_3), which is highly corrosive**.**



Picture 2B: The Ozone Molecule

In 1972, it was discovered that Ultraviolet (UV) *could* clean surfaces of organic contamination. The ideal nanometer location of absorption of ozone and organic molecules were identified. Ultraviolet light has a range of 100 NM to 400 NM Thus, UV light contains the optimal spectral absorption line (184.9 NM) for O_2 and can be a highly effective method for ozone production.

It was also learned that the combination of ozone and UV could clean surfaces up to 2,000 times quicker than ozone alone, as shown in the next table.

2.6.2 However, it has also been determined that ***ozone is very corrosive on metal parts and can be damaging to HVAC systems when combined with UVC.*** Thus any UV which produces ozone (184 NM), may prove destructive to aluminum coil fins and copper tubing.

Exposure type	Cleaning Time
"Black light" (>300nm)	No cleaning
O3 (produced by ozone generator), no UV	10 hours
UV @ 253.7 NM, no O3	1 hour
UV @ 253.7 NM, + O3 (produced by ozone generator)	90 seconds
UV 253.7 NM & 184.9 NM + O3 (produced by O2 absorption of 184.9 NM wavelength, plus presence of intermediate atomic oxygen)	20 seconds

2.6.3 Thus, there are several reasons for not using ozone in a central airflow system: (a) ozone is not only corrosive to the metals in the airflow system, but (b) ozone is also very corrosive to the lung tissue as we breathe it. *The EPA and American lung association are now strongly against the use of ozone indoors.*

To prevent the production of ozone by UV in a HVAC system, all UV rays below 200 NM need to be blocked. This can be done with a titanium-dioxide material in the UV lamp glass.

2.7 Ultraviolet Producing Hydroperoxide and Hydroxyl Radicals

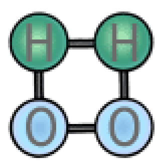
The organic materials that concern us have a strong absorption band between 200 NM and 320 NM Thus UVC at 254 NM (without ozone formation) can clean organic contaminants from a surface material. The reason is that most organic molecules are vulnerable to this short wave UV irradiation. This is because the continued existence of such molecules is dependent on molecular weights; and that weight is altered when short-wave UV irradiation reduces the number of electrons orbiting an organic molecule, causing decay of the material.

2.7.1 Beyond ozone, what is not well understood is that there are two other naturally occurring processes that accelerate the break down of organic materials on the A/C coil. These two processes are highly effective oxidizing agents on organic materials, but have little effect on the metals in the coil.

Indoor airborne organic particles are primarily byproducts of human, animal, insect and microbial output from the indoor environment (dead skin, hair, paint flakes, insect feces, carpet fibers, etc.). These particles collect on coil fins in two ways: (a) mold growth in the damp coil environment produces a sticky enzyme material for collection of airborne organic material for food (this forms an activated crusty surface on the fins); and (b) the close fitting coil fins collect airborne organic particles much like a filter. s

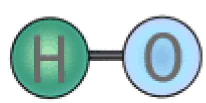
The particle collection and growth on the A/C coil results in decreasing coil efficiency and increased energy costs.

2.7.2 Hydroperoxide development*:* This first oxidizing process (within 200 – 320 NM) is the result of electron ejection by UV irradiation of organic materials, giving rise to free radical (hydrogen ion) development. The radicals react with ordinary atmospheric oxygen (O^2), forming hydroperoxide (H^2O^2) ions. The hydroperoxide process activates a chain reaction with the organic material from the continual UV destruction of the hydroperoxide, triggering further oxidation. This oxidation process primarily operates on organic compounds and not metals.



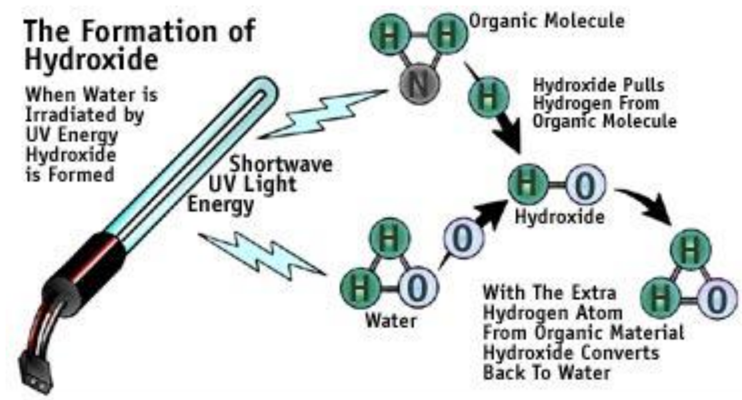
Picture 2C: Hydroperoxide molecule

2.7.3 Hydroxyl Radicals: Another key development at an operational coil is the generation of water through condensation on the fins. Studies by Mattex (1974) showed that the presence of water with UV light energy enhances the decaying process of organic molecules. It is the result of hydroxyl secondary oxidation, and it too is primarily targeted toward organic molecules.



Picture 2D: Hydroxide Molecule

The presence of water droplets being exposed to UV (200 to 320 nm) in the coil area breaks down water molecules (H^2O), resulting in the formation of hydroxyl (HO) radicals. These radical ions are stable but a very potent one-electron oxidant. The reason hydroxyl ions are so destructive to organic molecules is the ions steal hydrogen molecules from the organic materials, leaving decayed carbon ions.



The theft of hydrogen from organic molecules by hydroxyl radicals forms even stronger OH bonds, with even higher oxidation, as the result of the water at the coil. The process turns into a chain reaction…the breakdown and formation of new HO radicals' results in continual decay of the organic material.

2.8 Reaction of organic materials exposed to UV

The cleaning mechanism of UV is a photochemical process. Since the ideal range is 200 to 320 nm for organic degradation, ozone production, at 184 nm, is not needed nor should be used due to the destructive nature of ozone on metals.

2.8.1 On the other hand, hydroxyl radicals tend to target organic materials for oxidation and not metals. These radicals absorb hydrogen out of organic compounds. Because of this, hydroxyl is ideal for cleaning organic growth at the A/C coil without the corrosive effects of ozone on the aluminum and copper coil.

2.8.2 A damp coil is perhaps the best environment to experience the full effects of UV. It is in this ideal area that UV photon breaks down the collected organic material, setting off a chain reaction of hydroxyl and hydroperoxide formation, which further destroys organic materials.

This means that UV light in C bandwidth effectively cleans the coil of organic particle collection and destroys any growth of germs and mold accumulating at the coil. Once the coil is cleansed, "…a clean surface under UV radiation maintains surface cleanliness indefinitely."

Further, UV irradiation within the system degrades airborne microorganisms and other organic contaminates (particles and toxic VOC gases) circulating within the air stream of the home, with the same photochemical reaction.

2.8.3 House Dust: House dust is made up of a mixture of organic materials and molecules: from paint flakes to pet hair, from insect parts to fecal materials. Each house is different, but there is no question that the basis of all house dust is organic in nature.

Microorganisms and organic dust and debris floating in the air starts to break down when exposed to high levels of UV energy.

Simply stated, the exposure of an outside energy force can break the molecular bonds of many common contaminants found in indoor air today, thus, resulting in a cleansing effect which can improve the quality of life.

2.8.4 Breaking Down VOC's Smoke & Odors: Smoke, fumes, and vapors are some combination of organic compounds in a gaseous state. They can be broken down rather quickly to the elementary level with the right UV intensity and energy source.

Odor is based upon what the human nose can smell. This means that as compounds gasify, they give off some mixture of molecules that sensitize the nose. Odors come from compounds floating in the air. Applying sufficient energy will change the compounds' molecular structure, thus effectively reducing or eliminating the odor.

2.9 Application of New Ultraviolet Technology

2.9.1 The current ***ClarionHEALTH*** ultraviolet (UV) products are engineered to function within the central circulating air system of a typical home or business establishment. This means the UV device is inserted into the air stream.

ClarionHEALTH'S *HEALTHstar* UV unit is the only device in the marketplace capable, with sufficient intensity, to function in very unstable conditions of high wind speeds and temperatures near 45° F found in indoor air circulating systems. Other devices will lose up to 80% of the intensity in these severe conditions…not *HEALTHstar.* It is so powerful that it can sterilize this nest of growth and the circulating air at the same time.

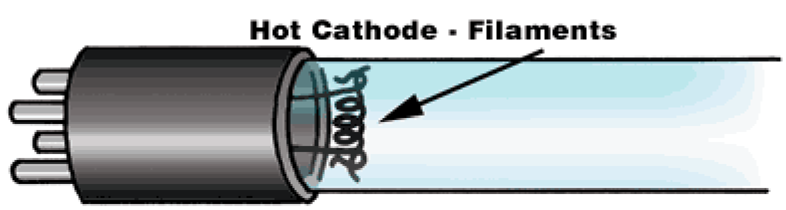
2.9.2 Special Designed UV Lamp

HEALTHstar's UV lamp has been submitted for patent protection. It is an unusual lamp. In an environment where hazardous (cold temperatures and high wind speeds) conditions pose a problem for ultraviolet intensity, a special UV lamp has to be used. That lamp is the *HEALTHstar's* lamp. It thrives in very cold temperatures. How?

Picture 2F: U bend Lamp

2.10 Hot Cathode Method

2.10.1 Hot Cathode " method of generating ultraviolet refers to elements of the lamp getting hot and igniting the internal gases. Hot cathode lamps generally use tungsten filaments at each end of the tube. These filaments are preheated by employing a glow switch starter and choke or an electronic trigger. This makes the "Hot Cathode" UV lamps similar to standard preheat fluorescent lamps used for lighting our homes and offices.



The tungsten *filaments* tend to govern the life of the UV lamp. They burnout. Frequent starts will cause the *filaments* at each end of the lamps to deteriorate even faster. In the end, preheat *filaments* shorten the effective life of the hot cathode UV lamps because they age with use.

Beyond the *filament* problem, the life of the lamp is also dependent upon the effective ultraviolet transmission of the glass and the life "mercury-vapor" gases or plasma. And this becomes a problem for this type of lamp. Operating the *filament* lamp in refrigerator like temperatures (around the A/C coil) can result in "excessive bulb blackening and rapid depreciation in ultraviolet output."

2.10.2 The hot cathode lamp has difficulty functioning at temperatures below 70° F. At 50° F filament lamps generally lose up to 90% of the UV intensity. The reason for this is there is no stabilizing current for the plasma across the lamp between the two filaments.

The filaments heat the two ends to create an ionized ball around the filament. Ionization means knocking-off electrons from the molecule (without the electron it is called an ion). The lost electron bounces across to hit another molecule, knocking off another electron, leaving another ion. The chain reaction continues across the lamp until the whole mass is ionized. The heated ions result in plasma, which irradiates light energy in the form of ultraviolet.

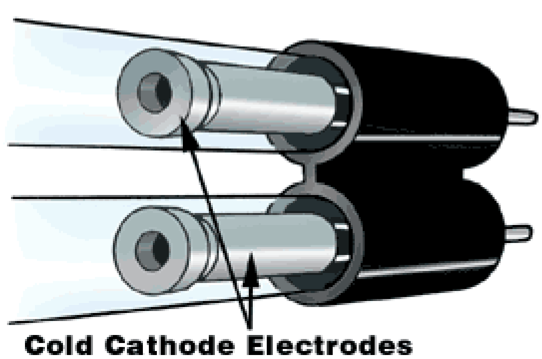
In a cold cathode lamp, the chain reaction of electrons knocking off other molecule elections requires a certain temperature level to maintain the reaction and keep the molecules excited. That temperature should be between 80° F and 110° F.

But if the coil cools the temperature around the hot cathode lamp to 50°, there is insufficient heat to maintain the process and the reaction collapses. There is nothing between the two ends to maintain the heat at colder temperatures. Therefore, the UV intensity drops by 90 percent.

2.11 Cold Cathode Method

2.11.1 The *cold cathode* lamp means it starts from a cold start - no preheating. This type of lamp uses cylindrical *electrodes* and is started instantly by means of a high voltage "spike." This is often referred to as the "striking" voltage. Since the *electrodes* seldom wear out, the *cold cathode* lamp normally has a much longer life compared to the *hot cathode*, *filament* lamp.

2.11.2 Since the life of the cold method is not dependent upon electrodes, it then comes down to the transmission of ultraviolet through the glass or the life the plasma. But here again the electrode lamp has an advantage - this lamp may be operated in very cold temperatures without excessive "blackening" of the glass, thus little or no loss of UV output. The high voltage assures a fast, instant start at even freezing temperatures.



There are two electrodes at opposite ends in the cold cathode lamp: one is a positive post the other is the negative. By continually sending a high voltage, low amperage charge between the two posts, one has a stabilizing heat source that will maintain the ionization process even in extremely cold or hot temperatures.

2.12 Temperature and Air Speed Factors

2.12.1 Lower temperature and air rushing past the UV lamp can affect both the operation and life of any UV lamp, particularly if the lamp is the hot method. As indicated above, both the plasma collapses and the glass can solarize or blacken excessively when using the *hot cathode* tube in cold temperatures. This blocks UV irradiation, resulting in depreciation in ultraviolet output. Further, lower temperatures cause rapid deterioration of UV output when accompanied by higher air velocity (wind speed) found in air conditioning systems.

Numerous fluctuations in temperatures and air velocities cause an "aging" process in hot cathode UV lamps. These fluctuations can impact the lamp, much like frequent starting. The chilling of the internal UV gases causes rapid changes in the electrical characteristics of the filaments. This ages the filaments much faster.

As was discussed in the previous section, the ideal temperature for the most effective UV output is about 80° F to 110° F, with a wind speed of less than 200 fpm. Any variance from these conditions can cause a deterioration of the mercury vapor and faster aging of the lamp