UV Lights & Lamps - A Manufacturer’s Perspective
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Definition of terms.
For clarity, this article uses the engineering terms “lamp” and “light” or “light assembly” or “light fixture”. “Lamp” is used only to refer to the device inside a UV light that produces the UV and is made up of a glass or quartz tube with one or two lamp bases. A UV “light”, “light assembly” or “light fixture” is a housing, a lamp, a socket (or two), a reflector, a filter, a ballast, an on/off switch, and a power cord or connector to a power supply. See Figure 1. Some UV “lights” also include a cooling fan or http://www.studiopress.com/themesdditionaional circuitry depending on their design.

Cross Section of a Typical
UV “Light” (also called
“Light Assembly”,
or “Light Fixture”)

Ballast

Reflector

Socket

Lamp base

UV filter

“Lamp”
Sometimes called a tube or bulb

Introduction.
Gas discharge lamps of various types, including medium-pressure mercury vapor, low-pressure mercury vapor and short-arc xenon are the most common sources of useful amounts of ultraviolet radiation. There are also other artificial sources of UV such as High Intensity Discharge lamps (HID), concentrated arc lamps, carbon arc lamps, flashtubes, deuterium lamps, incandescent lamps, and LED’s.

Most of this article will be about the low-pressure mercury vapor UV lamps and how they are manufactured, tested, and rated. When it comes to fluorescent lamp manufacturers we often think of only the big three; GE, Sylvania, and Philips. However, there are over 320 companies in the world that manufacture some type of fluorescent lamp, with about 30 in the USA. However, not all of them make UV lamps. There are at

Fig. 2, some of the many SW UV lamps made
least 10 companies just in the USA that manufacture some type of UV lamp (fluorescent or other kinds). UV lamps can be the phosphor type that produce LW370 (peak at about 368 nm), LW350 (peak at about 352 nm), or MW (peak at about 312 nm). They all look white when “off”. Some of the LW350 and LW370 phosphor lamps are made with a special dark blue glass that filters out much of the visible radiation coming from the lamp. This integral filter is part of the bulb wall (tubing). Those lamps look black when “off” and a blue when “on”. They are called black-light-blue or BLB by the lamp industry. Most of the SW lamps are designed to produce only the 254 nm radiation generated by the low-pressure mercury vapor discharge itself. These lamps are clear and are commonly called germicidal lamps. All the fluorescent or germicidal type lamps cited in this article are hot cathode, low-pressure, mercury vapor arc lamps (except otherwise noted).

Lamp Standards.

In order for one manufacturer’s fluorescent lamp to fit in a standard UV light fixture or any other fluorescent light fixture, that lamp has to be made to some specific set of standards or design specifications. The American National Standards Institute (ANSI) is one of the primary standards organizations that have published specifications that all fluorescent lamp manufacturers use. There are also several other industry standards organizations that have specifications that a lamp manufacturer follows when making and testing their lamps. The ANSI specifications define such things as the dimensions and tolerance for the physical size of the lamp and some general electrical specifications. There is a separate ANSI standard for each type of fluorescent lamp. They are usually defined by input electrical watts, but sometimes by physical size. When each lamp manufacturer makes his lamps to the same ANSI specification each manufacturer’s lamps will fit and operate in a standard light fixture. Note that the standard ANSI specification for a specific type (and wattage) of fluorescent lamp does not define the lamp phosphor that is used inside that lamp, only the dimensional and essential electrical properties. The phosphor specifications are defined by other standards; some by ANSI, others by Illuminating Engineering Society of North America (IESNA), or the Commission
For a specific type and model of a fluorescent lamp there could be dozens and dozens of specifications that would cover the manufacturing and testing of that lamp, and that just involves the size, wattage, fluorescent color, and shape.

**Ballast**

Low-pressure mercury vapor lamps cannot be directly operated on a 115 AC power line. The lamps have a so-called negative resistance, meaning that the lamp’s electrical resistance falls with rising lamp current. Without some means of limiting the lamp current, the lamp would quickly be destroyed. The lamp ballast’s primary function is to limit the lamp current to its rated value. Some ballasts may include autotransformer windings to allow the use of longer lamps on 115 AC power lines. Some ballasts are actually sophisticated electronic inverters (for example in the SuperBright II 3000 series models). They run off 12 VDC and provide conditioned starting voltage, and current regulation. All UV light fixtures or light assemblies have some type of ballast inside that light to control the lamp current.

**Starter Circuits**

The electrical circuit in the ballast has a big effect on a fluorescent lamp, including how the lamp is started (meaning “striking” the arc and keeping it going). There are several methods of starting a lamp. For most handheld UV lights a Preheat Start circuit is often used. That means that the filaments (cathodes) must be heated for a second or two before the high voltage is applied to “strike” the arc, or start the lamp. Preheat Start circuits often require an extra button to push that you have to hold for a second or two before the lamp will start. Another way that Preheat Start circuits start the lamp is by having a ‘starter’ connected to the lamp. The ‘starter’ controls the heating up of the filaments for a second or two before the lamp starts. Occasionally the ‘starter’ is built into the ballast. Another method for starting a lamp is called Trigger Start; no ‘starter’ is required. When turned on the lamp comes on almost instantly. Because of how a Trigger Start ballast works, the life of that lamp could be shorter than with a Preheat Start ballast with ‘starter’. Rapid Start is another method for starting a lamp; usually it is designed for larger and longer lamps, but some Compact Fluorescence (CF) lamps use that starting method. Rapid Start ballasts have a circuit that will electrically heat the filaments for one or two seconds before the lamp starts. Most 4 ft. long fluorescent lamps are Rapid Start. The other method for operating a lamp is called Instant Start. That method is just as it sounds, when power is turned “on” the lamp starts instantly. The UV SYSTEMS SuperBright II and the TripleBright II use Instant Start circuits, however, the TripleBright II has an additional patented circuit that allows almost unlimited life regardless of the number of times the lamp is started. Without this additional circuit, Instant Start circuits will normally result in less lamp life than in a correctly designed Preheat or Rapid Start lamp circuit. Because of the different starting methods, fluorescent lamps have to be designed for each of the different starting circuits. The filaments and fill gas pressure in a lamp designed for Preheat Starting is different than the filaments and fill gas pressure for a Rapid Start lamp. Sometimes a Rapid Start lamp will
work with a ballast designed for Preheat Start, but a Preheat Start lamp will not work satisfactorily with a ballast designed for Rapid Start lamps.

60 Hertz vs. High Frequency
All fluorescent type lamps will have improved efficacy when operating at a high frequency (typically above 20,000 Hz), as compared to 50 or 60 Hz. The improvement is a function of the specific lamp, ballast, and frequency. Improvements of 10% to 20% in output are common. The high frequency operation will not affect the life of the lamp, only the output.

“Over Driving” a Lamp
Some UV light manufacturers claim that they “over drive” their lamps in their UV lights to get more watts and UV output. That of course is possible, but they have to be sure that they have engineered that lamp and ballast combination carefully. The input electrical wattage going into a UV light is not directly related to the UV output watts coming out of a UV light. There are several factors involved in making a fluorescent lamp work correctly, but lamp operating temperature is one of the major ones. It is possible to have additional lamp current going into a lamp (being “over driven”), but if that lamp is inside an enclosed UV light (and that is always true for SW or MW UV lights), the lamp might overheat and the UV output might actually drop as it heats up. “Over driving” the lamp could have a very negative effect on the life of the UV lamp and even the ballast. Careful engineering, electrical, and radiometric testing must be done when trying to match a lamp (with specific design characteristics) to a ballast that is not designed for that lamp. And that takes us back to the ANSI and IESNA standards.

Testing using ANSI Standards
Because there are so many factors involved when measuring the electrical, photometric, radiometric, and rated lamp life values of a fluorescent lamp; the standards have been written so as to alleviate many of the variables involved when taking those measurements. For example, when measuring the input electrical wattage of a new design lamp the ballast that drives that lamp must be a “standard ballast” of a specific type and model. The electrical instruments used to measure the lamp must have specific characteristics (such as the correct tolerance, crest factor rating, frequency response, etc.). The lamp must be operated in free air (not enclosed inside a light assembly); and a specific electrical circuit must be used (to name a few of the variables). Then and only then can the new parameters be defined for that new designed lamp. Another example of reducing testing variables is the need to “age” (burn-in) a new lamp using a “standard ballast” for 100 hours before any photometric or radiometric tests are conducted. That is because some brand new lamps output can be unstable during their first few hours of use (especially phosphor coated lamps).

No UV Output Standards for UV Light Assemblies
Almost all of the standards and specifications for fluorescent lamps are written for lamps producing visible light and not for the UV lamps. However, some specifications can
apply to both visible and UV lamps (dimensions such as length, diameter, and lamp base, and nomenclature, etc.). However, the energy produced in visible light fluorescent lamps is defined in photometric units, while the energy produced in UV lamps is defined in radiometric units. **There are no ANSI, IESNA, or other recognized standards that define UV output of a UV light when the lamp is totally enclosed as in a SW or MW light assembly (as in a filtered UV light)!** Consequently there is no way to test the UV output of UV light assemblies to an approved industry ANSI standard or other lighting industry standard. UV SYSTEMS has developed a standardized testing procedure for large UV light assemblies called the Newsome/Plewman Testing Method. For more information about that testing procedure contact the author.

**Lamp Life**
The Rated Average Lamp life (also called Rated Average Lab Life) for a fluorescent lamp was intended for lamps used in general lighting and could theoretically be applied UV type fluorescent lamps. The Rated Average Lamp life is the number of hours before a lamp fails to start (or fails). However, for most UV lights the ANSI standard for lamp life would not be directly related to the actual lamp life you could expect with your UV light. The ANSI specifications for Rated Average Lamp life tests (sometimes just referred to a “lamp life”) calls for groups of lamps to be mounted horizontally in test racks in free air (not inside a UV light enclosure) and cycled for 3 hours “on” and 30 minutes “off”. The ANSI Rated Average Lamp life for that specific lamp is the average value of that entire group of lamps when each is operated by a specific “standard ballast”. If the “on” and “off” cycle changes, or if the lamps are enclosed (as in a UV light enclosure), or if the wrong ballast is used with that lamp; any of those factors can effect the actual life of that lamp. Note that the minimum and maximum life values in a group of test lamps can have a large variation. For example, if there were 12 lamps of the same type being tested they might fail after the following number of hours of use: 2400, 2900, 3200, 3600, 4100, 5500, 6950, 7600, 8100, 8600, 9450, and 9600 hours, and yet the Rated Average Lamp Life for that lamp type would be 6000 hours! Since fluorescent mineral collectors do not usually use their UV lights in the same way as the ANSI testing method (they do not turn them “on” for 3 hours each time!), the “lighting industries” lamp life rating are not very helpful to us.

In all UV lights the average rated lamp life will be affected by how many times that lamp is turned “on” and “off” and the ratio of “on” to “off” time (the exception to this is the cold cathode lamps in the UVP, Inc. UVG-68 and the R-52G lights and the hot cathode lamps in the UV SYSTEMS TripleBright II lights [with its patented special circuit]). For example if a test group of lamps was cycled “on” for only 12 minutes (instead of the standard 3 hours) the average rated life for that group would 60% shorter than at the 3 hour cycle value. Many of the standard G4T5 or G6T5 (4W and 6W respectively), germicidal lamps are rated by the lamp industry for 6000 or 8000 hours (depending on the manufacturer). Every time a fluorescent type lamp is turned “on” some of emissive coating that is on the filaments (cathodes) is sputtered off. When the emissive coating is
gone then the electrons must come from the tungsten filament and soon the filament will be broken and the lamp will not start, it has failed. The lamp and ballast is a combination or team, so it is possible for two different light manufacturers to use that same lamp but different ballasts and therefore each manufacturer might have different actual lamp life results. This is one reason why it is important for the UV light manufacturers to conduct their own lamp life tests, using realistic “on” times.

Most lamp manufacturers regularly life test the UV lamps they produce. By keeping a record of the actual life of the lamps they produce, they can make slight adjustments in their manufacturing techniques, in the rare instances when a batch of lamps gives short life test results. As you can imagine life tests are time consuming and expensive because of how long the testing takes. You cannot conduct reliable accelerated life tests on fluorescent type lamps, either for visible lamps or for UV lamps. Moreover, I know of no UV light manufacturing company (with the exception of UV SYSTEMS) that conducts any lamp life tests using realistic “on” and “off” times and test jigs that simulate enclosed UV light assemblies.

Quartz (hard glass) vs. UV-C glass (soft glass)
Since SW UV is not transmitted by window glass or the typical soda-lime glass used in most ‘visible light producing’ fluorescent lamps, a special glass must be used. The material is either made of special UV-C transmitting glass (called “soft glass” in the UV lamp industry) or more rarely from quartz (called “hard glass”). “Soft glass” is made by Philips (#160 glass), GE (#982 glass), and a few other manufacturers. “Soft” and “hard” in the lighting industry refers to a characteristic of the gas flames used to work the glass. “Hard glass” requires much higher temperature gas flames than “soft glass”. All UV light manufacturers (except for UV SYSTEMS) and the UVP, Inc. UVG-68 and R-52G use the “soft glass” in their SW UV lamps. UV SYSTEMS has measured some of the “soft glass” and “hard glass” tubing from different lamps using its Ocean Optics UBS2000 spectroradiometer. However, it is technically difficult to get repeatable accurate readings on a curve piece of glass tubing since the reference beam that passes through the glass can be refracted by the curvature of the glass. Sometimes the transmission values would vary just by moving the curved sample a millimeter or so. Most of the “soft glass” samples measured had a transmission of about 77% to 81% at 253.7 nm, while most of the “hard glass” (quartz) samples from the LS-16X or LS-60-254 lamps measured about 81% to 92% transmission. The results indicate that “hard glass” (quartz) transmits more of the 253.7 nm UV than the “soft glass” lamps. The exact percentage difference is hard to quantify as I stated above.

UV output depreciation of SW UV lamps is much less for quartz (“hard glass”) than for “soft glass” lamps. Once all loss of UV lamp output over time was blamed on solarization. That idea has recently changed. Quartz used in SW lamps will have negligible solarization. As you know solarization is a chemical process that reduces the SW transmission with exposure time. At least one UV lamp manufacturer has developed a proprietary protective coating process that is applied to the inside of his “soft glass”
lamps that reduces UV depreciation somewhat. The manufacturer of the UV SYSTEMS lamps also has a protective coating that is applied to the inside of all UV SYSTEMS lamps (SW, MW, LW350, and LW370) to reduce the reduction in output with time. Lamp engineers and scientists are still studying that reduction in output vs. time problem. Some now think that the actual reduction is not necessarily the bulb wall changing transmission (solarization), but some of the mercury and possibly some of the emissive coating migrating into the lamp wall over hours of use. The net effect is a reduction in output vs. time. That might also explain the empirical results that prolong UV output by using the protective coating on the inside of phosphor coated UV lamps. Quartz still has less UV reduction than “soft glass” but the actual solarization effect might be so slight (especially related to an uncoated lamp) when compared to the mercury migration problem, that it is insignificant for lamps that only last 6,000 to 12,000 hours. Some of the fused quartz lamps when new might appear slightly dull or not quite crystal clear because of the special protective coating, but the UV output vs. time is improved by having that protective coating.

How “Soft Glass” Lamps are Sealed

Myth about quartz SW UV lamps
Some UV light manufacturers claim that they use commercial SW lamps (4W, 6W, 8W, 9W, 13W, 15W, 18W, 25W, 30W or 36W) that are made from quartz (“hard glass”). However, no large lamp manufacturer making germicidal (SW) lamps uses quartz (“hard glass”). The exception is some high powered (500W and higher) custom made lamps that are used primarily for water or air disinfection applications, and the SW lamps made for UV SYSTEMS. The reason that all lower wattage (4W, 6W, 8W, 9W, 13W, 15W, 18W, 25W, 30W or 36W) germicidal lamps are made from “soft glass” is because they can be manufactured on the same production lines as fluorescent lamps of the same
wattages. Quartz glass requires much higher temperatures for working than soft glass and many of the production steps needed to make and seal-in the lamp electrodes differ radically from soft glass fluorescent to hard glass germicidal.

Each “soft glass” or fluorescent lamp has a lamp stem at each end. To make a lamp stem two to three pieces of glass tubing along with the filament lead-in wires are heated and fused together into one unit called a “lamp stem”. See Figure A and Figure 6. For all fluorescent lamps that use the typical soda-lime glass, a propane or natural gas flame will work just fine to make the lamp stem, since the flame is hot enough to work or fuse the soda-lime glass. The burners at each of these stations have just the one gas (propane or natural gas) going into them. The burners automatically mix the gas with air to produce the correct temperature flame to soften and “work” the glass tubing. The primary reason that “soft glass” is used in germicidal lamps is because it will soften (or melt if necessary) at the same temperature as the common fluorescent lamp soda-lime glass. That means that the lamp manufacturer does not have to change his automated machinery when he wants to manufacture a batch of germicidal lamps. One of the primary reasons that major lamp manufacturers do not use quartz (“hard glass”) is because they would have to change all the burners in their automated machine! Another reason is because quartz costs more than “soft glass” or soda lime glass. Quartz lamps require two gasses (not one) going to every burner, one oxygen and one hydrogen. Therefore to use quartz you have to have different burners at all positions in the process, and you have to program the automatic machines for quartz instead of soda-lime or “soft glass”. The custom SW lamps that UV SYSTEMS has made for it are made by a company that makes primarily UV lamps. Years ago they changed over so all the UV lamps that they make are made just from quartz (“hard glass”) since it was too difficult and expensive to have two sets of machinery, one for “soft glass” and one for “hard glass”. UV SYSTEMS only uses quartz (“hard glass”) in its SW SuperBright II or TripleBright II lamps.
Empirical Observations about Quartz vs. Soft Glass lamps under SW UV

I have observed that almost all quartz (hard glass) lamp tubing will fluoresce under SW UV a low intensity blue color. The blue appears to be almost the same hue and intensity as hardystonite. While the UV-C (soft glass) lamp tubing will fluoresce a very dull "orange-ish" (the exact hue is hard to describe). However, the stem inside the UV-C glass tube will always fluoresce a bright blue-white almost the same hue and intensity as hydrozincite from NV. For example, the stem shown in Figure 6 from a SW lamp will fluoresce a bright blue-white under SW. The fluorescence might be because the stem is made from inexpensive soda-lime glass (however, I have not confirmed that). Since the quartz lamps do not have that bright blue-white fluorescent stem that could be a way for the typical collector to determine if his SW lamp is made from quartz or not. In fact the quartz lamps do not have an internal stem they are sealed a different way as shown in Figure B. A quartz lamp cannot use a soda-lime or “soft glass” stem since the coefficient of expansion of quartz is significantly less and the lamp would crack where the stem was fused to the lamp tubing.

Emission material on the cathodes

Any fluorescent lamp has two cathodes usually in the form of a tungsten filament (called a cathode). The filament is always coiled and sometimes coiled-coiled or triple coiled. Barium, calcium, and strontium carbonates are coated on the filaments. During the lamp process those carbonates are converted to oxides. The coating is called emissive material and that is where the electrons are emitted from for the lamp arc. The exact mixture of carbonates and the amount of emission material is a function of the specific type of lamp and lamp manufacturer. Each time the lamp is started some of the emission material is sputtered off the cathode. Also during normal operation a very small amount of the emission material could also be sputtered off. When the emission coating is gone the lamp will fail...
The exact procedures for manufacturing a specific type of lamp of course involve science, but it also involves some art. That art is learned by empirical experience. The lamp manufacturing technique (including both science and art) is a closely guarded trade secret within each lamp company. The manufacturing technique can affect the life of the lamp (and the cost). That is part of the reason the lamp manufacturers closely guard their manufacturing processes. The two photos, Figures 8 and 9, show a LS-60-254 lamp used in a TripleBright or TripleBright II display light. It is an HO (High Output) lamp and as such it has considerable more lamp current going through than typical lower wattage lamps. Therefore, it has anode wires on either side of the cathode. The anode wires allow the heavy ions to strike the anodes instead of the emission material on the filament resulting in prolonging the life of the lamp. The anodes wires are designed to give longer life for all of the TripleBright and TripleBright II lamps.

When a lamp, ages some of the barium from the emission material along with some of the mercury in the lamp can form a coating on the inside of the lamp near the cathodes. In a SW lamp where you can see the coating it might look dark metallic or maybe silvery like a mirror. In a phosphor coating lamp the coating usually just looks black or dark gray. This darkening near the cathodes is normal in all lamps and it usually cannot be used to indicate when a lamp is about to fail. That is mainly because of the big variation in how the coating forms within each individual lamp. For example, some individual lamps might have a heavy coating on one end of a light and little or no coating on the other. The photo in Figure 10 shows a LS-16X from an original UV SYSTEMS SuperBright 2000SW. That lamp failed from normal use after hundreds and hundreds of hours of use.

**Phosphor coating**

For a MW, LW350 or LW370 lamp a phosphor has to be coated on the inside of the lamp. The phosphor converts the 254 nm light in the arc to the UV output determined by the phosphor. For LW UV lamps there are just two phosphors used commercial; one that peaks at about 351 nm (LW350) and one that peaks at about 368 nm (LW370). For MW it is a different story. There are several MW or near MW phosphors commercially available. For some special sun tanning lamp applications, mixtures of two, three or more different UV phosphors are used in those lamps. Fortunately those special sun tanning lamp phosphor mixtures are not the ones used primarily for MW lamps in the fluorescent mineral hobby. I say fortunately because it would worsen the existing
problem of the lack of a MW standard and increase the likelihood of variable fluorescent responses among collectors using different lamps on the same specimen. If two different collectors each with different MW phosphor lamps examined the same specimen they might see different fluorescence responses. There has been very little scientific research or controlled observations on the MW response of fluorescent minerals. More needs to be done.

Phosphors can be applied several ways by the lamp manufacturer. The most common method is the “pump up” method. The lamp tubing is mounted vertically and they pump up a solution of phosphor and binders from the bottom and then drain the liquid out. The result is the phosphor coats the inside of the tubing. The tubing is then partly dried and then put in a lehr oven to bake the binders out of the solution. The baking causes the phosphor to adhere to the inside of the tubing. The lehr oven is a long horizontal oven open on both ends and the tubing travels through the oven lying horizontally but being rolled so that none of the non-dry solution can form a spot or unevenness in the phosphor thickness. When the tubing comes out on the other end of the lehr oven the phosphor is bound to the tubing. The UV SYSTEMS lamp manufacturer has not yet found a suitable binder that will allow MW or LW phosphors to adhere or bind to the quartz tubing that is using in the UV SYSTEMS lamps. If a phosphor was applied to quartz tubing and the lamp was bumped the phosphor would just fall off.

**Tubing for MW or LW UV lamps**

For a MW lamp, UV-C or “soft glass” is used since the standard soda-lime glass will not transmit enough (if any) of the UV-B wavelengths for the MW lamp. For LW lamps the standard soda-lime glass that is also used for visible phosphor fluorescent lamps is used. The soda-lime glass will transmit enough of the UV-A wavelengths to make a very efficient UV lamp. Phosphors used in both “soft glass” or soda-lime glass have no problems adhering to the inside of the tubing.

Some MW lamps are more expensive than the SW or LW lamps. Mainly because of production costs. The volume of MW lamps is never as high as SW or LW lamps, so that means the lamps are made in smaller batches. This results in higher MW lamp costs. Plus the “soft glass” tubing costs more than the soda-lime glass, and the MW phosphors cost more than the visible or LW phosphors.

After the two lamp stems are made they are fused to the lamp tubing (“soft glass” for SW). Quartz lamps are typically sealed by pressing the ends together in a “press machine” that uses water cooled jaws to flatten and form the ends. See Figure B. The mount (filament plus lead-in wires) is caught and sealed in between two layers of glass. The tubing is bent (only if not a straight lamp), then it is pumped down (to a near vacuum), the filaments are processed, a small amount of fill gas is introduced, a tiny drop of mercury in inserted, and it is sealed. Then the lamp sockets are attached, the lamp is tested and the label is printed on the lamp.
I hope this information helps you understand more about UV lamps and how they work in your UV light.

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