UV Lamps
Terms & Conditions of Use

Temperature effects on UV lamp output

There is a lot of talk and misinformation; however, it is an unavoidable fact that practically all ultraviolet (UV) lamps in use today are affected by the temperature of their immediate environment in regards to UV output. Minimizing the impact of this output vs. temperature effect depends as much on the overall UV system design as on the lamp itself. Understanding of this fundamental characteristic will help facilitate safe and trouble-free installation of UV equipment.

- By Michael Sarchese

UV Lamps

First, it is worth taking a look at the main UV lamp types in use: conventional low pressure, which is further subdivided into regular output (LP) and high output (LPHO), and amalgam LPHO, which still falls under the broad category of low-pressure lamps. Very high power medium pressure (MP) UV lamps are used in some large water treatment systems, but their high operating temperatures—up to 900° C (1,650° F)—and low efficiency (less than 20%) make them unsuitable for the applications of interest to this article.

Just as with ordinary fluorescent lighting, all of these typical UV lamps rely on mercury vapor, which emits UV light when excited by electricity (a fluorescent light tube has a phosphor coating on its inner surface that absorbs the internal ultraviolet energy and then converts this UV energy to visible light). The amount of UV power radiated by the lamp depends not only on the amount of electric power input, but also on the pressure of the mercury vapor1, 2, and this pressure is dictated by the temperature.

In conventional LP and LPHO lamps, the mercury vapor pressure is governed by the temperature of tiny droplets of liquid mercury that condense at the coldest spot of the lamp, as shown in Figure 1. The maximum UVC output efficiency occurs when these coldest droplets are at 42° C1, 2. Fundamentally there is not much difference between conventional LP and LPHO lamps. The LPHO is driven at higher electric current and power, resulting in higher wall temperatures that necessitate a “designed” cold-spot zone behind the filament. Also, heavier filaments will be used in LPHO lamps to carry the higher electric current.

Amalgam Lamps

The main difference with an Amalgam lamp is that there is no liquid mercury. In this type of lamp the mercury is bound in a mixture with bismuth and indium2 as illustrated in Figure 2 (The Webster dictionary describes the term “amalgam” as an alloy composed of mercury and some other metal, for example, amalgam dental fillings are composed of mercury and silver). Amalgam blobs, as opposed to liquid mercury, alter the lamp behavior in two ways: First, the amalgam provides the optimum mercury vapor pressure at a higher temperature—about 82° C2—allowing for higher power input; and second, the amalgam blobs inside the lamp act as a passive pressure regulator, releasing mercury into the excited vapor if pressure falls, or absorbing mercury if pressure rises with the net result that the UV output of the lamp is stable over a broad temperature range.

Therefore, a fair question at this point would be, “Why not use amalgam lamps all the time?” Well, there are three downsides, the first being that their manufacture is a lot more labor intensive resulting in costs several times higher than conventional LP lamps. The second downside is that their higher power and operating temperature make them a poor choice for systems that have stagnant water for long periods of time. The water gets really hot, and above 130° C the amalgam may melt and disperse within the lamp. Systems that turn the lamp on only during water flow don’t work well with amalgam lamps because of the third downside. Simply put, unless the amalgam warms up to near 80° C there is not enough mercury vapor in the lamp to generate much UV light, and therefore, it takes longer (usually a few minutes) to warm-up and deliver full output. Given the above considerations, amalgam lamps are typically used in larger multi-lamp continuous flow systems, where their high cost can be offset by reduced number of lamps and smaller reactors.

Water Treatment Use

From a water treatment system design point of view there are a few things that can be done to keep the critical temperature zone of the lamp as close to optimum as possible. In most systems the lamp is placed in a transparent quartz sleeve which is immersed in the process water. One of the key purposes of the quartz sleeve is to provide thermal insulation between the lamp and water, thereby allowing the critical lamp zone to reach an adequate temperature despite water that may be just a few degrees above freezing. Three key design parameters that dictate the temperature differential between the water and critical lamp zone are the diameter of the lamp, the size of the insulating air gap between the lamp and sleeve, and the amount of power driven into the lamp. Other parameters that can be tailored for non-amalgam lamps are end-cap design and electrode position, while amalgam lamps can be tailored by adjusting the size, location and composition of the amalgam blobs. Figure 3 illustrates a typical operating curve for a non-amalgam lamp operated first at a high-power current of 980mA (LPHO) and then the same lamp operated and at an LP current of 480mA.

The benefit of being able to operate at a lower current and power is that, apart from saving energy, the water within the UV chamber will not get as hot during extended periods of no water flow (stagnant water). Unfortunately, there is just no escaping the fact that at normal and colder operating temperatures, the higher power LPHO operation delivers considerably more UV power. Therefore, it can be seen that a variable power system with the capability to force high-power operation when required during high flows and/or lower temperatures, and otherwise throttle back to low power offers the higher power advantage of LPHO as well as the cooler operating LP benefit.

There are some systems on the market that flow the water through a transparent quartz reactor and place the lamp (or lamps) completely outside the reactor. This type of arrangement may be less impacted by the water temperature, but tends to be sensitive to the temperature and flow of cooling air around the lamp. No data is presented on these systems in this article, in part because they require control of the temperature and flow of air as well as that of water, resulting in a matrix of interdependent test conditions that becomes considerably more complex.

Figure 4 on page 7 illustrates the temperature stability of an amalgam lamp in a properly designed system for continuous flow water treatment. Key factors for proper amalgam lamp operation are to ensure sufficient power input and thermal insulation to keep the amalgam blobs above their critical temperature. If the system design and application do not allow the amalgam to get into the proper operating range, the lamp will have very low UV output and tends to be quite unstable. This is one reason why variable power amalgam systems can be very tricky to operate in practice.

So, what does this all mean to selecting a system for a particular application? In the case of installations required under government regulations, a certified system with built-in UV monitor will likely be required, so the main point here is that the sensor calibration be performed under controlled conditions at the manufacturer’s facility. If water quality is such that the UV transmission (UVT) is low or promotes sleeve fouling (high level of hardness), the system will have less room to tolerate temperature extremes before going into an undesirable alarm condition. This reinforces the importance of assessing the incoming water quality and providing pretreatment as necessary. Re-calibration of sensors in the field to account for specific site conditions is extremely risky and can invalidate the required certification.

Regardless of whether or not the installation falls under government regulations, it can be seen that having a system with a properly calibrated UV monitor is preferred. Obviously a non-monitored system can be obtained at a lower cost, and if this becomes the over-riding issue then it is important to ensure that the non-monitored system is sized conservatively enough to allow for expected swings in water temperature. Of course the same cautions to water quality, pre-treatment and sensor calibration (for monitored systems) apply as outlined above.

As one encounters various systems and claims of temperature stability, keep in mind that regardless of the system design strategy used, the laws of physics dictate that the lamp’s UVC output will be affected by the temperature of its immediate surrounding environment. In the case of lamps in sleeves immersed in the water, the water temperature becomes the dominant factor; in systems with the lamp outside of the treatment chamber (as with a quartz reactor) the cooling air flowing around the lamp becomes the dominating factor. Having some understanding of this issue goes a long way towards evaluating whether the UV equipment manufacturer has done due diligence in testing the system behavior with respect to fluctuating temperature.

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