LIFE-CYCLE COSTS FOR ULTRAVIOLET DISINFECTION SYSTEMS

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ABSTRACT

Operators of large-scale ultraviolet (UV) disinfection systems are becoming aware of the total utilisation cost of their assets and are beginning to focus on the total life-cycle costs (LCC) of the asset over ownership horizons of up to 20 years, as the primary tool to making procurement decisions.

Life cycle costs (LCC) are defined as the sum of all costs incurred during the lifetime of utilisation of the asset. Many of these are not obvious and do need to be understood at the time of procurement, otherwise the end user risks procuring an asset at a discount to pay for it over its lifetime.

1.0 DISINFECTION SYSTEMS

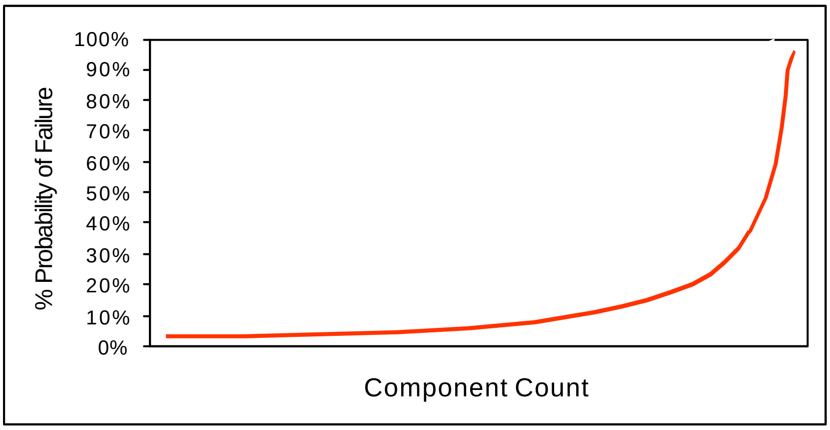
UV equipment is generally split into 2 distinct types. Medium pressure lamps are high power lamps with an output of 0.5Kw up to 12Kw. The traditional low-pressure mercury lamp has now been generally replaced by high output low-pressure lamps, which often use mercury in amalgam form. Typically 10-12 low-pressure lamps will have the same output as a single medium pressure lamp.

Medium Pressure UV equipment uses a smaller number of lamps and sleeves and therefore has the benefit of greater control, significantly reduced lamp and sleeve costs, and lower pumping costs due to the reduction of hydraulic resistance. The output of these lamps is polychromatic, with an output of 240-310nm defining the germicidal range. The molar mass of DNA absorbs most strongly at 265nm, which defines the most effective killing line. They have the disadvantage of consuming more power than alternative UV systems and this needs to be factored into the complete life cycle cost analysis.

The low-pressure systems that use amalgam lamps require a higher number of lamps, sleeves and ballasts to deliver an equivalent dose. The output of these lamps is monochromatic i.e. it is limited to a single UV output at 254nm, with the other outputs being emitted as visible light and heat.

Whilst the systems are more energy efficient than a medium pressure system, they have a significant number of cost implications due to their very high component count. Amalgam technology is often used to treat large effluent flows, where the lamps are immersed in an open, gravity fed channel.

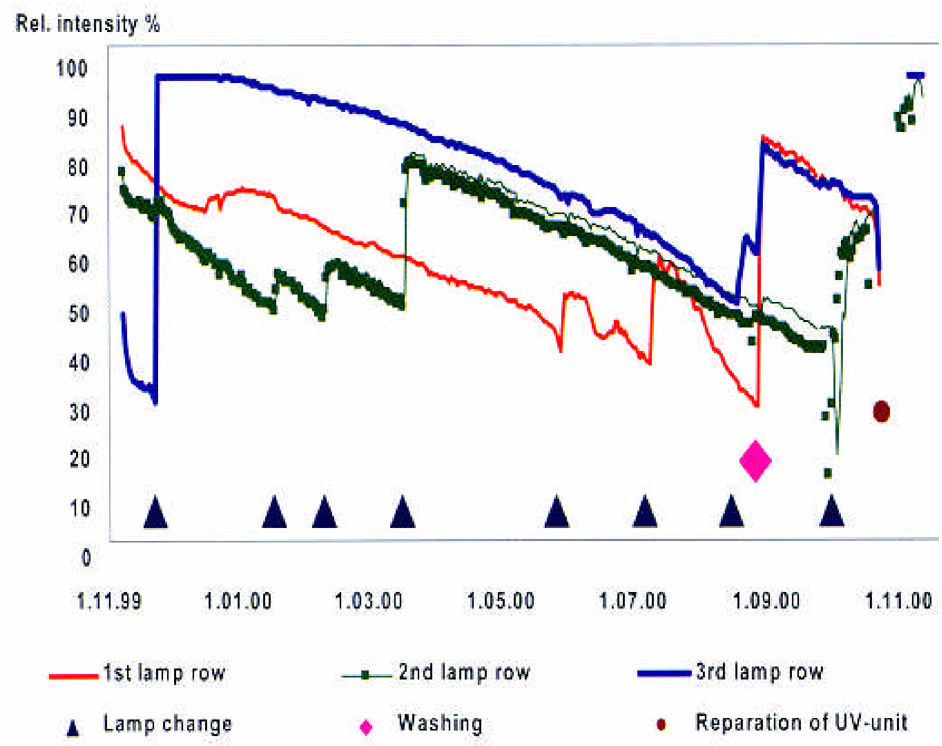
Figure 1: ***Relationship between Component Count and Probability of Failure***



The 'Mean Time Between Failure' (MTBF) is a very useful statistical measure of how reliable a product will be. One of the key drivers of MTBF is material selection. UV manufacturers need to possess extensive knowledge of the effect of aggressive UV light in moist environments when considering system design. The MTBF is also directly related to the component count, as the graph above illustrates.

A reactor containing several hundred lamps will therefore be prone to failure. The most common cause of failure is lamp failure, however failure mode analysis does reveal that the electronic ballasts have a limited life, and can contribute to failure, and a poorly designed monitor system that uses direct line of sight technology will also cause system failure. The graph below illustrates this well; a large drinking water installation in Helsinki recorded each lamp failure with a blue triangle, and notes the dimension of the time axis is limited to a 12 month period:

Figure 2: ***Twelve month operating analysis of large scale low-pressure installation in Northern Europe***



An additional problem posed by the use of many hundreds of lamps is the problem, delay and hence cost associated with an individual lamp failure. For example, if lamp 223 out of 384 fails, what exactly should the operator do? Should he replace this individual lamp and if so how should he record the event to maintain control of the process? It is not usual to record the hours run for every lamp. Replacing all of the lamps against an individual lamp failure would be prohibitively expensive.

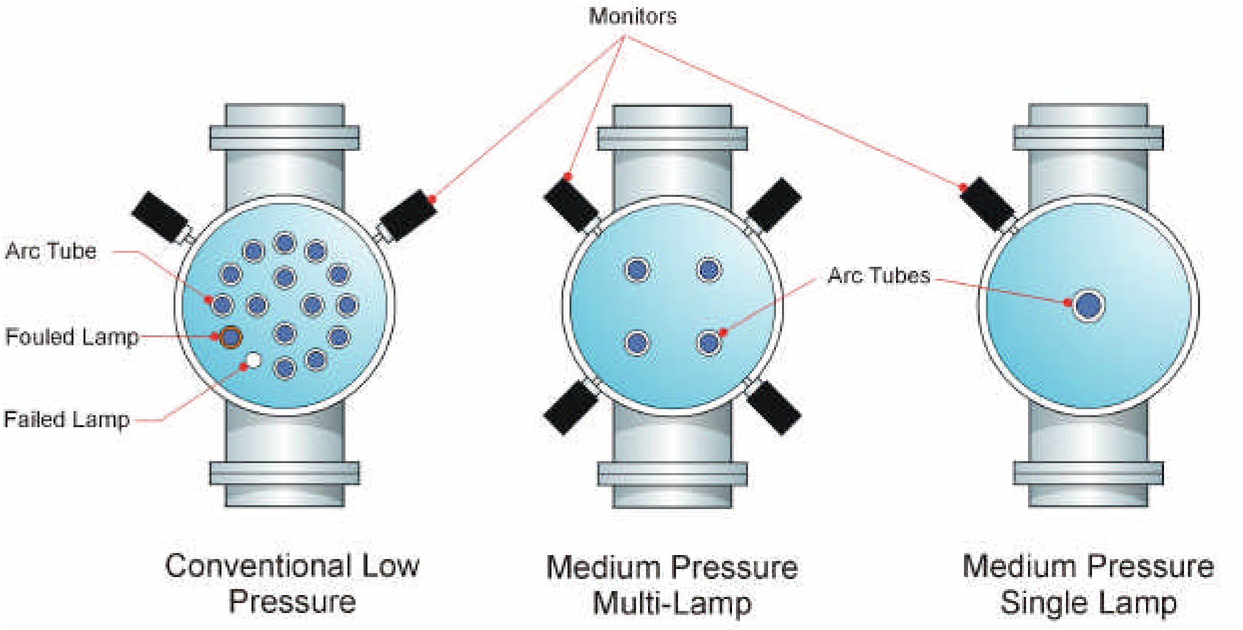
The issue of quartz sleeve cleaning is often overlooked and sometimes operators can be misled by inexperienced sales initiatives. Iron in solution will deposit onto the quartz and this phenomenon will occur with both low pressure and medium pressure equipment. As the Helsinki graph illustrates, chemical cleaning that involves acid pickling is slow and not yet optimised; the systems usually need to be completely stripped and hand cleaned. Note how the lamp intensity has degraded more rapidly following the (poor) chemical clean. The complex mechanical nature of the low-pressure geometry means that mechanical wiping is not possible. In stark contrast, a medium pressure system can be effectively wiped, which allows for planned maintenance chamber strip down to replace the wiper o-rings.

High numbers of lamps will also lead to a significant hydraulic resistance and will cause a large increase in headloss across the UV plant. This will lead to an increased pumping cost to the operator.

The inability to accurately monitor all the lamps is a key consideration in a high component count system. With the allocation of a single monitor for every 10 lamps running, one can only be sure that 10% of the flow is adequately disinfected.

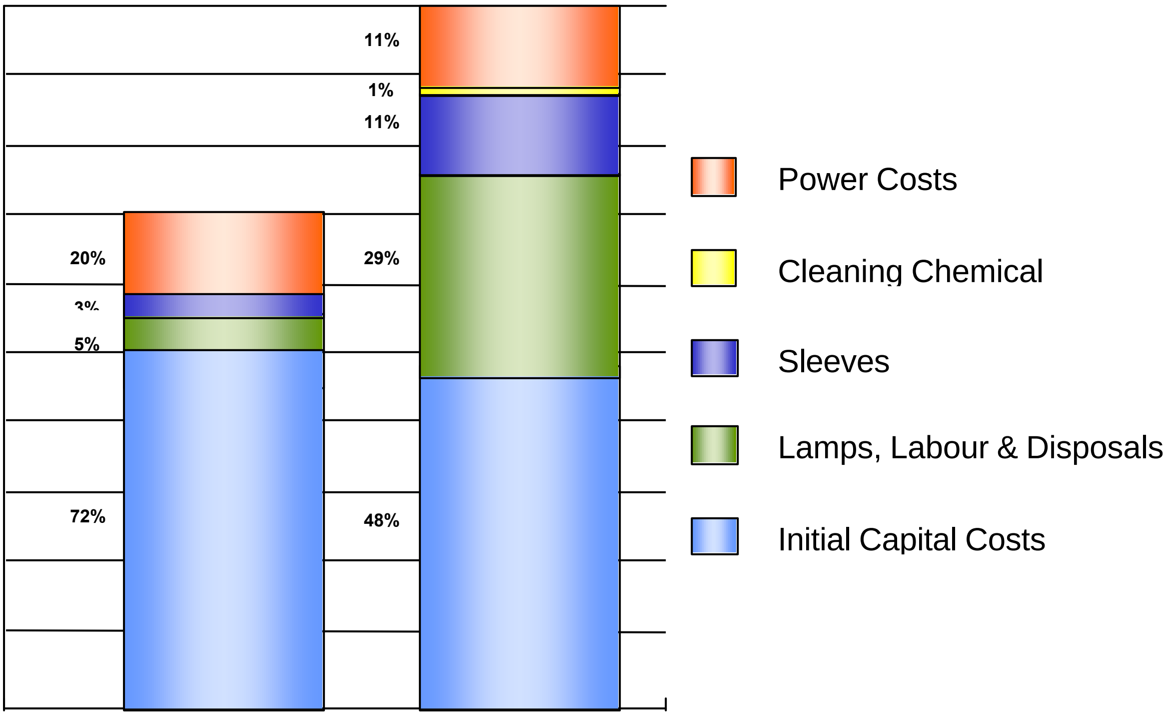
As the schematic below illustrates, with a limited number of lamps the UV monitoring can be meaningful and will ensure that the reactor is not inferring the water flow is adequately disinfected.

Figure 3: ***Meaningful Monitoring***



A medium pressure lamp operating at 5kW will contain approximately 300mg of pure elemental mercury. This lamp has the same germicidal output as ten or eleven 280w Amalgam lamps. Each Amalgam lamp contains over 100mg of mercury in Amalgam form causing lamp disposal issues, as the amalgam can not easily be absorbed in the crushing process. The increased Hg burden needs to be carefully considered in respect of ultimate lamp disposal.

Figure 4: ***Typical life cycle cost comparison for medium pressure and low pressure UV plant***



The chart above illustrates the difference in total spent between the comparable technologies. Note that the initial capital outlay is similar in both cases, and the power consumption is higher for the medium pressure system, with costs usually highly regulated and predictable. The total life cost for the Amalgam system is significantly composed of associated costs with lamps, sleeves and their safe disposal.

Customers will be able to evaluate these on-costs against their initial capital spend. Smart operators will not buy cheap to incur a high annual spend on components such as lamps and sleeves. UV manufacturers will be delighted to have a captive market to purchase from the sole supplier.

The implications of this are significant. Unlike a pump LCC evaluation, where the majority of the LCC will be energy costs, the real cost for a low-pressure lamp system operator over the life of the asset will be the purchase and disposal of the lamps. The most expensive consideration for a medium pressure system will be the energy costs. This needs carefully evaluation and price escalations contractually agreed with the vendor community.