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TO: Guy Bertelli, Kloppenberg Inc.
FROM: Mark Hernandez, PhD, PE, Principal Investigator

RE: Modeling Analysis of UV inactivation potential against selected pathogenic microorganisms retained by ACCENTS IN WATER features.

OVERVIEW: Isolated chamber experiments have shown that ACCENTS IN WATER features remove types of airborne bacteria that are often used as models for pathogenic bioaerosols (*Mycobacterium parafortuitum* and *Bacillus subtilis*). When challenged with high levels of airborne microbes, these water features removed these bioaerosols with an effective clean air delivery rate greater than 10 m^3/ hour. Once entrained in the water feature's flow, bacteria are recirculated through the feature's reservoir using a submersible pump which contains an in-line, low pressure ultraviolet lamp manufactured by Danner Inc., New York. Using the EPA Ultraviolet Disinfection Guidance Manual[1], (EPA 815 D 03 007), the inactivation potential of some airborne bacteria retained by ACCENTS IN WATER feature was assessed.

METHOD: The ultraviolet inactivation kinetics of a large number of pathogenic microorganisms that are significant to the microbial safety of water has been calculated from studies where UV exposure has been determined under optimal conditions: where the water is clean, has low turbidity, and high UV transmittance. The operation and maintenance of ACCENTS IN WATER features recommends pretreatments of water used to fill the feature's reservoir which qualifies this condition for UV inactivation analysis. The low pressure mercury lamps used in ACCENTS IN WATER features have been well characterized, and have approximately 85% of their power output as 254 nm monochromatic UV radiation. These lamps are housed downstream of a pump chamber which recirculates the feature's water past a UV lamp at a specified flow rate. We report here, estimates of bacterial inactivation potential when suspended in these feature's water through the range of flow rates recommended for normal operations. Widely accepted models[1,2] for UV inactivation were applied for these estimates using standard culture-based assays:

$$\mathbf{Log\ (N_t / N_o) = -k\ \ Fluence}$$

Where culturable bacteria following the residence time of the unit (N_{ti}), with respect to their numbers just prior to exposure (N_o), are proportional to an inactivation rate k (mJ/cm^2), the UV power density and the time exposed. The product of UV power density and the time exposed is termed Fluence. The sensitivity of different microorganism to UV exposure is expressed by the inactivation rate k.

MODELED VALUES: The UV fluence was calculated for the geometry and mean *one pass* residence time of well-mixed UV chambers in ACCENTS in WATER features, and compared to accepted literature values for potential pathogens (*Mycobacterium avium, Legionella pneumophila*, and *Staphylococcus aureus*). These calculations use the following conservative assumptions: (i) where 85% of the nominal power is present as monochromatic UV (254 nm), and (ii) where 10% of the UV is lost to non-specific occlusion of the quartz sleeve; 10% is lost to bulb aging effects; and 20 % is lost to non-ideal water transmittance (reductions collectively denoted as aged). Using the conservative operations estimates outlined above, the UV doses delivered by *Pondmaster* units installed in the larger ACCENTS in WATER features are summarized below for the range of flow rates they deliver. They are presented with the corresponding UV doses considered in the best available literature for a range of potential pathogens.

[1] Ultraviolet Disinfection Guidance Manual, United States Environmental Protection Agency 815-D-03-007
2 Hijnen, et al., Inactivation credit of UV radiation for viruses, bacteria and prozoan (oo)cysts in water: a review. Water Research (40) 2006

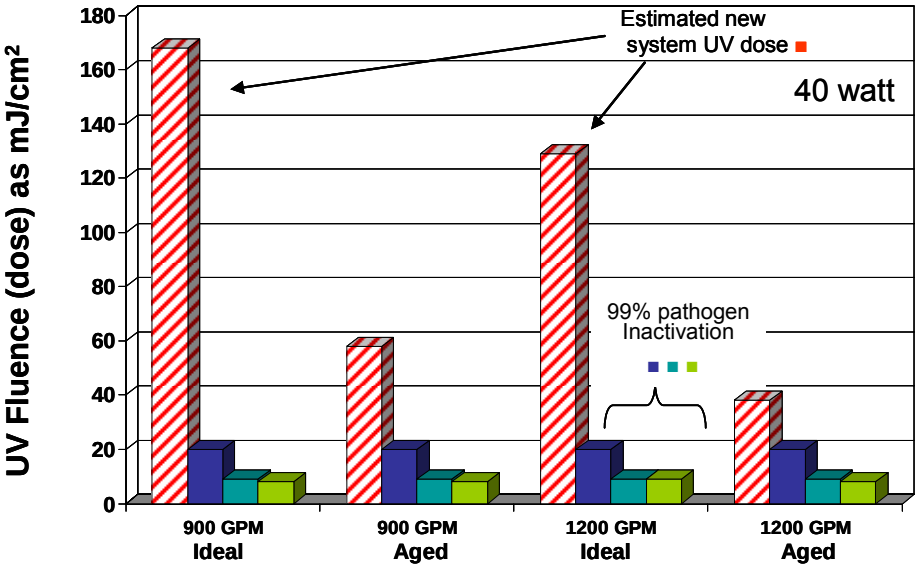

Figure 1. One pass UV dose delivered (■) in 40 W low pressure monochromatic chambers (c.a. 1100 cm^3) installed in ACCENTS in WATER FEATURES operated through the range of manufacturers recommended flow rates (900 GPM – 1200 GPM). Ideal estimate is for 85% of nominal fluence through clean water with no UV absorbance losses. Aged estimate incorporates composite of 40% UV absorbance losses due to sleeve occlusion, bulb losses, and depressed water transmittance. Exposure required for 99% inactivation of *Mycobacterium avium* (■), *Legionella pneumophila* (■), and *Staphylococcus aureus* (■) is presented for comparison.

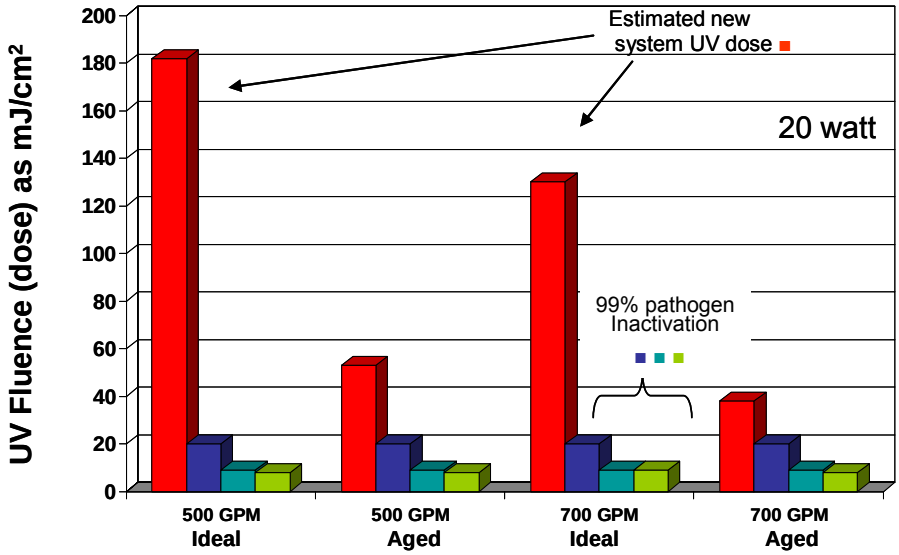

Figure 1. One pass UV dose delivered (■) in 20 W low pressure monochromatic chambers (c.a. 1100 cm^3) installed in ACCENTS in WATER FEATURES operated through the range of manufacturers recommended flow rates (900 GPM – 1200 GPM). Ideal estimate is for 85% of nominal fluence through clean water with no UV absorbance losses. Aged estimate incorporates composite of 40% UV absorbance losses due to sleeve occlusion, bulb losses, and depressed water transmittance. Exposure required for 99% inactivation of *Mycobacterium avium* (■), *Legionella pneumophila* (■), and *Staphylococcus aureus* (■) is presented for comparison.