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Effect of Ultraviolet Sterilization Cabinets on the Survival of Bacteria Contaminating Protective Eye Wear

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Submitted to

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Purpose:

The purpose of these tests was to determine the effect of Kerkau Model H-75, Model K-50, and Model F-100 Ultraviolet Sterilization Cabinets on the survival of bacteria on protective eye wear.

Background:

The microorganisms responsible for infectious diseases are transmitted by direct contact and by indirect contact with infected individuals or with contaminated particles or surfaces. Inanimate objects that become contaminated with infectious organisms serve as fomites, or vehicles for transmitting infections. Bacterial, fungal, parasitic, and viral infections are all known to be associated with exposure to contaminated fomites. Fomites can become contaminated in many ways, including by touching with contaminated hands. These contaminated surfaces can, in turn. serve as reservoirs of infectious microorganisms.

In order for fomites to serve as vehicles for infection transmission, the infectious microorganisms must be able to survive association with the fomites until they are picked up for transmission to a susceptible individual. Survival of infectious microorganisms on contaminated surfaces depends upon conditions, such as temperature, humidity, and light and can range from a few hours to many months.

The application of sanitizing devices that employ the principle of ultraviolet light is well known in the reduction of infection rates. The published literature contains numerous references demonstrating the effectiveness of ultraviolet light in the destruction of bacteria and viruses.

The tests performed in this study had a goal of documenting the effect of the specific ultraviolet sterilization cabinets on the survival of a common pathogen, *Staphylococcus aureus*, on protective eye wear.

Materials and Methods:

The ultraviolet sterilization cabinets and the test safety glasses used in these tests were provided by Kerkau Manufacturing, Bay City, Michigan. The three cabinet models tested were identified as Models K-50, H-75, and F-100. Each unit consisted of a painted steel cabinet that contained a General Electric G15T8 germicidal ultraviolet light, aluminum reflector linings, racks for eye wear placement, and a timer. The intensity of the ultraviolet light at 254 nm was measured at 9 locations within each test cabinet using a Cole-Parmer Series 9811 Radiometer. Ultraviolet light intensity was expressed as mW/cm^2.

Model F-100 had approximate outside dimensions of 30" W x 30" H x 12" D and had the ultraviolet lamp mounted vertically inside the center post between the doors of the unit. The unit and the locations of ultraviolet light measurement are illustrated in Figure 1.

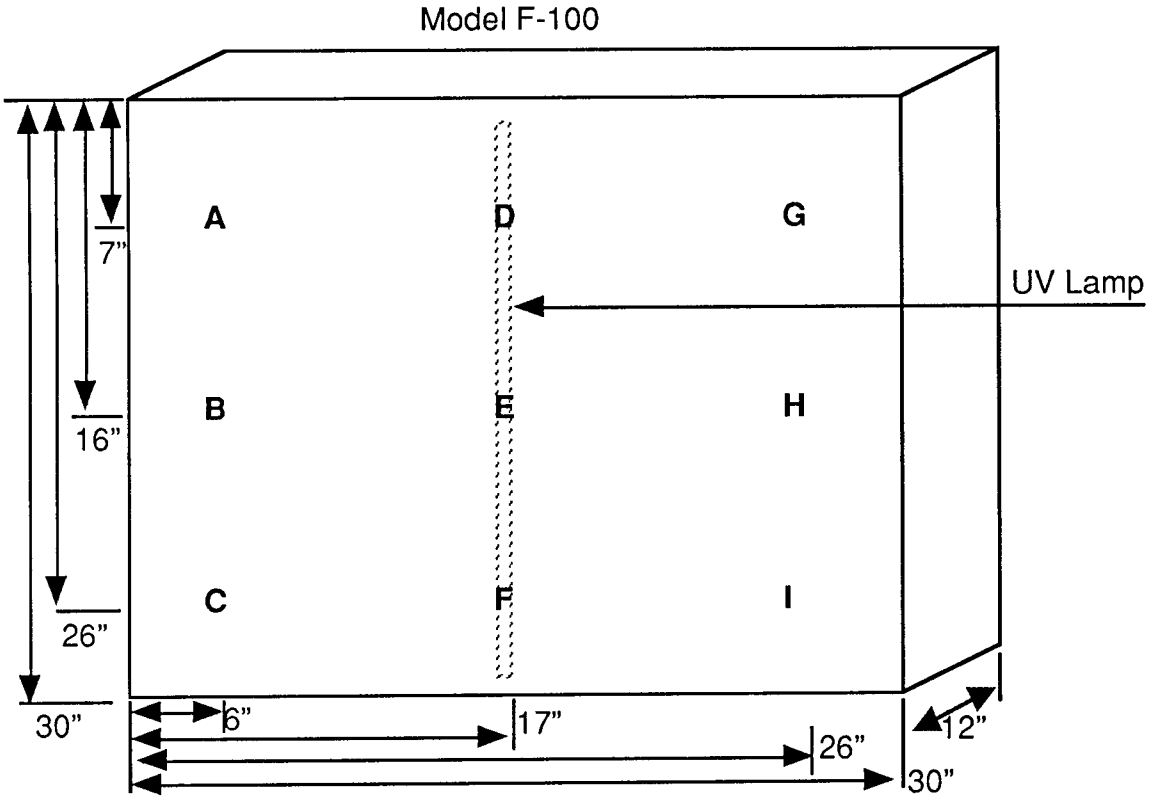

Figure 1. Model F-100 and UV Intensity Measurement Locations (Not to Scale)

Model H-75 had approximate outside dimensions of 24" W x 32" H x 9.5" D and had the ultraviolet lamp mounted horizontally inside the top of the unit. The unit and the locations of ultraviolet light measurement are illustrated in Figure 2.

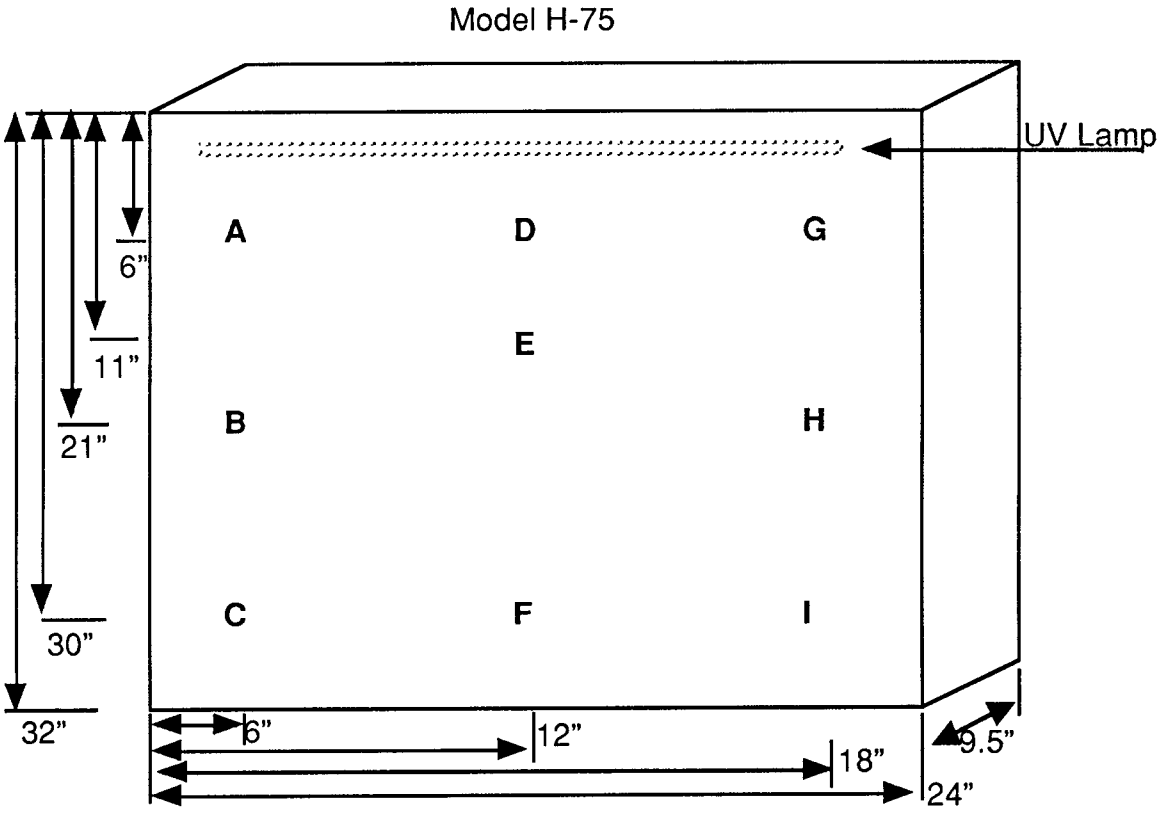

Figure 2. Model H-75 and UV Intensity Measurement Locations (Not to Scale)

Model K-50 had approximate outside dimensions of 24" W x 28" H x 9" D and had the ultraviolet lamp mounted horizontally inside the top of the unit. The unit and the locations of ultraviolet light measurement are illustrated in Figure 3.

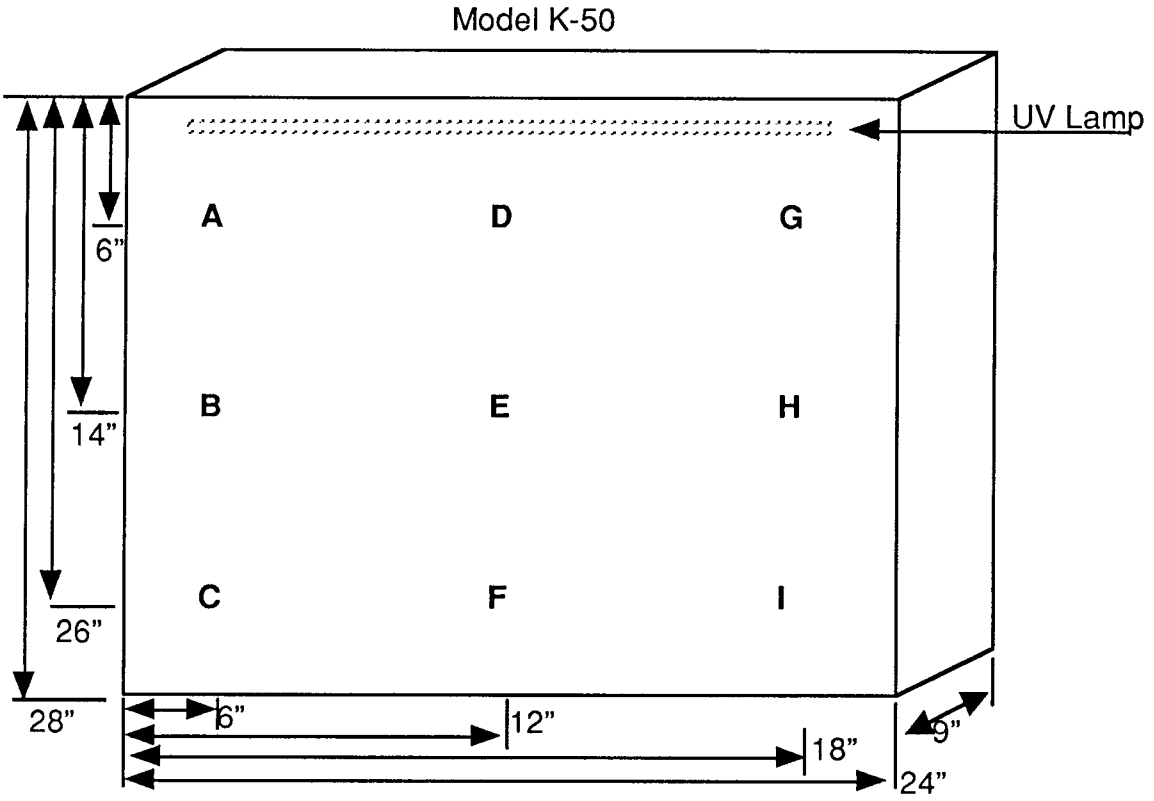

Figure 3. Model K-50 and UV Intensity Measurement Locations (Not to Scale)

Initial tests were performed to determine the suitable dilutions of bacterial culture to use in conducting the tests. The goal in selecting the dilutions was to demonstrate a maximum number of countable colonies and to show statistically discernible reductions in their numbers should they occur. The initial tests were also used to determine suitable exposure duration for evaluating microorganism reduction.

After dilution and duration parameters were established, the experimental approach was to compare the survival of the test bacteria under experimental and control conditions over time. The experimental condition was inside the unit with operating ultraviolet light and the control condition was outside the unit without an operating ultraviolet light. The

effect of the ultraviolet light on the survival was determined by comparing experimental tests taken at 5 and 10 minute time intervals at specific locations in each cabinet with controls.

In addition, tests were performed to determine the effect of the experimental condition at three different locations within each cabinet. The test locations were selected on the basis of measured ultraviolet light intensity at several locations within each unit. The locations selected included those with the highest and lowest ultraviolet light intensity. The third location was that which had ultraviolet light intensities that were closest to the average of the highest and lowest intensities.

The bacteria used in the test was *Staphylococcus aureus* subsp. *aureus* ATCC 12599. The culture was obtained from American Type Culture Collection, Rockville, Maryland and was grown in nutrient broth (Difco). Dilutions were performed in phosphate buffered water and assays were performed on triptic soy agar (Difco).

Tests were performed on plastic safety glasses, shown in Figure 4. Prior to conducting the tests, the outside of the right ear piece of each pair of safety glasses was swabbed with 70% propanol and permitted to air dry for at least 1 hr. The outside of the right ear piece of each pair of safety glasses was contaminated with a 0.1 mL of a 1 x 10^{-4} dilution of a freshly grown culture of*S. aureus* bacteria. The bacterial suspension was allowed to air dry in a negative pressure containment hood for 2 hr. and then placed in the selected position in each sanitizing cabinet. In each case, the inoculated ear piece was positioned toward the rear of the rack and in an upward position. The doors to the sanitizing cabinet were closed and timed exposure to the ultraviolet light was performed.

Figure 4. Plastic Safety Glasses Tested

After exposure in the sanitizing cabinet, the bacteria from each set of eye wear were cultured onto tryptic soy agar by contact sampling. Both positive and negative controls were performed with each test. Bacteria dilution concentrations were determined by using the spread plate technique on tryptic soy agar. Samples were incubated at 35° C for 24 hours. Colonies were counted and expressed as colony-forming units (CFU).

Results

Ultraviolet Light Intensity Measurements:

The ultraviolet light intensity in Model F-100 varied widely throughout the unit. As shown in Figure 5, the highest intensity, .128 mW/cm^2, was measured at location A and the lowest intensity, .008 mW/cm^2, was measured at location D. Bacteria survival tests were performed at location A, D, and B, which had an ultraviolet light intensity of .062 mW/cm^2. These locations are outlined in boxes.

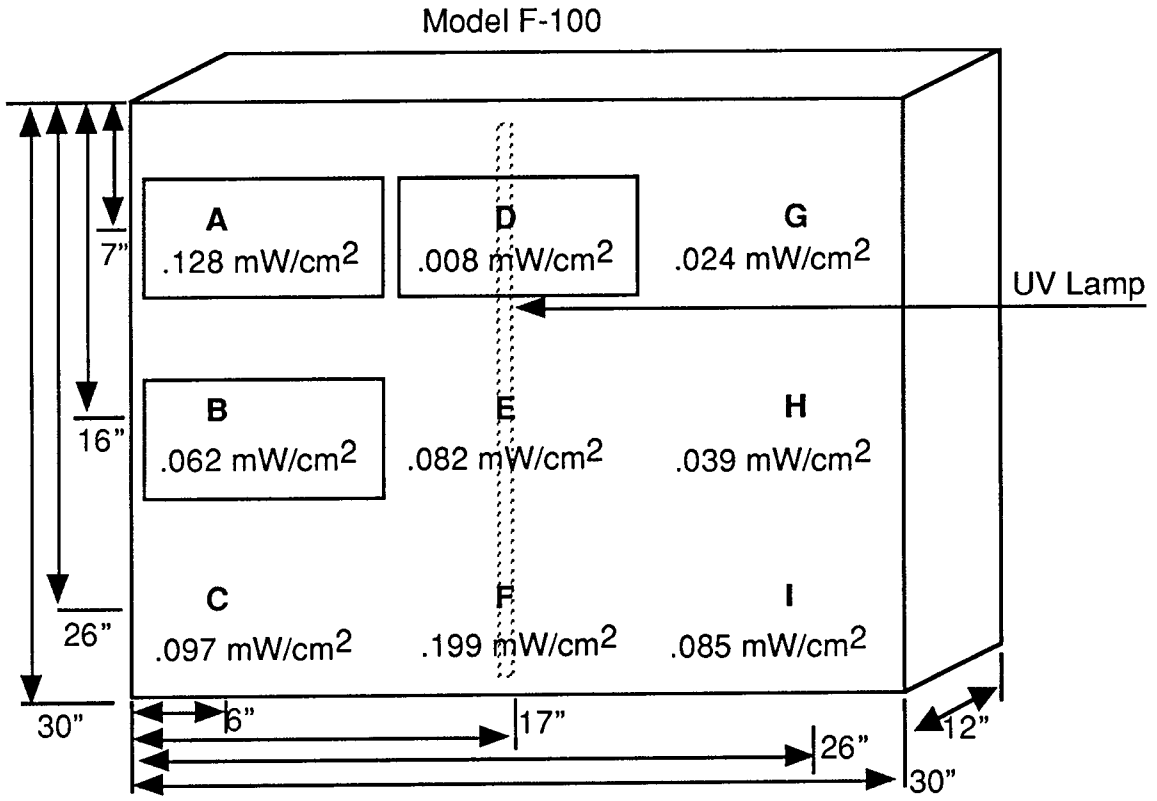

Figure 5. Model F-100 UV Intensity Measurements and Bacteria Test Locations

The ultraviolet light intensity in Model H-75 varied widely throughout the unit, but was highest on the top row, nearest to the ultraviolet lamp. As shown in Figure 6, the highest intensity, .2.530 mW/cm^2, was measured at location D and the lowest intensity, .162 mW/cm^2, was measured at location F. Bacteria survival tests were performed at location D, F, and A, which had an ultraviolet light intensity of 1.450 mW/cm^2. These locations are outlined in boxes.

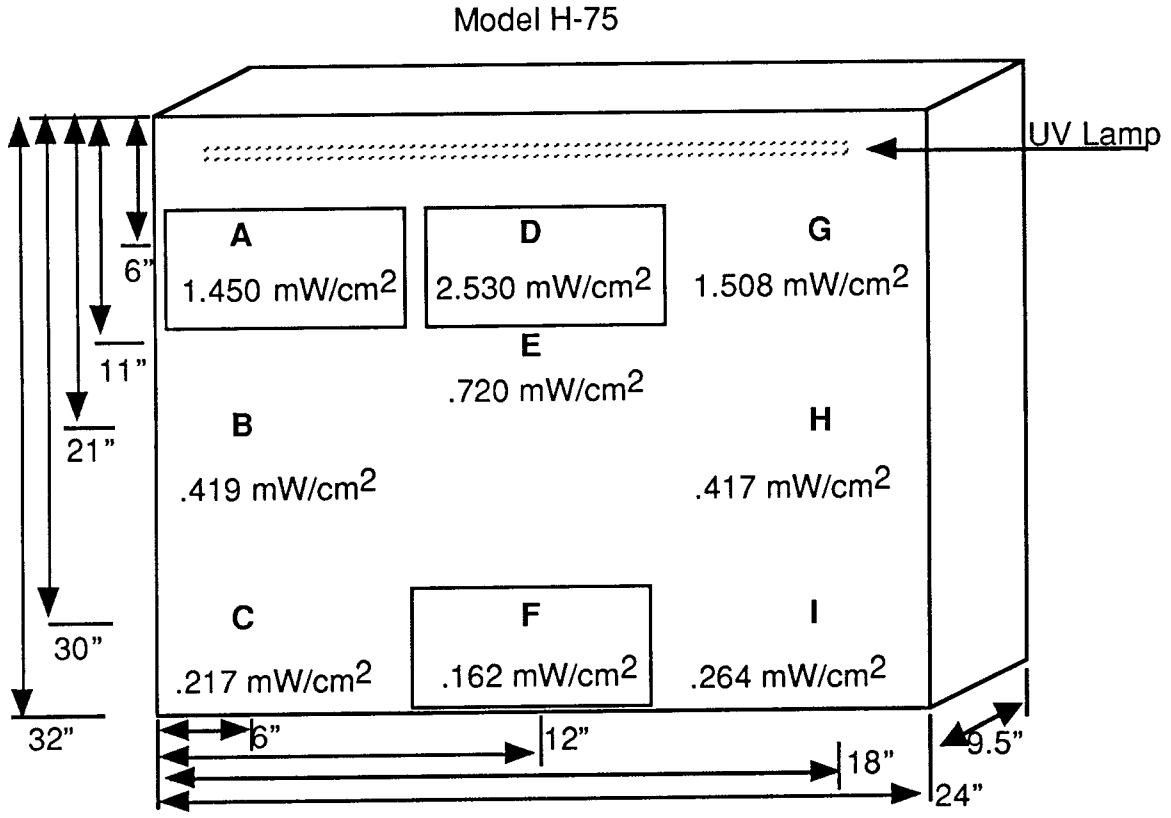

Figure 6. Model H-75 UV Intensity Measurements and Bacteria Test Locations

The ultraviolet light intensity in Model K-50 was also highest on the top row, nearest to the ultraviolet lamp. As shown in Figure 7, the highest intensity, .1.582 mW/cm^2, was measured at location D and the lowest intensity, .047 mW/cm^2, was measured at location C. Bacteria survival tests were performed at location D, C, and A, which had an ultraviolet light intensity of .635 mW/cm^2. These locations are outlined in boxes.

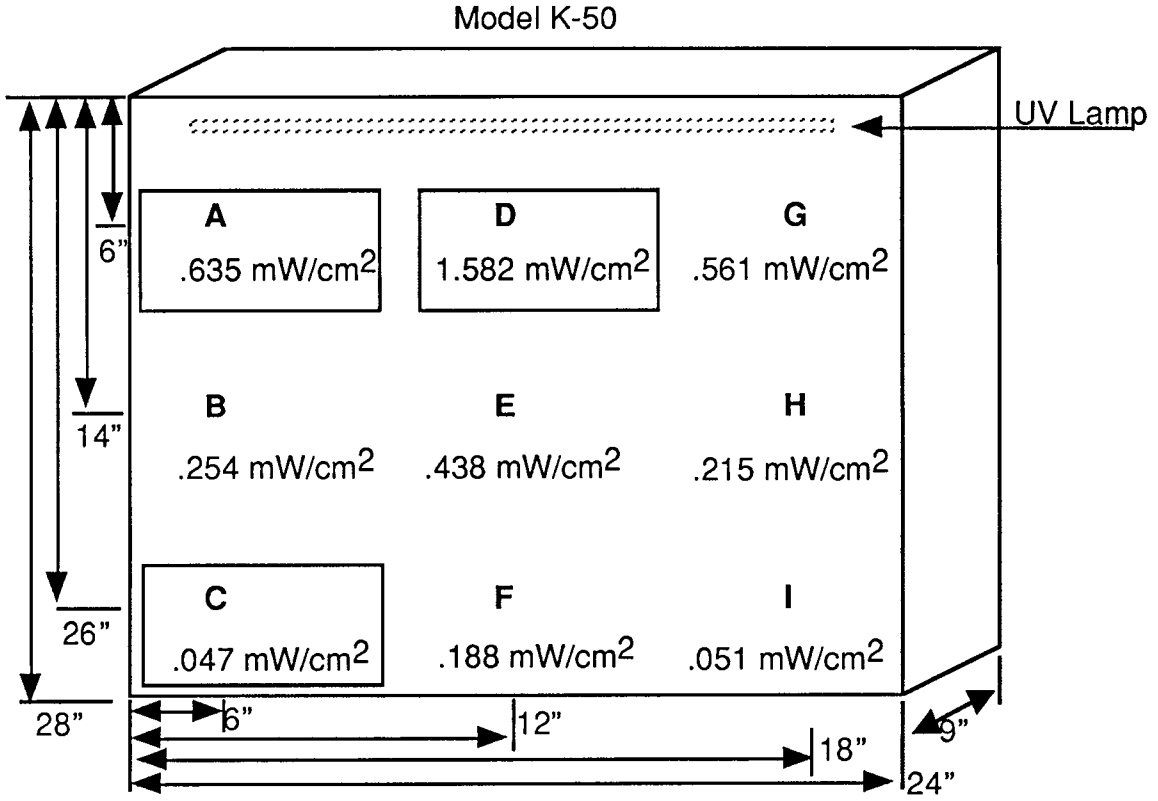

Figure 7. Model K-50 UV Intensity Measurements and Bacteria Test Locations

Bacteria Survival Tests:

Five Minute Exposure

The results of bacteria survival test in each model after 5 min. of operation are shown in Tables 1, 2, and 3 and in Figures 8, 9, and 10. Approximately 54000 CFU *Staphylococcus aureus* bacteria were inoculated onto the safety glasses as described above and, after 5 min. of operation, the number of

CFU recovered ranged from 0 to >90. Based on these results, the percent of the bacteria reduced ranged from <99.833% to 100%.

Table 1. Effect of Model F-100 on *Staphylococcus aureus* Bacteria on Safety Glasses after 5 min. Operation

Test No.	Test Location	No. CFU Inoculated	No. CFU Recovered	Percent Reduction	Negative Control CFU	Positive Control CFU
1-A-5	A	54000	>90	<99.833	0	TNTC*
1-B-5	B	54000	0	100	0	TNTC
1-D-5	D	54000	1	99.998	0	TNTC

*TNTC: "too numerous to count"

Figure 8. Effect of Model F-100 on *Staphylococcus aureus* Bacteria on Safety Glasses after 5 min. Operation

Table 2. Effect of Model H-75 on *Staphylococcus aureus* Bacteria on Safety Glasses after 5 min. Operation

Test No.	Test Location	No. CFU Inoculated	No. CFU Recovered	Percent Reduction	Negative Control CFU	Positive Control CFU
2-A-5	A	54000	0	100	0	TNTC*
2-B-5	D	54000	0	100	0	TNTC
2-D-5	F	54000	0	100	0	TNTC

*TNTC: "too numerous to count"

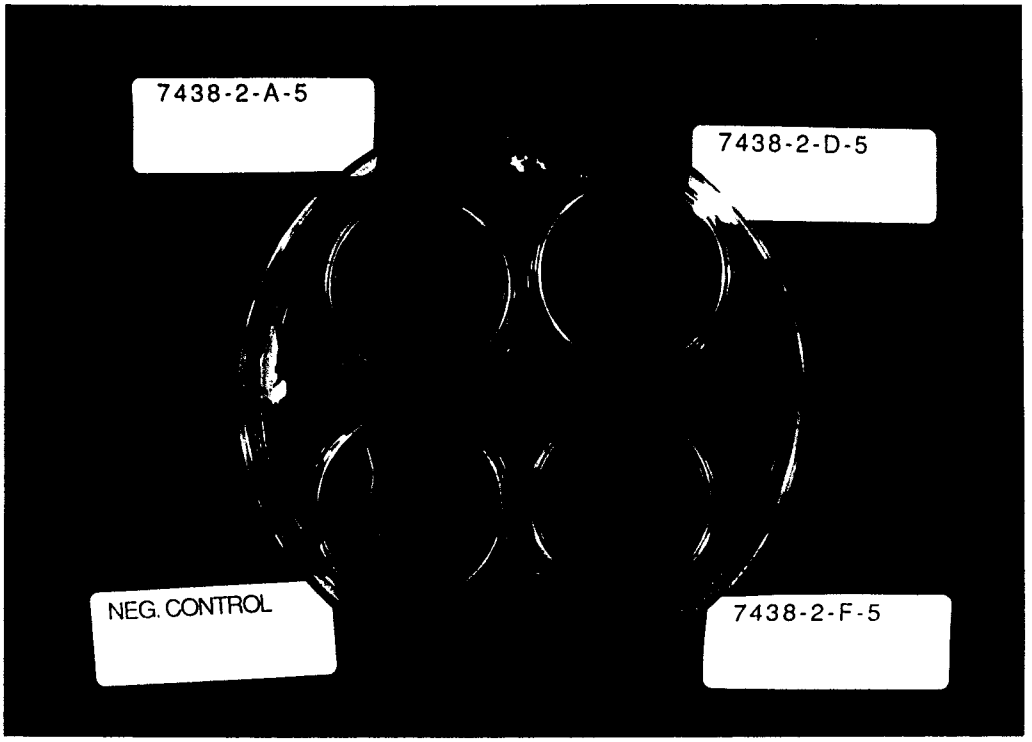

Figure 9. Effect of Model H-75 on *Staphylococcus aureus* Bacteria on Safety Glasses after 5 min. Operation

Table 3. Effect of Model K-50 on *Staphylococcus aureus* Bacteria on Safety Glasses after 5 min. Operation

Test No.	Test Location	No. CFU Inoculated	No. CFU Recovered	Percent Reduction	Negative Control CFU	Positive Control CFU
3-A-5	A	54000	1	99.998	0	TNTC*
3-C-5	D	54000	>65	<99.880	0	TNTC
3-D-5	F	54000	0	100	0	TNTC

*TNTC: "too numerous to count"

Figure 10. Effect of Model K-50 on *Staphylococcus aureus* Bacteria on Safety Glasses after 5 min. Operation

Ten Minute Exposure

The results of bacteria survival test in each model after 10 min. of operation are shown in Tables 4, 5, and 6 and in Figures 11, 12, and 13. Approximately 54000 CFU *Staphylococcus aureus* bacteria were inoculated

onto the safety glasses as described above and, after 10 min. of operation, no CFU were recovered from any of the inoculated safety glasses. Based on these results, the percent of the bacteria reduced was 100% for all three models tested.

Table 4. Effect of Model F-100 on *Staphylococcus aureus* Bacteria on Safety Glasses after 10 min. Operation

Test No.	Test Location	No. CFU Inoculated	No. CFU Recovered	Percent Reduction	Negative Control CFU	Positive Control CFU
1-A-5	A	54000	0	100	0	TNTC*
1-B-5	B	54000	0	100	0	TNTC
1-D-5	D	54000	0	100	0	TNTC

*TNTC: "too numerous to count"

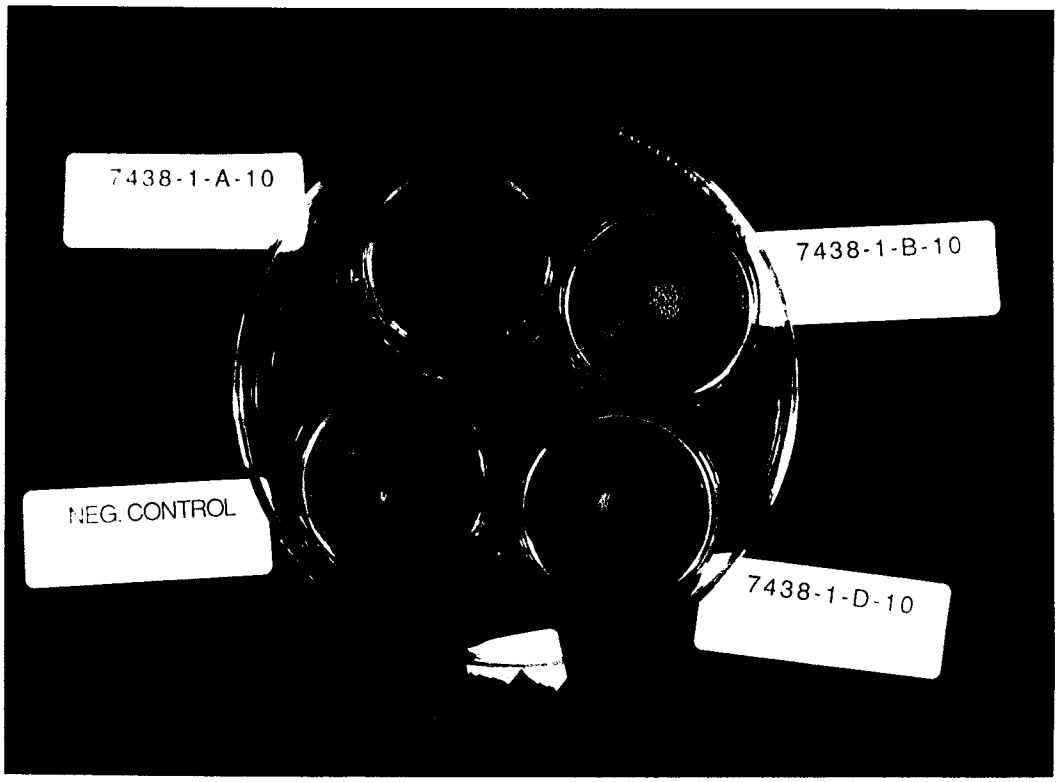

Figure 11. Effect of Model F-100 on *Staphylococcus aureus* Bacteria on Safety Glasses after 10 min. Operation

Table 5. Effect of Model H-75 on *Staphylococcus aureus* Bacteria on Safety Glasses after 10 min. Operation

Test No.	Test Location	No. CFU Inoculated	No. CFU Recovered	Percent Reduction	Negative Control CFU	Positive Control CFU
2-A-5	A	54000	0	100	0	TNTC*
2-B-5	D	54000	0	100	0	TNTC
2-D-5	F	54000	0	100	0	TNTC

*TNTC: "too numerous to count"

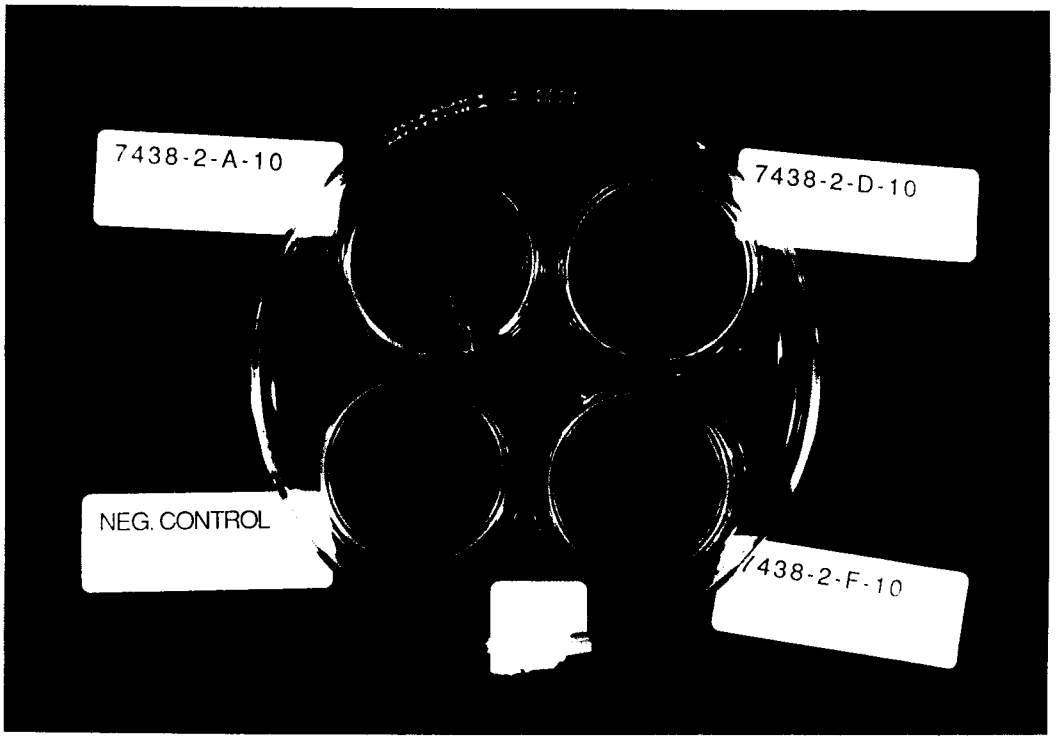

Figure 12. Effect of Model H-75 on *Staphylococcus aureus* Bacteria on Safety Glasses after 10 min. Operation

Table 6. Effect of Model K-50 on *Staphylococcus aureus* Bacteria on Safety Glasses after 10 min. Operation

Test No.	Test Location	No. CFU Inoculated	No. CFU Recovered	Percent Reduction	Negative Control CFU	Positive Control CFU
3-A-5	A	54000	0	100	0	TNTC*
3-C-5	D	54000	0	100	0	TNTC
3-D-5	F	54000	0	100	0	TNTC

*TNTC: "too numerous to count"

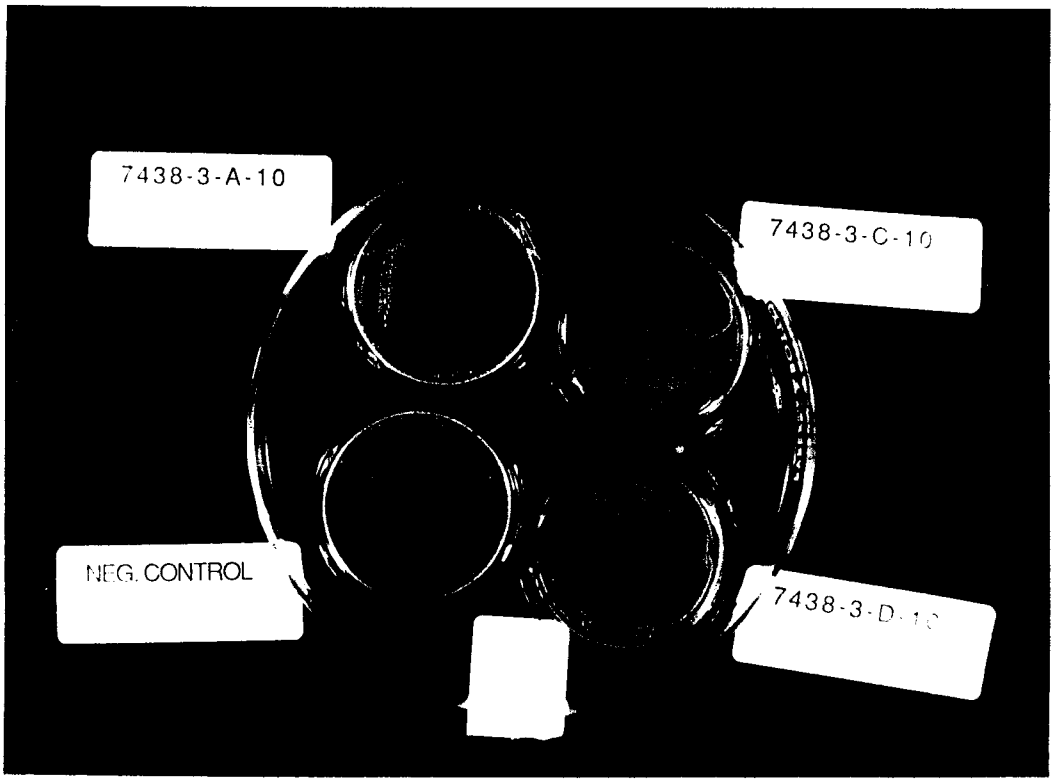

Figure 13. Effect of Model K-50 on *Staphylococcus aureus* Bacteria on Safety Glasses after 10 min. Operation

An example of the positive control cultures is shown in Figure 14. Positive control 1 was sampled from a pair of inoculated safety glasses. Positive control 2 and 3 were the inoculum that was placed onto the safety glasses. The negative control is without the inoculum.

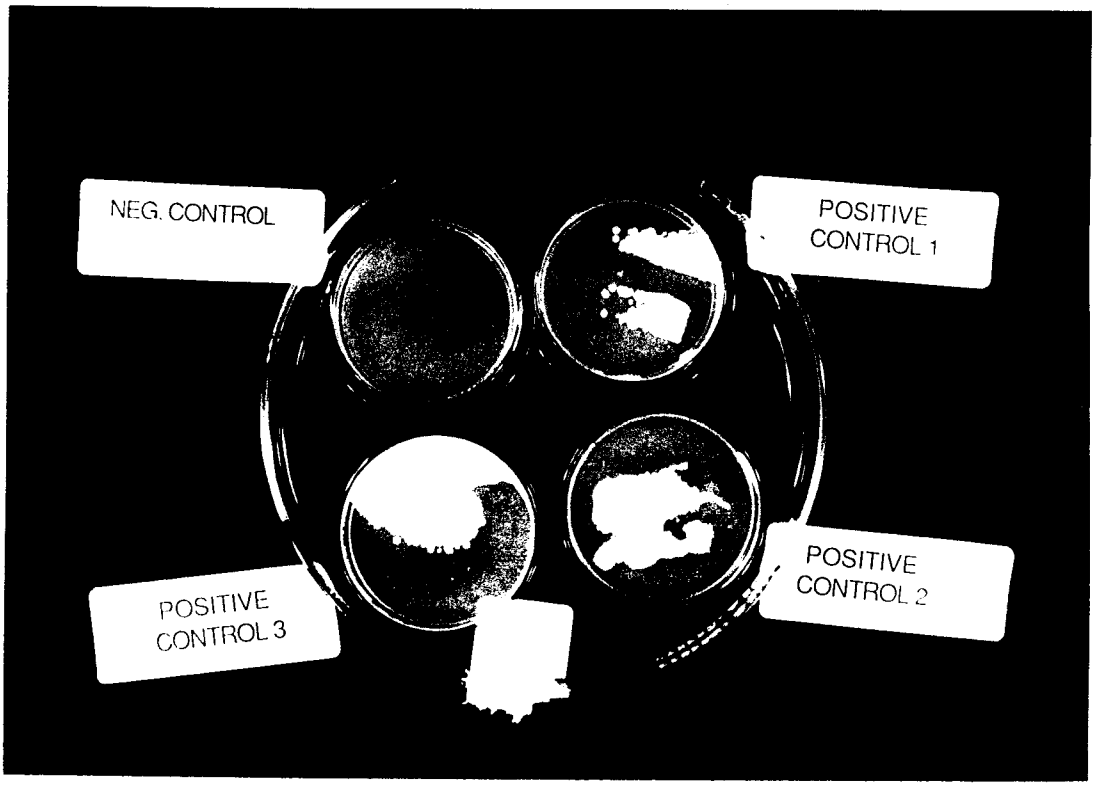

Figure 14. Positive Control Cultures

Conclusions

Ultraviolet light intensity measurements performed in Kerkau Manufacturing Co. ultraviolet light sanitizing cabinet Models K-50, H-75, and F-100 showed that the intensity varied at different locations within each model. The intensity was affected by the location of the measurement with respect to the position of the ultraviolet light in each unit. In some cases, ultraviolet light reflectance may have produced higher intensity levels at specific locations.

Tests performed using *Staphylococcus aureus* bacteria inoculated onto safety glasses placed in Kerkau Manufacturing Co. ultraviolet sanitizing cabinets for 5 min. showed bacteria reductions of <99.833% to 100% for Model F-100, 100% for Model H-75, and <99.880% to 100% for Model K-50.

Tests performed using *Staphylococcus aureus* bacteria inoculated onto safety glasses placed in Kerkau Manufacturing Co. ultraviolet sanitizing cabinets for 10 min. showed bacteria reductions of 100% for Model F-100, 100% for Model H-75, and 100% for Model K-50.

The tests were performed under conditions with few glasses in each cabinet and with bacteria inoculated onto a specific location on each pair of glasses. Although higher loading of the number of safety glasses in cabinets or inoculating bacteria onto different locations on the glasses may provide results different from those found in these tests, the sanitizing cabinets tested are effective in reducing the numbers of bacteria on safety glasses.