UVGI Airborne and Surface Pathogen Control in a Large County Jail

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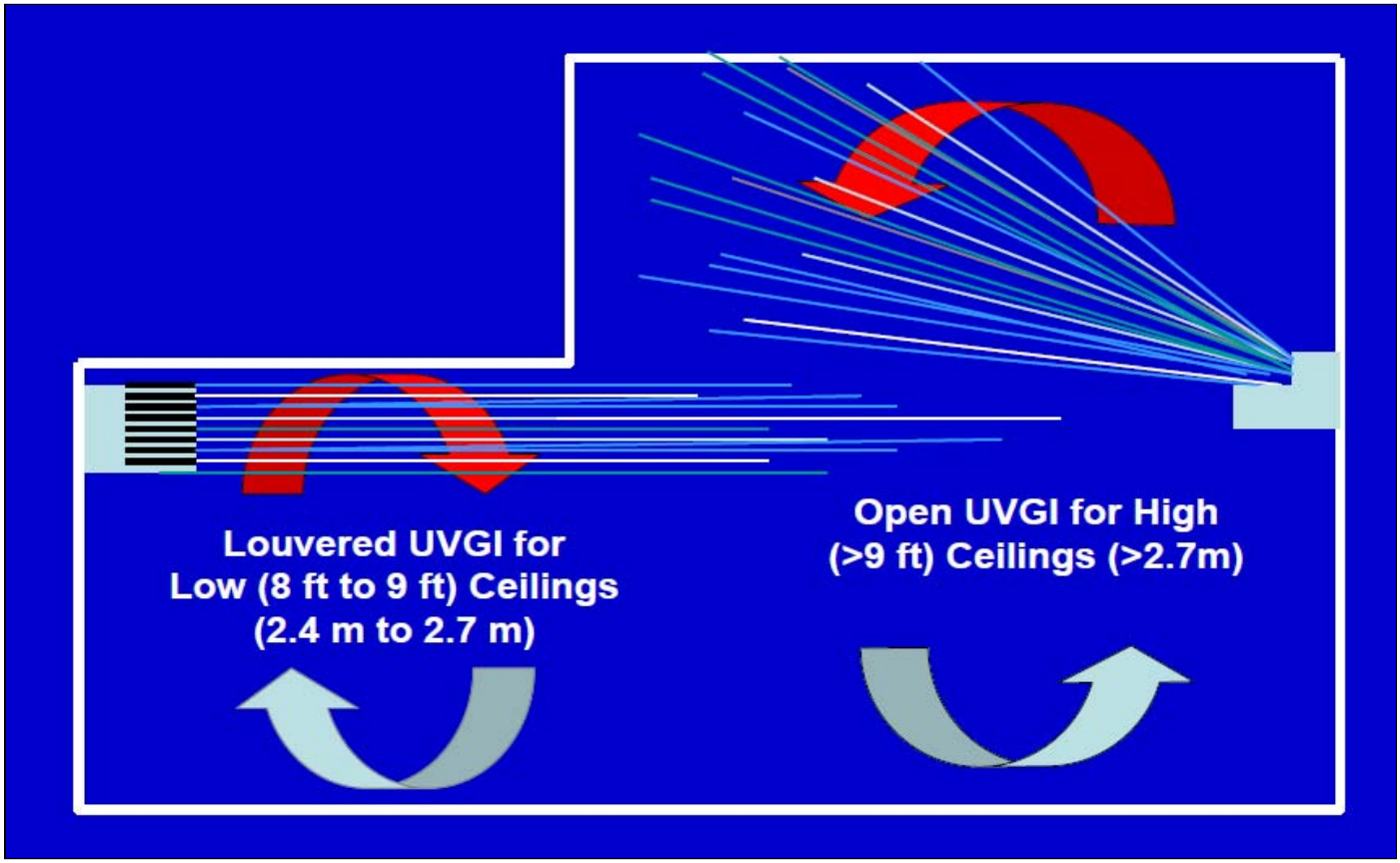
Built in the mid 1980's, the Sacramento (California) County Main Jail Facility is a well maintained, eight-story building in the city's downtown area. The facility's mechanical systems are included in a large rooftop penthouse that encloses two main mechanical systems for all prisoner housing areas. The basement and first two floors have several separate HVAC and exhaust systems. No special design requirements were built into the HVAC systems for the prevention of airborne disease transmission when the building was constructed except for the single-pass exhaust systems installed into several medical housing unit single-person cells.



Wall-mounted UVGI fixtures target contaminated air in igh-risk areas. They are engineered for either low ceiling or high ceiling spaces. Multiple units can be used to disinfect air in larger spaces.

By the late 1990's, the jail accommodated roughly 50,000 arrestees per year. In 1999, a triggering event of potential tuberculosis (TB) transmission occurred that made it clear that TB was likely capable of being transmitted from person to person via both close contact with infected individuals and distant contact through the jail's HVAC system.

A prisoner with active TB was unknowingly transferred into the custody of Sacramento County and released into the general population after approximately 30 days of incarceration. Public health officials later confirmed the diagnoses of the former inmate with active TB and concluded that some 5000 contacts had been made with current or former inmates and correctional workers. A regional public outreach was initiated in an attempt to locate and inform all persons who may have had close or prolonged contacted with the carrier. All employees that had direct or indirect contact with the former inmate (shared air in the Main Jail) were given TB skin tests, which resulted in approximately 15 worker's compensation claims for positive TB skin tests.

It was evident there were issues in regards to moving prisoners from facility to facility and within large facilities, screening of potentially infectious inmates, and not considering the facility a high-risk environment for transmission of airborne contagion as it related to HVAC design and maintenance. Several areas for improvement were identified subsequently and corrective actions were implemented. These actions included improvement in all communication regarding infectious inmates, both internally and externally; improved medical screening procedures; training and awareness in the identification of potentially infectious inmates, and the safe movement of prisoners.

Suggestions were made to improve the engineering controls at the jail. These facility engineering recommendations first suggested that existing filter banks be retrofitted with HEPA® filtration, and that the number of air changes per hour within the building should be increased. Though these suggestions are often practical and reasonable to accommodate in a new building, county engineers were pessimistic that thiscould be accomplished reasonably in an existing facility as the HVAC system would require the replacement of existing fan motors and resizing of ducts to overcome the very substantial static pressure that is common to HEPA filtration. The cost to simply upgrade the air handling units to HEPA filtration was estimated to be around $20,000 per unit. This course of action was further complicated by the fact that there was no space to locate

new HEPA filter banks and larger fan motors. In fact, attempting to retrofit an existing building's HVAC system to increase hourly air changes, while at the same time introducing HEPA filtration with greatly reduced airflow, proved to be an impossible task without reenegineering the building. The estimated total cost to reengineer the entire building's HVAC system would have well exceeded $1,000,000.

In addition, a requirement to shut down entire wings of the jail was not practical considering that some HVAC systems affected four or more floors in the facility. Additionally, the county had incurred a $20 million deficit in deferred maintenance issues prior to the TB outbreak. There simply was no budget for a multimillion dollar retrofit to the existing HVAC System.

Desperate for answers, the Sacramento County Safety Office researched other methods to reduce the spread of TB and other airborne contagion. Their efforts showed that ultraviolet germicidal irradiation (UVGI) was a viable "primary" engineering control that could be easily added to an existing building. UVGI is a sterilization method that uses ultraviolet light at sufficiently shrot wavelength to break down microorganisms found in food, air, and water purification. Ultraviolet light (UV) has been a known mutagen at the cellular level for more than 100 years. In 1903, Niels Finsen won the Nobel Prize fo Medicine for his use of UV against tuberculosis.

Engineers from a Memphis, Tennessee-based company were called in to assist in the proper product sizing, selection and placement. It was decided the intake area would become a beta test site for the installation of upper-air UVGI technologies at the jail. Off-the-shelf UVGI units were provided by the company for the test. site. Though the technology was new to the stakeholders in this situation, UVGI had been proven over many decades to be a viable method to eliminate the transmission of TB and other airborne contagion in at-risk congregate settings.

As with the introduction of any new technology, people needed to be educated in the use and benefit of UVGI. Several planning meetings were held, and included representatives from the sheriff's department; California's Division of Occupational Safety and Health, Correctional Medicine, Sacramento County Department of General Services, Sacramento County's Safety Office, Risk Management and Workers Compensation, and the County's Architectural Services Division.

Upper Air UVGI systems are engineered to allow for ongoing disinfection of airborne contaminate within the room while safely protecting room occupants, in this case both correctional workers and inmates. A narrow and precise beam of cleansing UV germicidal energy is projected parallel to the ceiling plane to control stray UV rays in the lower space of the room (below seven feet).

Air convection, the natural circular movement of air from the lower portion to the upper portion of a room, allows suspended organisms in the upper air to be disinfected and airborne microorganisms to be inactivated. This is a continuous process as air is always convecting to the upper portion of the room. Upper air fixtures must incorporate a safety switch to manually disrupt power if one is opened for service. They must also contain baffles or louvers to properly and safely direct the UV energy into the upper portion of the room.

The generally accepted criteria for proper room / fixture sizing is "one 36 Watt UV fixture (electrical input) for every 200 ft² of room area". UVGI installation of a 36W fixture that typically produces UV output averaging 30 to 50 µWcm² (microwatts per centimeters squared) has been shown to be effective in inactivating most airborne droplet nuclei containing mycobacterium (TB). And because viruses have been shown to be more susceptible to UV than bacteria, upper air UV is presumeably effective against virus as well. OHSA standards state that very low levels of UV (0.4 µWcm²) are harmless and acceptable in the lower room, with no known long-term health effects of UVC exposure at these levels.[1]

Importantly, it was possible to quickly implement upper air UVGI within the facility quickly, and without any expensive modifications to the existing HVAC system.

The beta test area at the main jail underwent before-and-after air sampling tests with the newly installed UV equipment. The study revealed a 69 percent average reduction in airborne bacteria was achieved through the booking intake area immediately after the UVGI fixtures were installed. To supplement the naturally occurring air convection, some tweaking and balancing of airflow was performed to optimize air flow, reductions of up to 92% was achieved in second-round testing. Proper air mixing is critical to the efficacy of the UVGI.

It was concluded that upper air UVGI could be used throughout the main jail as a viable and cost-effective primary engineering control in the battle to control airborne contagions. Other congregate at-risk areas were identified within the jail, and upper-air UVGI was subsequently installed in areas identified as high risk, including:

- Arrest/Intake/Sobriety/ Med Screening
- Booking/Dress Out/ Pre-trial Holding
- Classification Units
- Medical Housing / Mental Health Housing
- General Population

In order to disinfect the air in areas of the Jail not placed on the higher risk level noted previously, in-duct UV systems were installed into the existing HVAC Systems to reduce microbial counts in the airstream of the air-handling units and air ducts.

Numerous variables were taken into account by the company's engineers to properly disinfect air at speed

in the air stream. These variables include duct height and width, duct length where the UV lamps are applied, reflectivity of the air duct, air speed and temperature, and disinfection performance desired. Even a poorly designed HVAC system often allows for at least six air changes per hour in the space being conditioned. Under these conditions, very high disinfection levels are not always required as air is repeatedly disinfected - about once every 10 minutes. When upper air UVGI is positioned in spaces designated at high risk and general airflow is disinfected throughout the building, contaminate levels drop substantially and the risk of contracting airborne disease is greatly reduced.

In-duct airstream UV Systems often can be placed In proximity of the air conditioning cooling coils. Air-conditioning cooling coils in correctional facilities tend to quickly become fouled with mono-layers of microbial contamination, leading to mold growth and energy losses as the coil becomes clogged. Intense and regular chemical cleaning is required to maintain cooling coil efficiency. It was soon noted that after UV installation, cooling coils in proximity to UV lamps maintained cleanliness without intensive labor and use of chemicals, as well as maintained heat exchange efficiency that resulted in substantial energy cost savings.

Stationary surfaces, (cooling coils), receive UVC doses many orders of magnitude higher than microbes suspended in moving air, making UV relatively easy to use. Lower levels of UV maintain heat exchange efficiency and designed airflow and improves indoor air quality by reducing the growth of bacteria and mold on interior systems components. [2]

The main jail was retrofitted with UVGI equipment for a total cost of just under $100,000, about one-half of which was the cost of the UV equipment; the other half, the cost of labor and materials required to install the equipment. The installation was completed with minimal disruption to correctional workers and inmates. Further, all of the installations were performed by in-house skilled labor.

The maintenance costs of installed UVGI systems proved to be low as well, particularly in comparison with the continuous replacement of HEPA filters. As with most jails, the environment can be relatively dusty, and dust films on UV lamps can reduce output of UV. Proper maintenance and lamp cleaning is critical in regard to the efficacy of UVGI. Ongoing maintenance at the Sacramento jail includes cleaning the UV bulbs (lamps) quarterly and replacing the UV lamps annually at the end of the 9000-hour rated life. Because the lamps furnished were not proprietary to the UV equipment, the replacement lamps have been purchased affordably through the bidding process.

With some 75 UV fixtures in place, a single technician is now able to service all the fixtures in the facility within a single 40 hour week. Assuming an hourly labor rate of $85, the annual maintenance cost is $13,600. One hundred and fifty replacement lamps carry an annual cost of approximately $2,250. Although there are added energy costs to operate UVGI equipment, alternate HEPA and fan motor replacements was calculated to have carried an energy cost many magnitudes higher than that of the UV Systems selected.

Sacramento County Main Jail, Sobering Cell #5

Sample Location	Pretreatment CFU/16 cm²	Post TRU-D CFU/16 cm²
Sobering Cell Wall, Rt.	40	2
Sobering Cell Wall, Rt.	54	3
Sobering Cell Wall, Lft.	40	0
Sobering Cell Wall, Lft.	4	0
Telephone	40	4
Back Wall, upper	52	1
Back Wall, lower	75	0
Back Wall, head	44	0
Entry Wall, door handle	19	1
Entry Wall, mirror	27	0

Before irradiation culture samples were gathered from "high-touch" areas. After germicidal irradiation, all surface cultures met disinfections standards for A hospital operating suite. (CFU's = Clony Forming Units.)

The County of Sacramento realized that they had implemented solutions that worked. Over the next few years, projects were budgeted to implement UVGI installlation, including outlying jails, work release centers, juvenile hall, homeless shelters, drug treatment centers, and primary care clinics.

After a decade of successful UV application and the elimination of all reported TB conversions within the jail, a field trial was allowed with a portable automated UV device capable of disinfection of surfaces within the main jail's sobriety cell. The Sacramento Department of Health cultured surfaces without any prior manual cleaning outside of the normal schedule. The portable UVGI device was operated and indicated that after Just 30 minutes, enough UV dose had been applied to disinfect the entire space, including challenging areas of primary shadow. Before-after culturing documented that contamination had been eliminated to a level considered appropriate for a hospital patient room.

There were also additional benefits. Correctional workers understand the environmental conditions in which they work. Workers that witness the ongoing transmission of airborne infectious disease within the facility are likely to have lowered morale and will rightfully demand the right to work in a safe environ-

UV germicidal energy applied to coils disinfects the moving airstream and eliminates biological growth that can 'seed' the air with mold. Germicidal emergy also reduces energy costs by increasing heat transfer and air flow

ment. Visible, proactive technologies that are known to improve indoor air quality also improve worker job satisfaction by instilling confidence in the safety of their workplace. An unexpected benefit of UVGI installation was that workers commented that the odors typical to correctional facilities were reduced significantly. The jail simply "smelled better".

In 1999, there were those that fought with vigor about implementing a "new" technology as a primary control to prevent the ongoing spread of TB in a large, metropolitan jail. The data regarding UV application was scattered and old, dating back to the prevalent use of UV in the 1930s through the 1950s. However, in 2006, The Centers for Disease Control and Prevention and the Department of Health and Human Services published *Guideline for Prevention and Control of Tuberculosis in Correctional and Detention Facilities: Recommendations fromthe CDC.* This Guideline was endorsed by the Advisory Council for the Elimination of Tuberculosis, National Commission on Correctional Health Care, and American Correctional Association.

The Guideline states, "…UVGI should be applied in-duct, (i.e, inside the ductwork of existing HVAC systems) or in the upper room area to be treated, to insure that organisms are inactivated. Upper-air systems should be designed, installed, and monitored to ensure both sufficient irradiation in the upper room to inactivate *M. tuberculosis* and safe levels of UVGI in the occupied space." [3]

Summary

Upper air and in-duct airstream UVGI Systems are a simple, low cost intervention that can be used in high risk correctional settings for the control of TB infection and transmission of other airborne contagions.

Surface disinfection of the correctional environment can be achieved via portable automated UV surface sterilization systems that are cost effective, easy to use, noncorrosive, and have no adverse environmental effects.

The proposition is simple. If correctional facilities can disinfect air and surfaces more thoroughly and more often, the environmental reservoirs of infectious disease pathogens will be reduced, greatly reducing the risk of a correctional facility acquired infection.

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References

1. American Society of Heating, Refrigeration and Air Conditioning Engineers. 2008. *HVAC Systems and Equipment Handbook*, Ultraviolet Lamp Systems, chapter 16, pg. 16.7 and 16.8.
2. American Society of Heating, Refrigeration and Air Conditioning Engineers. 2008. *HVAC Systems and Equipment Handbook*, Ultraviolet Lamp Systems, chapter 16, pg. 16.6 and 16.78.
3. Centers for Disease Control.2006. Guidelines for Prevention and Control of Tuberculosis in Correctional and Detention Facilities. *Morbidity and Mortality Weekly Report* (MMWR), 55, 14

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