Evaluation of Environmental Controls at a Faith-Based Homeless Shelter Associated with a Tuberculosis Outbreak – Texas

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Contents

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The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation.

Highlights of this Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a technical assistance request from the Executive Director of a large faith-based homeless shelter in Dallas, Texas. The request asked NIOSH to assess the heating, ventilation, and air-conditioning systems and make recommendations to improve overall environmental controls, as the shelter had epidemiological links to an ongoing tuberculosis (TB) outbreak.

What NIOSH Did

- Visited the shelter on June 3-5, 2013.
- Met with representatives from the Dallas County Department of Health and Human Services to discuss the ongoing TB outbreak, and to outline our goals and objectives for our site visits.
- Recorded the physical sizes of occupied spaces.
- Measured ventilation air flow into/from occupied spaces.
- Collected information on air-handling units.

What NIOSH Found

- The shelter was working closely with the Dallas County Department of Health and Human Services on TB outbreak response efforts, including implementation of more robust administrative controls.
- Air-handling units ranged from newer, well maintained systems to old, inoperable systems. Ventilation filters were often missing or installed in incorrect configurations.
- Little outdoor air was being supplied to occupied spaces by building mechanical systems in their current configurations.
- There was no clearly defined area to separate guests suspected of having tuberculosis or other airborne infectious disease from the general guest population.
- Most bathrooms and shower rooms at the facility were incorrectly operating under positive pressure compared to adjacent spaces.
- A written respiratory protection plan did not exist.

NIOSH investigators conducted an assessment of environmental controls at a homeless shelter linked to an ongoing tuberculosis outbreak. The investigation revealed problems with the existing environmental controls, along with needed improvements in administrative controls and respiratory protection. Detailed recommendations are provided in this report to improve the shelter environment and reduce the likelihood of disease transmission.

What the Shelter Can Do

- Continue to work in close conjunction with the Dallas County Department of Health and Human Services to improve overall administrative controls to help ensure rapid identification of guests suspected to have tuberculosis.
- Develop a written comprehensive infection control plan with input from the Dallas County Department of Health and Human Services.
- Repair or replace existing air-handling units, as necessary to ensure all occupied spaces of the facility are served by mechanical ventilation.
- Make additional ventilation system changes to ensure all occupied areas of the shelter receive outdoor air in amounts that meet Dallas Mechanical Code and ASHRAE standards.
- For each air-handling unit, install the highest efficiency air filter possible that is compatible with the proper operation of the air-handling unit.
- Create an enclosed, ventilated space at the shelter for use as a respiratory separation area.
- Install a properly designed upper-air ultraviolet germicidal irradiation system in the chapel/gymnasium.
- Repair or replace bathroom and shower room exhaust fans so those spaces are maintained under negative pressure relative to adjacent spaces.
- Develop and implement a written respiratory protection program for shelter staff and volunteers that meets the requirements of the Occupational Safety and Health Administration's respiratory protection standard 29 Code of Federal Regulations 1910.134.
- Develop and implement a written operation and maintenance plan for shelter heating, ventilation, and air-conditioning systems, to include a filter replacement schedule.

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Abbreviations

µm	Micrometer
AHU(s)	Air-handling unit(s)
ACGIH	American Conference of Governmental Industrial Hygienists
ACH	Air changes per hour
AII	Airborne infection isolation
ANSI®	American National Standards Institute
ASHRAE®	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CDC	Centers for Disease Control and Prevention
cfm	Cubic feet per minute
CFR	Code of Federal Regulations
DCHHS	Dallas County Department of Health and Human Services
DRDS	Division of Respiratory Disease Studies
DTBE	Division of Tuberculosis Elimination
FGI	Facility Guidelines Institute
HEPA	High-efficiency particulate air
HVAC	Heating, ventilation, and air-conditioning
ICP	Infection control plan
µW/cm2	Microwatts per square centimeter
mJ/cm2	Millijoules per square centimeter
MERV	Minimum efficiency reporting value
nm	Nanometer
NCHHSTP	National Center for HIV/AIDS, Viral Hepatitis, STD, and TB Prevention
NIOSH	National Institute for Occupational Safety and Health
O&M	Operation and maintenance
OSHA	Occupational Safety and Health Administration
REL	Recommended Exposure Limit
RH	Relative humidity
TB	Tuberculosis
UV	Ultraviolet
UVGI	Ultraviolet germicidal irradiation

Summary

On March 21, 2013, the National Institute for Occupational Safety and Health (NIOSH) received a request for technical assistance from the Chief Epidemiologist of the Dallas County Department of Health and Human Services, on behalf of the Executive Director of a large faith-based homeless shelter in Dallas, Texas, which was one of two shelters linked to an ongoing tuberculosis outbreak among homeless people in the Dallas area. The request asked NIOSH to assess the heating, ventilation, and air-conditioning (HVAC) systems and make recommendations to improve overall environmental controls at the shelter.

During an on-site evaluation of the homeless shelter in June 2013, we collected physical and ventilation measurements in all key areas of the facility. We focused on areas where shelter guests typically congregate or spend significant amounts of time. We recorded the make and model number of air-handling units (AHUs) providing air to the facility, and visually inspected the units, when possible. We also measured the air flow rate through all supply diffusers and return grilles.

Over the last two decades, the shelter has acquired all of the pieces of a former commercial office building. Thus, the shelter inherited HVAC equipment from various manufacturers. We were able to identify ventilation quipment from at least 13 different manufacturers during our assessment (see Table 1). Air-handling units ranged from newer, well maintained systems to old, inoperable systems. Ventilation filters were often missing or installed in incorrect configurations. Certain aspects of the ventilation systems' operation could potentially contribute to airborne disease transmission among shelter guests. Some areas of the shelter were not being served by mechanical ventilation during our visit, because various AHUs were not functional. Additionally, it appeared the AHUs were not providing adequate outdoor air to the occupied spaces, as is required by the *Dallas Mechanical Code* and ASHRAE standards. In addition to alleviating odors and maintaining occupant comfort, outdoor air serves to dilute infectious aerosols, such as *Mycobacterium tuberculosis* droplet nuclei that are responsible for TB transmission.

Since the TB outbreak began, the shelter has taken numerous steps to improve administrative controls, particularly when it comes to identifying guests showing signs and symptoms of TB. We recommend additional improvements to the administrative and environmental controls at the shelter. From a ventilation standpoint, we suggest that all occupied spaces at the shelter be served by mechanical ventilation and all areas supplied with adequate amounts of outdoor air, as prescribed by the *Dallas Mechanical Code* and ASHRAE standards. In addition, we identified areas, at least one of which should be converted for respiratory separation purposes. This space could serve to separate a guest suspected of having TB or other respiratory diseases from the remainder of the guest population, until medical evaluation, transport or treatment could be obtained. We also recommend developing a written infection control plan, an HVAC operation and maintenance plan, and a written respiratory protection program. Having these plans/programs in place will help the shelter under normal operating conditions, and especially during future outbreaks of respiratory disease.

Introduction

Since the middle of 2009, Dallas County (TX) has experienced an increase in the number of epidemiologically-linked cases of tuberculosis (TB). Molecular analyses conducted by the CDC identified two separate clusters of TB in the community, and both clusters are disproportionately affecting the Dallas-area homeless community. Since September 2009, 58 TB cases belonging to the G10508 genotype cluster have been identified. Of those 58 cases, 43 (74%) had a recent history of homelessness in Dallas-area homeless shelters. Since June 2009, 37 TB cases belonging to the G10509 genotype cluster have been identified, with 21 (57%) reporting recent homelessness.

The Texas Department of State Health Services and Dallas County Department of Health and Human Services (DCHHS), with input from CDC, have identified two large homeless shelters as potential sites for ongoing disease transmission. As such, the DCHHS TB Elimination program has conducted several mass-screenings for TB disease at the two shelters and is working closely with the shelters (and others in the area) to identify and evaluate individuals potentially exposed to TB.

In additional response to the ongoing outbreak, a team of epidemiologists from the CDC National Center for HIV/AIDS, Viral Hepatitis, STD, and TB Prevention (NCHHSTP), Division of Tuberculosis Elimination (DTBE) conducted an on-site investigation in January 2013. In their report dated April 10, 2013, the CDC team included a recommendation to improve environmental controls at the homeless facilities implicated in disease transmission. On March 21, 2013, the Division of Respiratory Disease Studies (DRDS), National Institute for Occupational Safety and Health (NIOSH), CDC received a request for technical assistance concerning the TB outbreak in Dallas County. The request was made by the Chief Epidemiologist of the DCHHS. The request specifically asked NIOSH to evaluate the faith-based shelter's heating, ventilation, and air-conditioning (HVAC) systems and make recommendations to improve overall environmental controls. DCHHS persuaded the second shelter to submit a request for technical assistance to DRDS/NIOSH/CDC on May 22, 2013. Thus, a total of two requests were received to assess facilities that provide assistance to the homeless and which had epidemiologic links to past or ongoing TB transmission.

In response to the two requests for technical assistance, a NIOSH team visited the two facilities in June 2013. This report describes the measurements and associated findings from our assessment at the first homeless shelter. It details and prioritizes our recommendations for improving environmental controls at the shelter and outlines the current plan for future NIOSH involvement.

Background

Tuberculosis and Homeless Populations

TB is a disease caused by *Mycobacterium tuberculosis* (*M. tuberculosis*) bacteria. When a person with active TB disease coughs or sneezes, tiny droplets containing *M. tuberculosis*

may be expelled into the air. Many of these droplets dry, and the resulting residues remain suspended in the air for long periods of time as droplet nuclei. If another person inhales air that contains the infectious droplet nuclei, transmission from one person to another may occur. Homeless people have been identified as a high-risk population for TB infection and disease since the early 1900s [Knopf 1914]. With the increase in homelessness in the United States since the 1980s, TB among homeless persons has become a subject of heightened interest and concern [CDC 1985; 1992; 2003a,b; 2005a; Barry et al. 1986; Slutkin 1986; McAdam et al. 1990; Nolan 1991].

The Homeless Shelter

The shelter is a faith-based provider of food, beds and clothing to the homeless men, women and children in Dallas County, TX. The men's shelter and administrative offices opened at its current location in the outskirts of Dallas, TX, in 1993. It is for men only and is the oldest homeless service provider in Dallas. It has a daily census of approximately 335 people, and has been at capacity every night since 2008. Women and children are referred to the other branches of the shelter. Homeless services are provided to over 4,000 men, women and children per year.

Our site visit included only the men's shelter, which moved into what was an existing two-story commercial office building. A one-million dollar donation made the move possible from the shelter's former location in downtown Dallas. Since the building consisted of several smaller offices and shops, renovations were necessary to transform the space into areas useful for a homeless shelter. The renovations began almost immediately, and continue to this day. The shelter recently purchased more "storefront space" and created a dorm with 68 additional beds in March 2013. There is a current renovation project for an additional 130 beds in development. After that addition is complete, the entire facility will have 465 beds. The renovations have primarily been to the inside physical layout of the building with walls being torn down or erected to create useful space for the shelter's many programs. The piecemeal nature of the ventilation systems remains virtually untouched by the renovations, with many small areas (e.g., a former office or shop) still being served by its own air handling unit(s). However, the shelter has installed some new ventilation systems to occupied spaces that replace multiple older units that still exist on the roof and are intentionally no longer used.

Daily intake of overnight clients staying at the men's shelter is processed through another of Dallas' homeless services providers, and takes place between 4:30-6:30 p.m. daily, seven days a week (new clients need to be in line by 4:00 p.m.). As part of the intake process, a client is assigned a particular bed at the men's shelter we visited or another area shelter. Clients receiving a bed at the men's shelter are bussed to the shelter during the late afternoon to early evening and bussed back to the intake processing facility the following morning. Any client receiving a bed at the men's shelter is guaranteed that same bed as long as he continues to show up each night. Once onsite, overnight clients relinquish clothing, shower, and are issued temporary clothes for the night. The facility has secure lockers, where clients are allowed to store any personal possessions. Clients sleep in bunk beds in three large dormitory-style rooms with varying ceiling heights up to 9-foot ceilings. During periods of bad weather or

increased need, the shelter provides additional clients with sleeping bags and houses them in a large, open room used as a gymnasium and chapel area.

Aside from overnight clients, other guests live at the shelter and are enrolled in long-term programs. A long-term faith-based program is designed to increase the clients' spirituality and teach the skills necessary to reintegrate into society and live an independent life. The program is self-paced, and usually takes between eighteen months and two years to complete. Clients in the initial stages of the program have their own dormitory area on the second floor of the facility. Clients that are fully-committed to the program have their own separate dormitory area, also on the second floor of the facility. The shelter also supports homeless veterans through the Veterans Administration (VA) per diem program. These veterans stay in two separate, second-floor dormitory areas. Through this program, administered by the Dallas VA, veterans who are "formerly homeless or in danger of becoming homeless" are sent to the shelter to live in a transitional living environment for up to two years. The shelter is approved to have up to 40 veterans in the program at any one time. Since the program's inception, there have been between 34-40 veterans living at the shelter at all times.

The first-floor of the shelter is equipped with a fully-functional commercial kitchen and dining area. Dinner is served to all overnight guests, along with breakfast the following morning. Clients enrolled in the faith-based program and veterans get additional meals. The facility's lock-out hours are from 7:30 p.m. to 8:30 a.m. the following morning. Clients enrolled in the faith-based program and veterans are permitted to be inside the shelter at any time, but the shelter is mostly empty during the day.

Since March 2010, the shelter has had an onsite health clinic operated by the Department of Family and Community Medicine at the University of Texas Southwestern Medical Center. The clinic is free and open to clients on Tuesdays and Thursdays of every week. Physician's Assistants and interns staff the clinic, but no medication is dispensed from the facility. When the clinic is open, clients suspected of having respiratory disease are referred to Parkland Hospital for medical testing. Engineered infection control measures are minimal for airborne infection control.

Assessment

On June 3, 2013, an opening meeting was held at the DCHHS. An update was given on the current status of the ongoing TB outbreak among the homeless population, and the assessment team provided background information on NIOSH, the nature of the technical assistance requests, and the ventilation measurements we planned to collect at each facility. Aside from NIOSH and DCHHS staff, representatives from each homeless facility we planned to visit during the week were present, as well as a representative from Parkland Hospital in Dallas, TX.

We arrived at the shelter on Monday, June 3, 2013, soon after the opening meeting was completed. We were met by the facilities manager and members of the facilities staff,

who briefly showed us around the facility and gave us an overview of typical client flow and the services provided. At the conclusion of the tour, we began taking physical and ventilation measurements in all key areas of the facility, focusing on areas where clients typically congregate or spend significant amounts of time. The dining areas, main reception areas, dormitories, and day rooms were the areas of primary concern. However, we took measurements throughout the building.

We visually inspected all of the rooftop air-handling units (AHUs) and recorded the make and model number, when possible. We were unable to inspect AHUs mounted above the drop ceilings during our visit. When possible, we measured the air flow rate through supply diffusers and return grilles using either a TSI Incorporated (Shoreview, Minnesota) Model EBT731 Alnor Balometer Capture Hood or a Model 8373 Accubalance Plus Air Capture Hood equipped with appropriately-sized capture hoods for the vents/grilles being measured. The Model EBT731 measures volumetric air flow rates of 25-2500 cubic feet per minute (cfm) with an accuracy of ±3% of the reading plus ±7 cfm for measurements above 50 cfm, while the Model 8373 measures volumetric air flow rates of 30-2000 cfm with an accuracy of ±5% of the reading and ±5 cfm. Both air capture hood models are equipped with a directional air flow indicator that provides confirmation of flow direction. We determined the approximate internal volume of the measured spaces with either a standard tape measure or a Zircon Corporation (Campbell, California) Model 58026 LaserVision DM200 laser distance measuring device. The device accurately measures up to 200 feet and has function keys for calculating the area and volume of a room for HVAC load formulas. When the existence of air flow or the air flow direction was questioned, we used a Wizard Stick hand-held fog generator (Zero Toys, Concord, Massachusetts) to qualitatively confirm and visualize the air flow pattern.

We completed taking measurements at the shelter around midday on Wednesday, June 5, 2013. Before leaving the facility, we met briefly with the Executive Director to discuss our general findings from the assessment. An in-person, formal closing meeting for our on-site response to the technical assistance requests for both homeless facilities was not practical at the time of our visit. Thus, a meeting was held via teleconference on Wednesday, June 12, 2013. This meeting provided an opportunity to discuss our general findings with representatives from the DCHHS staff.

Results and Discussion

General Tuberculosis Infection Control

All tuberculosis control programs should include three key components: administrative controls (e.g., intake questionnaires and policies), environmental controls (e.g., ventilation and filtration), and a respiratory protection program. Ideally, environmental controls and respiratory protection should supplement aggressive administrative controls. Detailed explanations for each of these key control elements, as well as a discussion on the hierarchy

of their implementation, are outlined in CDC's *Guidelines for Preventing the Transmission of* Mycobacterium tuberculosis *in Health-Care Settings, 2005* and *Prevention and Control of Tuberculosis in Correctional and Detention Facilities: Recommendations from CDC* [CDC 2005b, 2006]. In high risk environments, such as homeless shelters, or in areas where administrative controls alone are inadequate, environmental controls and respiratory protection should be used as secondary and tertiary levels of control, respectively.

Administrative Controls

During our visit, and in previous conversations with representatives from DTBE, the Texas Department of State Health Services, DCHHS, and shelter administrators, we learned that skin tests and chest x-rays for TB were conducted at the shelter quarterly in conjunction with DCHHS prior to the outbreak (the testing is done every 60 days since the outbreak). Otherwise, it was apparent that limited TB administrative controls were in place at the shelter prior to the current disease outbreak. Efforts were taken to improve the overall administrative controls in place by the time of the NIOSH site visit. Employees and volunteers were trained on symptoms of TB disease and prevention of TB transmission. Additionally, intake screening procedures were adopted to help identify guests on target screening lists, or others suspected of having TB, and refer them to DCHHS for critical medical screening. These procedures should help identify infected individuals more rapidly in the future and serve to help keep infected guests away from those that are not infected.

We cannot overstate the importance of having active and robust administrative controls in place. As with most homeless facilities, the men's shelter provides services to a large number of clients who are often in very close proximity to one another. This is particularly the case in the various dormitory-style sleeping areas, the dining areas during meals, and the chapel/recreation area during periods of high occupancy. Even the best ventilation systems are incapable of preventing the spread of infectious disease between clients close to one another. Thus, promptly identifying people with suspected disease, keeping them separated from the general client population, and following up with appropriate medical evaluations and treatment (if necessary) are the most important elements of reducing or eliminating the spread of infectious disease.

While enhancing administrative controls is a significant first step, the development of a written comprehensive TB Infection Control Plan (ICP) for the shelter should be considered. The administrative controls program would be just one part of the overall ICP. At the time of the NIOSH investigation, no such ICP was reported to exist. Information on creating detailed ICPs and TB ICP templates for homeless shelters can be found at the Curry International Tuberculosis Center website at http://www.currytbcenter.ucsf.edu/. Collaborating with DCHHS and the Texas Department of State Health Services would serve to further strengthen the written plan. These ICPs are particularly useful when overall TB infection control requires the coordination and subsequent follow-up of different agencies. In response to this current TB outbreak, there was good communication and coordination between shelter administrators and DCHHS. However, the process should be formally documented in a protocol or checklist format. This ensures that each time there is a TB-

related incident, all necessary agencies understand their responsibilities and should perform their assigned predetermined actions in a consistent manner. A written TB ICP should be created, understood, and adhered to by all necessary agencies. Incorporating the input of staff involved in the maintenance and operation of facility ventilation systems into the overall infection control program can also help strengthen the program. Participation in plan development provides these staff members with additional insight as to what ventilation requirements are necessary to prevent and/or isolate TB disease and helps to ensure that ventilation modifications outlined in the plan are feasible. Input from the ventilation staff should be sought during the formal creation of the ICP and during all subsequent revisions to the plan.

Environmental Controls

General Ventilation System Information

General information on the shelter's AHUs is provided in Table 1. Unfortunately, a combination of scheduling conflicts and the lack of availability of the knowledgeable facilities manager resulted in our inability to gather all pertinent information for many of the AHUs. While the employee that escorted us during our inspection of the rooftop units did his best to assist us, we were unable to obtain specific information for all of the above-ceiling HVAC fan units associated with each of the 12 condensing-only units mounted on the roof. Since some of the older ventilation systems had been intentionally deactivated and their function replaced by newer equipment, it was unclear which existing systems should be functional and which were no longer necessary. Additionally, many of the rooftop units had labels that were faded or missing, so the make and model of the units could not be identified. Since our site visit, follow-up attempts to obtain the missing information have been unsuccessful.

As mentioned previously, the shelter has acquired various pieces of a former commercial office building since 1993. Thus, the shelter inherited HVAC equipment from various manufacturers as it expanded into all of the areas of the building. We were able to identify ventilation equipment from at least 13 different manufacturers during our assessment (see Table 1). The age of the equipment ranged from around 5 years to systems that were at least two decades old. Cooling to the shelter is provided by direct-expansion air conditioning with equipment using one or more refrigerants. Heating is predominantly, if not entirely, provided by natural gas.

We were unable to identify any outdoor air intakes on the perimeter of the building that could be attached to the above-ceiling HVAC fan units we were unable to inspect. So, it is unlikely those units were providing any outdoor air to the occupied spaces. Most of the AHUs on the rooftop were also configured so that no outdoor air was being supplied to the occupied spaces they served, either because the outdoor air dampers were sealed closed or no outdoor air dampers existed. However, some of the systems on the roof were providing some outdoor air to the facility when they were operational. AHUs 1-B, 7, 29, 31, and 32 did have outdoor air dampers that were at least partially open so that fresh air was being provided to the spaces they serve (see Table 1).

Filtration

The ventilation filters used at the shelter consisted of a combination of disposable filters from various manufacturers (see Table 1). While most of the filters were either Glasfloss Z-Line (ZL) filters (Glasfloss Industries, Dallas, TX) or Flanders Pre-Pleat 40 filters (Flanders Corporation, Washington, NC), there were AAF StrataDensity filters (American Air Filter International, Louisville, KY) and other unidentifiable filters being used as well. In some cases, the filters installed inside the AHUs were appropriately sized and fit tightly within the filter rack. However, there were multiple instances of the filters being either improperly sized, loose in the filter rack, or both. For instance, Figure 1 shows a large gap between filters installed inside AHU 12 serving offices on the second floor. Figure 2 shows the filters installed inside AHU 19 serving the Full Program dormitory on the second floor. Here, it is clear that improperly sized filters were forced into the AHU. In both cases, there was likely significant filter bypass (air passing between the filters instead of through the filters), which should be eliminated to the extent possible. All AHUs should be equipped with a configuration of filters that matches that prescribed by the AHU manufacturer. If a proper filter configuration still exhibits gaps between the filters, gasketed blanks can be inserted into the ends of the filter racks to better seal the filters to one another and the sides of the AHU, which will eliminate bypass.

In addition to the ventilation filters in the AHUs, several return grilles on the second floor of the building had ventilation filters installed behind them. As an example, Figure 3 shows a Glasfloss Z-line filter installed behind a return grille in the Initial Program dormitory area. Many other return grilles on the second floor, particularly in the library and lounge area, had True Blue Filters (True Blue Company, Laporte, IN) behind them as well. While these filters likely provided some filtration, it was unclear whether these filters were used as replacements for filters in AHUs or in conjunction with AHU filters. If the filters behind return air grilles were meant as replacements for AHU filters, the deviation from intended design provides ample opportunity for filter bypass and air to be pulled into the AHU in the space between the return grilles and the AHU itself.

The Glasfloss Z Line and Flanders Pre-Pleat 40 disposable panel filters both have a published Minimum Efficiency Reporting Value (MERV) of 8. For ventilation air filters, the MERV value provides information on the overall filtration efficiency. A MERV 8 filter corresponds to a single-pass removal efficiency of greater than 70% for 3.0 to 10 micrometer (μm) particles [ANSI/ASHRAE 2012]. However, MERV 8 filters are not rated against particles in the 1.0–3.0 μm size range, which includes droplet nuclei responsible for *M. tuberculosis* transmission [ANSI/ASHRAE 2012]. The AAF StrataDensity filters have a reported MERV of 4, which provides a filtration efficiency of less than 20% against 3.0 to 10.0 μm particles and are unrated for particles in the 1.0–3.0 μm size range [ANSI/ASHRAE 2012]. The True Blue filters have a reported MERV of 7, so their filtration efficiency would fall somewhere between that reported for MERV 4 and MERV 8 filters. The filtration efficiencies for the unidentified filters are unknown.

When part of an *M. tuberculosis* infection-prevention strategy, air filters should provide a removal efficiency of greater than 90% of particles in the 1.0–3.0 μm size range, which corresponds to a MERV 13 or higher. During future HVAC design modifications, system evaluations, or retrofits, the selection of filters for use in the AHUs should be closely examined for the potential to increase filtration efficiency. Selecting filters from only one manufacturer that provides all the necessary sizes might also help alleviate confusion during filter changes and save money on bulk filter purchases. However, care should be taken when choosing more efficient filters, because increased efficiency is typically associated with increased pressure drop across the filter (resistance to air flow). Filters in the AHUs should have the highest possible efficiency (i.e., highest MERV rating) while still maintaining the air flow required for conditioning and outdoor air supply through each system.

Preventive Maintenance

The ventilation system preventive maintenance program at the shelter was coordinated by the facilities manager. The AHUs that we could visually assess ranged from newer, well-maintained units to older units in various states of disrepair. There were also at least three rooftop units serving a portion of the second floor Client A Sleeping Area (AHU 6), the second floor library (AHU 15), and a portion of the first floor learning center (specific AHU unclear), that were reported to be nonfunctional. It was not clear whether this was due to equipment failure or intentional deactivation. Filter changes and other typical AHU maintenance tasks are addressed by facility staff employed by the shelter. Outside ventilation contractors are also brought in when necessary. Overall, the HVAC preventive maintenance program was generally effective (i.e., most systems were operational), but there was no written plan outlining the preventive maintenance schedules and procedures for the shelter HVAC systems. A written HVAC Operation and Maintenance (O&M) Plan should be developed. Combining all maintenance tasks, schedules, procedures, and training requirements into a written plan would help ensure that all equipment is properly maintained at appropriate time intervals and that any emergency maintenance issues are addressed correctly. Consultation with the filter media manufacturer or their vendor representative(s) should provide the recommended filter replacement frequency for inclusion into the O&M plan. A detailed plan would also help ensure that the quality of work remains consistent as staff changes over time. Once developed, this written plan should be revised periodically to be current with any ventilation system and equipment modifications at the facility.

Ventilation Measurements and Indoor Air Quality

An adequate supply of outdoor air, typically delivered through the HVAC systems, is necessary within indoor environments to dilute pollutants that are released by equipment, building materials, furnishings, products, and people. Chapter 55, *Dallas Mechanical Code*, of the Dallas City Code regulates the "design, construction, quality of materials, erection, installation, alteration, repair, location, relocation, replacement, addition to, use, and maintenance of mechanical work in the city." The most recent version of the *Dallas Mechanical Code* took effect on November 1, 2013 (after the NIOSH visit). That version of the *Dallas Mechanical Code* adopted the 2012 edition of the *International Mechanical*

Code, with some minor Dallas-specific changes and amendments [City of Dallas 2013; ICC 2012]. When it comes to ventilation standards, in most cases, the *Dallas Mechanical Code* has adopted the same recommendations published in *American National Standards Institute (ANSI)/ASHRAE Standard 62.1-2010: Ventilation for Acceptable Indoor Air Quality* (which was in effect at the time of the NIOSH survey) and carried over into the more recent *ANSI/ASHRAE Standard 62.1-2013.* These ASHRAE recommendations provide specific details on ventilation requirements for acceptable indoor air quality in a variety of indoor, occupied spaces [ANSI/ASHRAE 2013a].

The *Dallas Mechanical Code* and *ASHRAE 62.1-2013* recommend outdoor air supply rates that account for both people-related and building-related contaminant sources. Specific exhaust air flow rate requirements for some spaces are also listed. Although there are no specific guidelines for homeless shelters and related facilities, there are published guidelines applicable to the shelter. These outdoor air supply and exhaust air requirements are summarized in Table 2. Table 2 also lists the default occupant densities for various spaces. These default values, given in terms of the number of occupants per 1000 square feet, are provided by the *Dallas Mechanical Code* and ASHRAE to assist building and HVAC system designers when actual occupant densities are unknown. Although actual occupant densities for the occupied spaces of the shelter are generally known, the default values still serve as a reference to determine whether the occupant density in a given space is higher or lower than what is considered typical.

The collected physical and ventilation measurements are presented in Table 3. The third column from the right of the table presents the actual occupant densities in each space. Values preceded by an asterisk (*) denote areas with occupant densities higher than the default values presented in Table 2. High occupant densities are not solely indicative of ventilation problems and each case must be examined individually. For example, the overnight client dormitory areas and the Initial Program dormitory area show high occupant densities because many people actually sleep in close proximity to one another in these spaces. On the other hand, several of the offices throughout the facility also show high occupant densities. Much of this is because the offices are smaller than what is considered typical. For private offices, a high occupant density would be less of a concern, however, many of these areas also represent spaces where shelter staff members could be face-to-face with a potentially infectious client. In these cases, special consideration should be given to air flow patterns in the spaces to minimize the potential of exhalations from one person passing through the breathing zone of multiple other people. This is especially true when airborne infectious disease transmission is a concern.

The second-to-last column in Table 3 presents the outdoor air requirements for each space, as established by the *Dallas Mechanical Code* and ASHRAE. As previously noted, only some of the AHUs at the shelter were even capable of introducing outdoor air into the occupied spaces they served, and many of those had the outdoor air dampers closed. We did not have instruments that allowed us to accurately quantify the amount of outdoor air introduced by each AHU but given the damper positions, the amount of outdoor air supplied by each AHU was anticipated to be below that prescribed by the *Dallas Mechanical Code* and ASHRAE.

It is important to ensure that all occupied spaces at the shelter are receiving adequate amounts of outdoor air to inhibit airborne disease transmission and improve indoor air quality. In addition to alleviating odors and better maintaining occupant comfort, outdoor air serves to dilute infectious aerosols, such as *M. tuberculosis* droplet nuclei. To supply appropriate levels of outdoor air, it is essential that all occupied spaces of the shelter are mechanically ventilated. This would require repairing existing equipment that is in disrepair or totally nonfunctional. Otherwise, new AHUs should be purchased to replace the damaged and inoperable AHUs. It is unlikely that the capacity to introduce and temper (i.e., heat or cool and dehumidify) appropriate amounts of outdoor air exists with every AHU in their current state, particularly given the heat and humidity typical of Dallas summers. Regardless, each AHU should be assessed to determine if adequate capacity does exist to temper the recommended amounts of outdoor air under all periods of occupancy and all weather conditions. If so, after repairing and replacing AHUs as necessary, opening existing outdoor air intakes and installing new intakes where none exist may be all that is necessary to meet required outdoor air levels.

If the capacity to temper sufficient outdoor air does not exist as the AHUs are currently configured, then one of two common approaches could be employed to introduce outdoor air into the occupied spaces (or a combination of the two). The first approach would be to make additional modifications to the existing AHUs to allow them to bring in the required outdoor air. This would initially require evaluation, by a knowledgeable HVAC engineer (a reputable ventilation or engineering design contractor that is familiar with ASHRAE, Facility Guidelines Institute [FGI], and CDC guidelines and recommendations), of each AHU's current conditioning capacity and the amount of additional capacity needed under worst-case conditions of occupancy and weather. Once that information is known, various modifications to each AHU can be compared to determine the most cost-effective method for meeting outdoor air requirements. Potential modifications could range from new outdoor air intakes, new cooling and heating coils, new fans, or some combination of these options. Although incorporating outdoor air into the existing AHUs may be the simpler of the two solutions and could require the least capital expense, it may cost significantly more in energy expenses over time. At least on hot days, as was the case during our assessment, the AHUs are mainly recirculating air that is relatively close to the desired indoor temperature and humidity conditions (since only minimal outdoor air was brought in). After circulating through the occupied space, this air requires less conditioning to return it to the desired delivery temperature and humidity levels. Once significantly more outdoor air is mixed with the room return air, the mixed air stream passing through each AHU will be further from the desired indoor conditions for most of the year. Each AHU will then need to work harder to temper the mixed air stream.

A second method of bringing outdoor air into the shelter would be to install a dedicated outdoor air system. This would involve installing at least one new AHU, with ductwork extending to all occupied spaces and dedicated specifically for supplying outdoor air. This new AHU should be sized to provide adequate outdoor air flow for the entire building (approximately 5000 cfm) while also providing the entire capacity to temper and dehumidify this outdoor air. The new AHU should provide tempered and dehumidified (supercooled to 45–50°F dew point) outdoor air to each space (or existing AHU) in quantities necessary

to meet *Dallas Mechanical Code* and ASHRAE outdoor air requirements under worst-case conditions. Terminal reheating or blending of this air with air delivered by the primary AHUs may be necessary to prevent thermal discomfort from the supercooled outdoor air. Conversely, multiple smaller dedicated outdoor air systems could serve the same purpose as one large system. For example, two smaller dedicated outdoor air systems could be used to provide outdoor air to individual floors of the building. Regardless of how it is accomplished, the primary advantage of the dedicated outdoor air system is that it would not require major modifications to the existing AHUs (aside from repairing systems in need of repair and replacing inactive ones), which would continue to recirculate air through the spaces they serve while providing air filtration, heating and cooling. In fact, if the dedicated outdoor air system is designed properly, all of the heating and cooling loads for the required outdoor air could be transferred to the new AHU(s). This would allow the outdoor air intakes in the existing AHUs to be closed permanently. Depending on the available capacity in the existing AHUs, the dedicated outdoor air system approach may require more capital expense and more renovations for the required ductwork than the first option, but it could also provide significant energy cost savings, making it a more viable long-term solution.

A knowledgeable HVAC engineer should be consulted to discuss these and other potential options for introducing outdoor air into all occupied spaces at the shelter. At the same time, consideration should be given to optimizing air flow patterns to further protect shelter guests and staff from the potential of airborne disease transmission. The air flow pattern is important in any occupied space, but it is particularly important in areas where clients congregate, and especially in the overnight client sleeping areas. The overnight guests are not integrated into shelter programs so their backgrounds and medical status may be unknown. While even the best ventilation system cannot guarantee preventing disease transmission between people in close proximity to one another, improving air flow patterns could help reduce the overall transmission potential among guests in each sleeping area. A qualified HVAC/ventilation engineer should be consulted for the design of air flow schemes that will provide adequate ventilation to room occupants while minimizing the potential for disease transmission. The final chosen design scheme should be smoke tested to verify performance.

We noticed another issue affecting air flow patterns in other occupied spaces as well. Short-circuiting of air is a concern in some areas. An extreme example is shown in Figure 4, where a supply vent and return grille are directly next to one another in the second floor lounge area. The close proximity of the supply to the return can easily result in short-circuiting of air, where supply air is immediately pulled into a return grille without providing any useful ventilation to room occupants. Many other areas of the shelter had similar configurations, although not as extreme. Regardless, to alleviate this concern, the distance between the supply vent and return grille should be maximized to the extent possible and supply air discharge directed in such a manner to inhibit short-circuiting.

We observed that exhaust air from most of the bathrooms and shower rooms throughout the campus was less than recommended by the *Dallas Mechanical Code* and ASHRAE. The last column in Table 3 provides the recommended exhaust flow rates from occupied spaces, when such recommendations exist. Values in this column preceded by an asterisk (*) denote areas

where the measured exhaust flow rates were less than the recommended rate as presented in Table 2. To control humidity and odors, bathrooms and shower areas should exhaust more air than the AHU is supplying. This will maintain these areas under negative pressure. Separate exhaust fans should be used to exhaust air directly outside at least 25 feet from any air intakes. There should be no recycling or re-entrainment of return/exhaust air from the bathrooms and shower rooms. For high occupancy public bathrooms, the *Dallas Building Code* and *ASHRAE Standard 62.1-2013* both include the same exhaust recommendations, but they differ in how the recommendations are applied. The *Dallas Building Code* states that if the exhaust fans are operated continuously, 50 cfm per water closet should be exhausted. If the exhaust fans are operated intermittently (e.g., fans activated by a light switch), 70 cfm per water closet should be exhausted. The *ASHRAE Standard 62.1-2013* recommendation for public bathrooms is based on expected usage. It states that 70 cfm per water closet should be exhausted when periods of heavy use are expected to occur. If periods of heavy use are not anticipated, then exhausting 50 cfm per water closet is sufficient. For private toilets in bathrooms intended to be occupied by only one person at a time, both codes specify that the exhaust ventilation should be 25 cfm if the exhaust fan is designed to operate continuously or 50 cfm if the exhaust fan only operates during periods of occupancy (e.g., exhaust fan controlled by a wall switch). The exhaust fans in all bathroom and shower areas of the facility should be checked to ensure functionality and their exhaust rates should be verified for compliance with the *Dallas Mechanical Code*. [Note: The kitchen hood exhaust systems in the Dining Building were not evaluated at the time of the NIOSH site visit. These systems are not discussed in this report.]

While not a major concern from an airborne disease transmission standpoint, temperature and relative humidity (RH) affect the perception of comfort in an indoor environment. The perception of thermal comfort is related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperature. Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. *ANSI/ASHRAE Standard 55-2013: Thermal Environmental Conditions for Human Occupancy* specifies the combinations of indoor thermal environmental and personal factors that produce acceptable thermal environmental conditions to a majority of occupants within a space [ANSI/ASHRAE 2013b]. Assuming slow air movement (less than 40 feet per minute) and 50% RH, the operative temperatures recommended by ASHRAE range from 68.5°F–75°F in the winter, and from 75°F–80.5°F in the summer. The difference between the two temperature ranges is largely due to seasonal clothing selection. ASHRAE also recommends that RH be maintained at or below 65% [ANSI/ASHRAE 2013b]. The U.S. Environmental Protection Agency recommends maintaining indoor relative humidity between 30–50% because excessive humidity can promote the growth of microorganisms [EPA 2012]. Temperature and RH levels were not recorded during our visit. Nevertheless, we recommend maintaining the indoor temperature and RH levels within the ranges established by ASHRAE to provide the most comfortable environment to clients and employees at the shelter.

Respiratory Separation Areas

Currently, the shelter does not have areas set aside for separating clients suspected of having TB or other respiratory diseases from the remainder of the guest population. Rapidly identifying people with suspected TB disease and keeping them separated from others until appropriate medical evaluations and treatments are initiated is one of the most important elements in reducing or eliminating the spread of airborne disease. Excluding those clients enrolled in shelter programs, the background and medical status may be largely unknown for guests seeking shelter in the Overnight Client Dormitory areas. Given this fact, we strongly recommend creating an area inside the facility which can be used for respiratory separation when needed. It is important to recognize that respiratory separation is not an alternative to medical evaluation. Rather, it is proposed to be a temporary holding area for guests awaiting transport for medical evaluation. It may also be used to house guests exhibiting signs of respiratory distress without having identified disease. When respiratory separation is not required, the areas can be used for traditional client housing, as is typically the case.

A respiratory separation area is not intended to be equivalent to an airborne infection isolation (AII) patient room found in hospitals and other healthcare settings. However, it can be designed using some of the same protective concepts, namely negative room pressure and elevated ventilation rates. The respiratory separation area should be maintained under negative pressure relative to the adjacent spaces. This means that air from outside the respiratory separation area should migrate inwards into the respiratory separation area and not in the opposite direction. This is easily maintained by exhausting more air from the respiratory separation area than is being supplied. Operable windows, either within the respiratory separation area or in adjacent areas, should not be allowed to interfere with this intent. Negative pressure helps reduce the potential that a guest housed in the respiratory separation area with active TB disease (or any other disease where airborne infection is a concern) could expose other healthy individuals in adjacent areas. In addition to maintaining negative pressure, all return air from the respiratory separation area should preferably be exhausted directly outside. In no circumstances should air from the respiratory separation area be allowed to re-infiltrate the building or go back through an AHU without first having passed through a high-efficiency particulate air (HEPA) filter.

For true AII rooms in healthcare facilities, the CDC and FGI recommend a differential pressure of $\geq$0.01 inches of water gauge (2.5 Pascals [Pa]) across the closed door between the isolation area and adjacent areas [CDC 2005b; FGI 2010]. Although the minimum pressure difference needed for maintaining airflow into a room is quite small (about 0.001 inches of water gauge), the higher prescribed pressure differential is easier to measure and maintain as the pressure in surrounding areas changes due to the opening and closing of doors, ventilation system fluctuations, and other factors. The FGI and CDC also recommend a total of 12 air changes per hour (ACH) through the isolation room (CDC allows 6 ACH for existing AII rooms) and at least 2 ACH of fresh outdoor air. True AII rooms are designed to house individuals with confirmed respiratory disease. A respiratory separation area at the shelter would not be used to house guests with confirmed disease, so it would not be necessary to meet the strict air flow and differential pressure requirements detailed above.

However, knowledge of the AII design strategies could be useful in designing a respiratory separation area. It is vastly more important to establish a negative pressure area that can be used for respiratory separation than it is to focus on the respiratory separation area meeting quantitative ventilation requirements.

Since the overnight dormitories house all overnight guests in the large, open sleeping areas, ideally a small room, complete with its own solid ceiling, should be constructed in one corner of one of the dormitory rooms specifically for respiratory separation. Having a sealed, separate room would allow the space to be used for separation purposes by: 1) installing a new dedicated exhaust fan through the outside wall of the room to provide the required exhaust air flow when the room was in use for respiratory separation, and 2) installing tight-closing dampers (or some other mechanism) to completely seal all air returns from the new room to the AHU serving that space (if necessary). An exhaust fan should be chosen that is capable of maintaining the room under negative pressure relative to the adjacent, larger sleeping area at all times, with minimal noise. The fan could be mounted directly through the wall of the building or on the roof with ductwork running through the wall and up to the fan on the outside of the shelter. It is imperative that exhaust air from the new exhaust fans is directed away from all current/future AHU air intakes and gathering areas outside the shelter.

When a client checks into the shelter for overnight shelter while presenting symptoms of respiratory disease, they could be allowed to sleep inside the new respiratory separation area until they can be evaluated by medical personnel. To prepare the room for respiratory separation, the room's dedicated exhaust fan should be activated to maintain the space under negative pressure. When respiratory separation is not required, the room can be used for another purpose (e.g., storing sleeping mats) by simply deactivating the exhaust fan.

If construction of a separate room inside one of the overnight dormitory rooms is impractical, an alternative (but less-desirable) approach is to install impervious retractable partitions (e.g. accordion-type room dividers) that could be used to enclose a corner of the sleeping area when respiratory separation is warranted. Another area in the shelter that could be considered for this purpose is the weight room and/or small area off the chapel/gymnasium. These spaces already had retractable partitions that could be used to separate them from the larger space. Additionally, this area is well away from the overnight guest population during normal operations. Regardless, the partitions should touch the floor and extend as close to the ceiling as possible. An exhaust fan would need to be installed through one of the solid outside walls enclosed by the partitions. Again, the fan could be mounted directly in the wall or on the roof with ductwork running through the wall and up to the fan on the outside of the building. Since there would be more leakage into the separation area around the partition walls, a larger fan would likely be required to maintain negative pressure over that required for a solid room.

If a retractable partition enclosure is selected for respiratory separation, the partitions should fit as snug to the floor and ceiling as possible. The new exhaust fan should be activated to maintain the enclosed space under negative pressure any time the space is used for separation purposes. For the majority of the time, when respiratory separation is not required, the

corner of the room can be used as normal by shutting down the exhaust fan and pushing the retractable partitions out of the way.

For any respiratory separation area, a written plan for testing and operating the space is strongly recommended. A detailed written plan should be developed for the rapid conversion of the space from standard usage to use for respiratory separation. The plan should include steps for cleaning and refurnishing the area for separation purposes, and step-by-step procedures for shelter staff to follow to effectively initiate respiratory separation.

When occupied for separation purposes, all respiratory separation areas should be visually tested daily to ensure negative pressure is being maintained. Testing can be done cheaply and easily with tissue flutter strips or smoke tubes. The results of the testing should be documented each day when in use. When the spaces are being used for other purposes, they should be tested a minimum of once per month to ensure proper operation in the event they would be needed for respiratory separation.

Auxiliary HEPA Filtration

The higher the dilution ventilation rate within a given respiratory separation area, the faster the room air will be cleared of existing airborne pathogens. In order to increase effective ventilation within a separation area, in-room HEPA filtration units may be used. These units may be portable or permanently-mounted within the space. Some models can be ceiling mounted, which could reduce the potential for tampering. If such units are used, their placement and discharge orientation must be selected, installed, and maintained carefully to maximize room air mixing effectiveness without disrupting the desired flow of air into the respiratory separation area. These criteria become even more important if a retractable partition enclosure is used to establish a respiratory separation area.

One unique use of portable HEPA filtration units is through the use of a *ventilated headboard*. The ventilated headboard is a NIOSH-developed technology that consists of lightweight, sturdy & adjustable aluminum framing with a retractable plastic canopy sheeting that can extend over the pillow area of a cot, mat or bed. Low-velocity airflow into the canopy is created using a high-efficiency fan/filter exhaust unit. This local control technique allows for near-instant capture of aerosol originating from the patient while simultaneously providing air cleaning to the entire room. NIOSH engineers are available to provide additional information or to assist in the selection and acquisition of ventilated headboards.

Ultraviolet Germicidal Irradiation

Ultraviolet germicidal irradiation (UVGI) is the use of ultraviolet (UV) energy (electromagnetic radiation with a wavelength shorter than that of visible light) to kill or inactivate viral, bacterial, and fungal organisms. The UV spectrum is commonly divided into UVA (wavelengths of 400-315 nm), UVB (315-280 nm), and UVC (280-200 nm). The entire UV spectrum can kill or inactivate microorganisms, but UVC energy provides the most germicidal effect, with 265 nm being the optimum wavelength [ASHRAE 2011, 2012].

Modern UV lamps primarily create UVC energy at a near-optimal 254 nm by electrical discharge through low-pressure gas (including mercury vapor) enclosed in a quartz tube. UVC from mercury lamps is often referred to as UVGI to denote its germicidal properties. Although UVC is invisible to the human eye, small amounts of energy released at visible wavelengths produce the blue glow commonly associated with UVC lamps.

Research has demonstrated that UVGI is effective in killing or inactivating *M. tuberculosis* under experimental conditions [Riley et al. 1957, 1962; Riley and Nardell 1989; Xu et al. 2003]. UVGI has also proven effective in reducing the transmission of other infectious agents in hospitals, military housing units, and class rooms [Willmon et al. 1948; Wells and Holla 1950; McLean 1961]. Due to the results of controlled studies and the experiences of clinicians and engineers, UVGI has been recommended as a supplement to other TB infection-control and ventilation measures to kill or inactivate *M. tuberculosis* [David 1973; Riley et al. 1976; CDC 2005b, NIOSH 2009].

The addition of a well-designed upper-air UVGI system could provide additional protection to clients in key locations within the shelter. In congregate settings typical in homeless shelters and healthcare facilities, upper-air UVGI systems (often called upper-room systems) are often used to interrupt the transmission of airborne infectious pathogens within the occupied spaces themselves. Upper-air UV lamp fixtures are suspended from the ceiling and/or mounted on walls at a minimum height of 7 feet above the floor (Figure 5) [Riley and Nardell 1989; Brickner et al. 2003; NIOSH 2009; ASHRAE 2011, 2012]. Lamps are shielded to direct radiation upward and outward to create an intense zone of UVC in the upper portion of the room while minimizing UVC levels in the lower occupied spaces. These fixtures inactivate airborne microorganisms by irradiating them as air currents move them into the path of the UV energy. Some upper-air lamp fixtures utilize small fans to enhance air mixing (right photograph in Figure 5) [First et al. 1999a,b; CDC 2005b; NIOSH 2009; ASHRAE 2011, 2012]. The overall effectiveness of upper-air UVGI systems improves significantly when the space is well mixed [Riley and Nardell 1989; Brickner et al. 2003]. Although convection air currents created by occupants and equipment can provide adequate air circulation in some settings, mechanical ventilation systems and/or ceiling fans that maximize air mixing are preferable. Floor fans can also be placed in the room to ensure adequate mixing.

Application and placement criteria for upper-air UV fixtures are provided in various publications, and manufacturer-specific advice on placement and operations should always be followed [First et al. 1999a,b; Riley and Nardell 1989; Brickner et al. 2003; CDC 2005b; NIOSH 2009; ASHRAE 2011, 2012]. For decades, a rule of thumb for upper-air installations has been one 30-watt (nominal input) fixture for every 200 square feet of floor space to be irradiated [Riley and Nardell 1989]. Many effective systems have been designed to this criterion, yet it is important to note that not all 30-watt lamps provide the same output of UVC energy. Ultimately, UVC output is dependent on the type of lamp, the lamp manufacturer, the ballast used to power the lamp, the complete fixture design, and other factors. A more recent study has suggested installing fixtures to maintain a uniform UV distribution of around 30-50 microwatts of UVC energy per square centimeter ($\mu W/cm^2$) in the upper portion of the room [Xu et al. 2003]. While essentially "normalizing" the

recommended output over all lamps and fixture designs, this level of irradiance should be effective at inactivating most airborne droplet nuclei containing Mycobacterium, and would presumably be effective for inactivation of most viruses as well. Using the results of the Xu et al. study, NIOSH developed guidelines for designing upper-air UVGI systems for controlling the spread of tuberculosis [NIOSH 2009]. While the guidelines were specifically targeted for healthcare settings, they are just as applicable to congregate sleeping areas in homeless facilities.

We recommend consulting with a qualified UVGI fixture manufacturer or system engineer, familiar with the NIOSH upper-air UVGI guidelines, to design and install an upper-air UVGI system in the chapel/gymnasium area. The high ceiling height in that space provides an excellent opportunity to utilize a variety of commercially-available fixtures to create a large irradiance zone in the upper portion of the room. The ability to mount the fixtures at higher heights will also help prevent the fixtures from being tampered with and prevent unnecessary UV exposures to people using the stairs to the second floor in the area. The existing ventilation systems will also provide air mixing within the entire space that is critical for optimum upper-air UVGI system performance. Other areas where upper-air UVGI should be considered are all dormitory sleeping areas and the dining room. However, unlike the chapel/gymnasium, these spaces have shorter ceiling heights, so decisions on fixture selection and placement would be more critical. All of the upper-air UVGI systems should be designed to provide UV irradiance levels of at least 30-50 $\mu W/cm^2$ in the upper portion of the room while limiting UVC exposure to occupants in the space. If desired, NIOSH engineers are available to review proposed UVGI design strategies prior to their purchase and installation.

In humans, UVGI may be absorbed by the outer surfaces of the eyes and skin. Short-term overexposure may result in photokeratitis (inflammation of the cornea) and/or keratoconjunctivitis (inflammation of the conjunctiva). The NIOSH Recommended Exposure Limit (REL) for ultraviolet irradiation (254 nm) is 6.0 millijoules per square centimeter (mJ/cm^2) for an 8-hour exposure time [NIOSH 1972; ACGIH 2012]. This REL corresponds to a maximum continuous exposure of 0.2 $\mu W/cm^2$ of irradiation to a person inside the room over the 8-hour period. If periods of longer potential exposures are anticipated, the measured UV irradiance in the lower portion of the room should be lower than 0.2 $\mu W/cm^2$. The NIOSH guidelines clearly explain calculating permissible exposure times given actual irradiance levels in the occupied zone. Actual UVC irradiance levels in the occupied portion of the room, along with corresponding permissible exposure times, should be measured and documented by the system designer/installer prior to initial system use.

Once the upper-air UVGI system is in place and working properly, the fixtures should be operated any time occupants are in the respective areas. It is preferable to operate the system 24 hours a day every day. As with any environmental control system, the new upper-air UVGI system will require periodic maintenance. The output from UV lamps naturally decreases over time as the lamps are burned. Frequently turning the lamps off and on also shortens the useful life of the lamps. The UV output from lamps will also decrease due to accumulated dust. Therefore, lamps should be inspected periodically (e.g., quarterly) and cleaned when necessary. UV lamps are typically cleaned by wiping the lamp tubes with

isopropyl alcohol (rubbing alcohol) and a clean, lint-free cloth. Cleaning the lamps with water can result in smearing of the dust that can further reduce lamp performance. The fixtures housing the UV lamps should be inspected and cleaned as well. Typical UVGI lamps are rated for around a year of continuous use. Lamps should be replaced annually, or in accordance with appropriate manufacturer recommendations.

IMPORTANT SAFETY PRECAUTION: All UVGI systems must be inactivated before workers enter the irradiated upper portion of the space. All maintenance personnel that might spend time in the chapel/gymnasium should be trained in exposure hazards posed by the UVGI fixtures. Employees responsible for lamp and fixture maintenance should receive additional safety training, including appropriate lockout/tagout procedures to prevent accidental UV exposures during maintenance tasks. All initial maintenance and training requirements should be explained by the UVGI system designer/installer. The required maintenance tasks and service logs, along with training requirements and logs should be included in the written O&M plan recommended above. A subcomponent of this plan should include a UVGI safety plan. Complete information on upper-air UVGI system design, operation, maintenance, and safety can be found in the NIOSH guideline document available online at: http://www.cdc.gov/niosh/docs/2009-105/pdfs/2009-105.pdf [NIOSH 2009].

Respiratory Protection

During an outbreak of airborne infectious disease, there could be instances when shelter staff members or volunteers find themselves in close contact with guests suspected of being infectious. Ideally, these cases would be identified during the administrative screening process and appropriate precautions initiated, but when these circumstances cannot be avoided, it is wise to consider the availability of respiratory protection to protect staff and volunteers. The first step toward the implementation of respirator use is to develop a document that clearly outlines a formal respiratory protection program. The Occupational Safety and Health Administration (OSHA) Respiratory Protection standard (29 Code of Federal Regulations [CFR] 1910.134) outlines the requirements for comprehensive respiratory protection programs. In accordance with 29 CFR 1910.134, a written Respiratory Protection Program, with an identified program administrator, is required for any facility that requires employees to wear respirators. The program must include training, medical evaluations, and respirators at no cost to employees or staff required to wear respirators on the job. Initial fit testing by a trained individual is required for all employees that will potentially wear a respirator. Annual fit testing is required after that, with additional fit testing upon major changes to the facial features of the respirator user (i.e. major weight gain/loss, change in facial hair, scarring, etc.).

To comply with applicable OSHA regulations regarding respiratory protection, we recommend that the shelter create a written respiratory protection program as outlined in 29 CFR 1910.134, appoint a program administrator, and initiate training and initial fit testing for employees. Many online resources exist to assist in the development of a respiratory protection program. OSHA has published a Respiratory Protection informational booklet

online (http://www.osha.gov/Publications/OSHA3079/osha3079.html) and a more detailed Small Entity Compliance Guide for the Revised Respiratory Protection Standard (http://www.osha.gov/Publications/3384small-entity-for-respiratory-protection-standard-rev.pdf) to explain all parts of an appropriate respiratory protection program and how to comply. The Small Entity Compliance Guide also contains a sample respiratory protection program in Attachment 4 that can be used as a model program. The Washington State Department of Labor and Industries has also developed a user-friendly, fillable template that is helpful in developing a respiratory protection program at http://www.lni.wa.gov/Safety/TrainingPrevention/Programs/Respiratory.asp.

The DCHHS, Texas Department of State Health Services, local healthcare facilities or fire/ambulance stations can potentially assist with training and fit testing the employees required to wear respirators. Alternatively, qualitative fit testing kits (Bitrix™) can be purchased for around $200.00. When paired with a trained and competent fit test administrator (see 29 CFR 1910.134), these kits would allow cost-effective, on-site fit testing annually.

Conclusions

Since the increase in cases of TB disease in 2009, the shelter has taken significant steps to improve the administrative controls at the shelter. The shelter has developed important lines of communication with DCHHS and improved staff training and awareness of TB symptoms. Identifying guests with symptoms of TB disease or those listed on the DCHHS target screening lists will help further reduce the potential for future cases of TB disease and bring the ongoing outbreak under control. Having consistent protective strategies upon suspect case identification is also important. While enhanced administrative controls are now in place, there was no written ICP established for the campus, and shelter administrators are encouraged to promptly coordinate with DCHHS and the Texas Department of State Health Services to establish one.

Overall, the facility was clean and well maintained. However, from an environmental control perspective, the gradual inheritance of dozens of AHUs from various manufacturers has resulted in some nonfunctional or ineffective ventilation equipment. The HVAC preventive maintenance program in place at the shelter is managed by the current facilities manager and his maintenance staff. While the results were generally effective given the complexities they must deal with, developing a written preventive maintenance or O&M plan for the shelter's AHUs would further strengthen the preventive maintenance program, particularly as staff members change.

Most of the ventilation systems are not capable of providing outdoor air to the occupied spaces in their current configurations. Among those systems with outdoor air capability, most of them had their outdoor air dampers sealed closed during our visit. For those few units with outdoor air dampers at least partially open, we were unable to accurately determine the amount of outdoor air being introduced by each AHU, but the amount was anticipated to be less than that required by the *Dallas Mechanical Code* and ASHRAE guidelines. Given the

number of guests served at the shelter and the close proximity of guests to one another within many of the occupied spaces, it is important that these spaces consistently receive adequate amounts of outdoor air. In addition to alleviating odors and better maintaining occupant comfort, outdoor air serves to dilute infectious aerosols, such as *M. tuberculosis* droplet nuclei responsible for TB transmission. This will require repairing or replacing current ventilation systems that do not work or fail to work as necessary. Then, with renovations, the other existing AHUs might be made to provide the necessary outdoor air. If not, they could be augmented with the installation of a new, dedicated outdoor air system to provide the necessary outdoor air. A knowledgeable HVAC engineer should be consulted to discuss options for introducing outdoor air throughout the shelter. At the same time, consideration should be given to improving the air flow patterns in the various living and sleeping areas within the building. Once these changes have been implemented, other ventilation equipment and/or supplemental ultraviolet germicidal irradiation systems could be investigated if additional environmental controls are desired.

The shelter did not have an area set aside for separating more transient, overnight guests suspected of having TB or other respiratory diseases from the remainder of the guest population. The background and medical status of these overnight guests may be largely unknown. Therefore, it would be prudent to modify an area in the overnight dormitory or in the chapel/gymnasium for use as a respiratory separation area in the event an overnight guest presented with symptoms of respiratory infection. When respiratory separation is not required, the area could be used for some other purpose.

Given that the chapel/gymnasium is used for large client gatherings and has a high ceiling, a complete upper-air UVGI system could be installed in the space to further reduce the potential for airborne disease transmission. A qualified UVGI system designer or fixture manufacturer should be consulted for options. The system should be designed, operated, and maintained in accordance with NIOSH guidelines available online at: http://www.cdc.gov/niosh/docs/2009-105/pdfs/2009-105.pdf [NIOSH 2009]. Upper-air UVGI systems should also be considered for all dormitory areas and the dining room. Once all changes and improvements to environmental controls at the shelter have been implemented, the shelter should develop a written preventive maintenance or O&M plan for the shelter.

For instances where improvements to administrative and environmental controls do not sufficiently mitigate the risk for disease transmission, respiratory protection might be necessary. There was no formal respiratory protection program in place during our visit, but such a program should be implemented at the shelter. Having this program in place will provide additional protection to shelter staff and volunteers working in close proximity to guests with suspected TB or other airborne diseases. All respirator use at the shelter should be covered by an OSHA-mandated respiratory protection program.

Administratively, a positive approach is being taken toward reducing the likelihood of future TB transmission at the shelter. However, the ventilation systems need significant attention to further reduce the risk. While ventilation systems and other environmental control systems cannot guarantee prevention of future TB disease transmission, improving the environmental

controls will reduce the potential for airborne disease transmission, along with providing better indoor air quality throughout each building. The following recommendations are aimed at improving the overall infection control program at the shelter, with emphasis on improvements to the existing environmental controls so they will meet all applicable standards and guidelines.

Recommendations

Based on our assessment of environmental controls at the shelter, we have developed the following list of recommendations, in order of priority:

1. **Continue to improve and enhance the TB administrative controls at the complex and develop a written Infection Control Plan.**
    - Continue working with the DCHHS to screen campus staff, volunteers, and guests for TB disease.
    - With input from DCHHS, develop specific procedures for handling a suspected or confirmed case of TB disease.
    - Continue educating staff and volunteers on the signs and symptoms of TB disease so they can readily identify suspect cases and implement established precautions.
    - Consider displaying informational posters about TB signs and symptoms to educate guests.
    - Consider displaying signs encouraging proper cough etiquette and hand hygiene.
    - Develop a formal written TB Infection Control Plan. Seek guidance and input from DCHHS and the Texas Department of State Health Services. The plan should include:
        - All aspects of the TB infection control program and associated responsibilities (to include reasonable scenarios of guests presenting with symptoms and associated response requirements), especially those functions requiring coordination with other agencies, such as the local and state health departments.
        - The improved administrative controls put in place at the shelter since the beginning of the TB outbreak, including skin tests and chest x-rays offered every 60 days and the new TB Card (green card) identification process for ensuring every client has been tested for TB prior to housing at the shelter, which were implemented after the NIOSH visit.
        - Input from ventilation staff and/or guests tasked with servicing ventilation systems. Obtaining input from ventilation maintenance staff serves to strengthen the environmental control section of the plan while giving maintenance staff additional insight into the ventilation requirements for reducing or preventing airborne disease transmission.
        - Schedule for updating and revising the ICP.

2. **Create a respiratory separation area at the shelter.**
    - Choose a reputable ventilation or engineering design contractor that is familiar with current *Dallas Mechanical Code*, ASHRAE, FGI, and CDC guidelines and recommendations. Ideally a small enclosed room specifically for respiratory separation should be constructed in one of the corners along an exterior wall inside one of the overnight client dormitories. If construction of a separate room is impractical, a less-desirable approach is to install impervious retractable partitions that could be used to enclose a corner of one of the overnight client dormitories when respiratory separation is warranted. Another possible area for a separation area with partitions is the weight room/meeting room adjacent to the large chapel. Regardless of location, the partitions should touch the floor and extend as close to the ceiling as possible. While there are various ways to develop a respiratory separation area, it should include the following:
        - Ensure that all supply and return ductwork for the AHU serving the newly-constructed room or area enclosed by partitions (if any) is intact and sealed. Install tight-sealing return dampers on each HVAC return (if any) from the room or enclosure to eliminate return air flow when the space is used for respiratory separation. Ensure that supply air diffusers provide good air mixing and air flow patterns in a newly-constructed room.
        - Design and install an auxiliary exhaust system that enables the respiratory separation area to be maintained under negative pressure when housing guests for separation purposes. One approach to this requirement would be to select and install exhaust fans directly through the outside wall of the room or space enclosed by partitions. The fan can be mounted through the wall itself or mounted on the roof with ductwork through the wall to the fan.
        - Install the highest efficiency air filters in the AHU that will still allow adequate airflow to meet the AHU's conditioning requirements. Adjust and balance the system as necessary to ensure proper air flows at all times when the room or curtain enclosure is used for respiratory separation and normal purposes. Ensure that adequate outdoor air is supplied to each space at all times (see Recommendation 2 above).
        - Develop a detailed written plan for the conversion of the room or partition enclosure from normal functions to use for respiratory separation. The plan should include:
            - Procedures for staff to follow to establish the respiratory separation area (if partitions are used), start the exhaust fan, close the return air dampers (if any), and test for negative pressure.
            - Measures for preparing the area for back-to-back occupants requiring separation.
            - Procedures for cleaning and returning the area to normal use after the need for respiratory separation has passed.

- Operate the new system as designed and according to the written plan. When in use, the respiratory separation area should be visually tested with smoke tubes or flutter strips daily to ensure negative pressure is being maintained while the space is occupied for separation. When the area is being used for normal purposes, it should be tested monthly to ensure proper operation in the event it would be needed for respiratory separation. The results of all pressure testing should be documented.

3. **Make necessary repairs to AHUs requiring maintenance and/or replace nonfunctional equipment so all occupied spaces in the shelter are served by a mechanical ventilation system.** This is the first critical step in improving overall environmental controls at the shelter. Once all areas are served by mechanical ventilation, improvements to meet outdoor air requirements (see Recommendation #7 below) can be investigated and final decisions made.

4. **Repair, replace, or install new bathroom exhaust fans.** Ensure that air is being exhausted from each bathroom and shower facility and that each area is under negative pressure, in accordance with the *Dallas Mechanical Code* and ASHRAE requirements. Ensure that all exhaust air from bathrooms and shower facilities is exhausted directly outside and that no return air from bathrooms is recirculated back to an AHU or entrained in the outdoor air entering any current or future AHU.

5. **Develop a comprehensive, written HVAC O&M plan.** This plan should be updated as improvements to HVAC systems are being made. The O&M Plan should include:
   - Preventive maintenance schedules and all regularly scheduled maintenance tasks (filter changes, fan belt inspections, UV lamp changes, etc.) and who is responsible for conducting each task.
   - Written procedures for each maintenance task to ensure the work is done properly each time, regardless of who performs the work.
   - Training requirements for maintenance staff.
   - A method for logging maintenance activities for each AHU.
   - A method for updating or revising the O&M Plan as procedures or systems change.

6. **Install an upper-air UVGI system in the chapel/gymnasium.**
   - Choose a qualified UVGI fixture manufacturer or system engineer, familiar with the NIOSH upper-air guidelines, to design, install and test the system. The system designer/installer should also provide initial training on exposure hazards, safety, and system maintenance.
   - The system should be designed to provide UV irradiance levels of at least 30–50 $\mu W/cm^2$ in the upper portion of the room while limiting UVC exposure to occupants in the area to a level below the NIOSH REL for UVC of 6.0 mJ/cm^2 for an 8-hour exposure time.
   - Operate the upper-air UVGI system all day, every day, or at least at all times the area is occupied.

- Establish a UVGI safety, operation, and maintenance program.
- Conduct training and maintenance in accordance with NIOSH guidelines (http://www.cdc.gov/niosh/docs/2009-105/pdfs/2009-105.pdf) [NIOSH 2009] and/or applicable manufacturer recommendations.

7. **Introduce the required amounts of fresh outdoor air to all occupied spaces under all occupancy and environmental conditions.**
   - There are multiple options available that can allow adequate outdoor air to be supplied to the occupied spaces of the facility. If capacity exists in the current AHUs after repairs and replacements are made (see Recommendation #3 above), the easiest method would be to make necessary adjustments to existing outdoor air dampers and install new outdoor air intakes, where necessary, so that appropriate amounts of outdoor air are brought in at all times. Other options are also available and discussed in this report. All options, including the associated capital, maintenance, and annual operating costs should be considered. Work with a reputable ventilation or engineering contractor familiar with the current *Dallas Mechanical Code*, ASHRAE, FGI, and CDC guidelines to select the best option for the shelter.
   - Improve air flow patterns within all occupied spaces, particularly in areas where clients congregate, such as dormitories, the dining room, and the chapel/gymnasium. Air flow patterns should provide effective ventilation and temperature control while flowing from clean areas to areas more likely to be contaminated.

8. **Improve filtration efficiency in all AHUs.** Select higher efficiency filters (higher MERV ratings) for use in each AHU, as long as the new filters do not adversely impact the required air flow delivery capacity of the AHUs.

9. **Develop and implement an OSHA respiratory protection program in accordance with 29 CFR 1910.134.** To meet the OSHA requirements, you must:
   - Designate a program administrator who is qualified by appropriate training or experience to administer or oversee the program and conduct the required program evaluations.
   - Provide respirators, training, and medical evaluations at no cost to employees or staff required to wear respirators on the job.
   - Develop a written program with worksite-specific procedures when respirators are necessary or required by the employer. The written respiratory protection program needs to include:
     - Respirator types and proper respirator selection.
     - Required medical evaluations for employees prior to respirator use.
     - Procedures for initial and annual respirator fit testing.
     - Instructions for proper respirator use.
     - Information on appropriate respirator maintenance and care.
     - Initial and yearly training requirements for respirator users.
     - Procedures for evaluating the effectiveness of the respiratory protection program.

- Update the respiratory protection program as necessary to reflect changes in workplace conditions that affect respirator use.

Outline of Future NIOSH Involvement

This report will serve to close out NIOSH Technical Assistance at the shelter. However, we understand that the work outlined in the recommendations above will take several months to complete and will represent a significant investment of time and financial resources. As the work proceeds, NIOSH could assist by:

- Reviewing Requests for Proposal developed to initiate the bidding process.
- Reviewing bids received in response to Requests for Proposals for technical content.
- Providing technical assistance related to environmental control strategies, including upper-air UVGI systems.

It is not necessary for NIOSH to be on-site during ventilation renovations. Yet, as projects are initiated, we can assist you by reviewing:

- Proposed modification strategies for outdoor air introduction or respiratory separation area designs.
- Preliminary design schematics or equipment selection documents.
- Air flow testing and balancing reports.

Once the renovations are complete, if additional NIOSH assistance is desired or warranted, the request for technical assistance can be reopened.

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Table 1. General air-handling unit (AHU) information

AHU Identifier	Main Location Served by AHU[A]	AHU Manufacturer[B]	AHU Model Number[B]	Brand of Filters Installed in AHU[B]	Actual Filter Configuration in AHU[C]	Notes[B]
RTU-1	2nd Floor Full Program Dormitory	Trane	YSC120A3ELA1Z0000000000	Glasfloss Z-Line	(4) 20×25×2	
RTU-2	2nd Floor Full Program Dormitory	Trane	YSC120A3ELA1W0000000000	Glasfloss Z-Line	(4) 20×25×2	
1-B	2nd Floor Locker Room, Shower Area, and Restrooms for Overnight Guests	Carrier (Bryant)	580DPV120180AAAA	Flanders Pre-Pleat 40 and Glasfloss Z-Line	(4) 20×20×2	Some Outdoor Air
2						Condenser Only
3		York				Condenser Only
4		York				Condenser Only
6	2nd Floor Client A Sleeping Area					Not Functional
7	2nd Floor Client A and B Sleeping Areas	Carrier	580DPV150220AAAA	Flanders Pre-Pleat 40	(4) 20×20×2	Some Outdoor Air
New #1	1st Floor Seniors' Sleeping Area (West Side)	York	ZS-10N18ATAAA5A	Could Not Get Inside – Probably Same as New #3		Filters in return grilles as well
New #2	1st Floor Seniors' Locker Room, Entryway, Restroom and Showers	Coleman	TCJD6054153A			Condenser Only
New #3	1st Floor Senior Citizens' Sleeping Area (East Side)	York	ZS-10N18ATAAA5A	American Air Filter	(4) 20×24×2	
New #4	2nd Floor Chaplain's Office off Game Room	Goodman	GSC130483BB			Condenser Only

Table 1 (continued). General air-handling unit (AHU) information

AHU Identifier	Main Location Served by AHU[A]	AHU Manufacturer[B]	AHU Model Number[B]	Brand of Filters Installed in AHU[B]	Actual Filter Configuration in AHU[C]	Notes[B]
11				Flanders Pre-Pleat 40	(2) 14×25×1	
12	2nd Floor Rooms 223-232	Carrier	580DPV150220AAAA	Flanders Pre-Pleat 40	(4) 20×20×2	
13	Clothing Office	York	H1DB036506A			Condenser Only
14		Trane	BTD748A100B0			Condenser Only
15	2nd Floor Library	Climate Control		Flanders Pre-Pleat 40	(2) 14×25×1	Not Functional
16		Carrier (Day & Night)	590ANK024000AAAA			Condenser Only
17	2nd Floor Game Room	Carrier		None	None	Filters in return grilles
18	Chapel Area	Carrier (Bryant)	580DPV120180AAAA	Flanders Pre-Pleat 40	(4) 20×20×2	
19	2nd Floor Full Program Dormitory			Glasfloss Z-Line	(2) 20×25×1	
20	2nd Floor Hallway, Stairwell, and Initial Program Restroom	Climate Control		None	None	
21		Snyder General	3WA0368	None	None	
22		Payne		None	None	
23	1st Floor Learning Center and/or Dining Room	Carrier (Bryant)	580DPV120180AAAA	Glasfloss Z-Line	(4) 20×20×2	

Table 1 (continued). General air-handling unit (AHU) information

AHU Identifier	Main Location Served by AHU[A]	AHU Manufacturer[B]	AHU Model Number[B]	Brand of Filters Installed in AHU[B]	Actual Filter Configuration in AHU[C]	Notes[B]
24	1st Floor Kitchen	Carrier (Bryant)	580DPV090125AAAA	Flanders Pre-Pleat 40	(4) 20×20×2	
25	2nd Floor Director's Conference Room	Frigidaire		None	None	
26	Chapel Area	Carrier (Bryant)	580DPV120180AAAA	Flanders Pre-Pleat 40	(4) 20×20×2	
27	1st Floor Rooms 102-111	Ruud	UKKA-A060CK10E	Glasfloss Z-Line	(2) 16×25×1	
28	2nd Floor Director's Office	Carrier (Bryant)	580DPV090125AAAA	Flanders Pre-Pleat 40	(4) 16×20×2	
29	2nd Floor Rooms 204-210			Glasfloss Z-Line and Clarcor	(1) 20×25×1 & (1) 14×25×2	Some Outdoor Air
30	1st Floor Learning Center	Carrier (Bryant)	580JP05A072A2A0AAA	American Air Filter	(2) 16×25×2	
31	2nd Floor Chaplain Offices	Carrier (Bryant)	580DPV090125AAAA	Flanders Pre-Pleat 40	(4) 16×20×2	Some Outdoor Air
32	2nd Floor Hallway	Carrier (Bryant)	580DPV036074AAAA	Glasfloss Z-Line	(2) 16×25×2	Some Outdoor Air
33		Rheem				Condenser Only
34						
35		Goodman	CK60-1			Condenser Only
36		Goodman	CK30-1A			Condenser Only
37	2nd Floor Full Program Dormitory	Janitrol				Condenser Only

[A] Based on reported information from facility staff during the NIOSH visit. May or may not be entirely correct.
[B] Information collected during visual inspection of AHU, when possible.
[C] Value in parenthesis represents the number of filters; dimensions are width × height × depth in units of inches.

Table 2. Applicable outdoor air supply flow rates, minimum exhaust air flow rates, and default occupancy densities from the *Dallas Building Code* (Chapter 55, effective November 1, 2013) and ASHRAE Standard 62.1-2013[A]

Occupancy Category	People Outdoor Air Flow Rate (cfm/person)[B]	Area Outdoor Air Flow Rate (cfm/ft²)[C]	Minimum Exhaust Air Flow Rate[D]	Default Occupant Density (#/1000 ft²)[E]
Barracks/Dormitory Sleeping Areas	5	0.06	—	20[F]
Bedrooms/Living Rooms	5	0.06	—	10[F]
Office Spaces	5	0.06	—	5
Conference Rooms	5	0.06	—	50
Multipurpose Assembly Spaces	5	0.06	—	120[F]
Reception Areas	5	0.06	—	30
Break Rooms[F]	5[F]	0.12[F]	—	50[F]
Central Laundry Rooms[F,G]	5 (7.5)[F,G]	0.12 (0.06)[F,G]	—	10 (20)[F,G]
Occupiable Dry Storage Rooms[F]	5[F]	0.06[F]	—	2[F]
Unoccupiable Storage Rooms[H]	—	0.12[H]	—	—
Lobbies/Prefunction Spaces	7.5	0.06	—	30[F]
Library	5	0.12	—	10
Lecture Classrooms	7.5	0.06	—	65
Computer Labs	10	0.12	—	25
Dining Rooms	7.5	0.18	—	70
Central Kitchens[F]	7.5[F]	0.12[F]	0.7 cfm/ft² [C,F]	20[F]
Barber Shops	7.5	0.06	0.5 cfm/ft² [C]	25
Beauty and Nail Salons	20	0.12	0.6 cfm/ft² [C]	25
Public Bathrooms	—	—	50 or 70 cfm/toilet and/or urinal[I]	—
Private Bathrooms	—	—	25 or 50 cfm[J,K]	—
Shower Rooms[H]	—	—	20 or 50 cfm/shower head[H,K]	—
Locker Rooms	—	—	0.25 cfm/ft² [C]	—

[A] Requirements published in: *Dallas Building Code*: Mechanical (CHAPTER 55: 2012 International Mechanical Code with Dallas Amendments), effective November 1, 2013, and American National Standards Institute (ANSI)/ASHRAE Standard 62.1-2013: *Ventilation for Acceptable Indoor Air Quality*. In most cases, the *Dallas Building Code* has adopted ventilation recommendations directly from ASHRAE Standard 62.1.

[B] cfm/person = cubic feet per minute (also commonly shown as ft³/min) per person typically in the occupied space (CONTINUED ON NEXT PAGE)

Table 2 Footnotes continued:

[C] cfm/ft^2 = cubic feet per minute (also commonly shown as ft^3/min) per square foot of occupied space

[D] Mechanical exhaust should be released directly outdoors at least 25 feet away from air intakes. Recirculating exhaust air back into the building should be avoided, but is permissible under some circumstances.

[E] #/1000ft^2 = number of people per 1000 square feet of occupied space. These values are typical maximum occupant densities in spaces that are useful for building/HVAC system design. If actual occupant densities are known, they should be used instead of these default values.

[F] Requirements are only published in ASHRAE Standard 62.1-2013. No directly corresponding values appear in the *Dallas Building Code*.

[G] The *Dallas Building Code* and ASHRAE Standard 62.1-2013 both include identical recommendations for "coin-operated laundries." Those values are shown in parentheses.

[H] Requirements are only published in the *Dallas Building Code*. No directly corresponding values appear in ASHRAE Standard 62.1-2013.

[I] The *Dallas Building Code* and ASHRAE Standard 62.1-2013 both include the same exhaust recommendations for public bathrooms, but they differ in how the recommendations are applied. The *Dallas Building Code* applies the recommendations based on exhaust fan type. If exhaust fans are operated continuously, the lower rate may be used. If exhaust fans are operated intermittently (e.g., fans activated by a light switch), the higher rate should be used. The ASHRAE Standard 62.1-2013 recommendation is based on expected usage. Provide the higher rate when periods of heavy use are expected to occur (e.g. prior to guests leaving in the morning). If periods of heavy use are not anticipated, the lower rate may be used.

[J] These rates are for bathrooms intended for use by one person at a time.

[K] If exhaust fans are operated continuously, the lower rate may be used. If exhaust fans are operated intermittently (e.g., fans activated by a light switch), the higher rate should be used.

Table 3. Total air delivered by ventilation systems, occupant densities, and recommended outdoor air and exhaust flow

Space[A]	Supply Air Flow (cfm)[B]	Exhaust Air Flow (cfm)[B]	Approximate Area (ft^2)[C]	Typical Occupants[D]	Occupant Density (#/1000 ft^2)[D,E,F]	Recommended Outside Air Flow (cfm)[B,G]	Recommended Exhaust Air Flow (cfm)[B,F,G]
Chapel/Recreation Facility							
Chapel/Recreation Area	6120	4470	2955	30	10	330	N/A[H]
First Floor							
Main Entrance/Lobby	2240	1860	1410	4	3	110	N/A[H]
Game Room/Clinic Waiting Area	1345	NMF[I]	1670	5	3	130	N/A[H]
Dining Area	5120	2025	1995	8	4	420	N/A[H]
Barber Room	155	0[I]	195	2	10	30	*100
Senior Sleeping Area	3860	3865	4235	64	15	570	N/A[H]
Senior Locker Room	440	750	610	30	49	N/A[H,J]	150[J]
Senior Shower/Bathroom	530	0[I]	460	15	33	N/A[H,J]	*1160 (560)[J,K]
Intake Administrator Office (#128)	735	0[I]	180	2	*11	20	N/A[H]
Intake Assistant Office #1 (#134)	140	0[I]	210	1	5	20	N/A[H]
Intake Assistant Office #2 (#127)	180	0[I]	175	2	*11	20	N/A[H]
Computer Training Room	525	830	675	12	18	200	N/A[H]
Computer Room Bathroom	NMF[I]	35	55	1	18	N/A[H,J]	*50[J]
Overnight Client Dormitory A	1375	1200	2980	102	*34	690	N/A[H]
Overnight Client Dormitory B	1710	1250	1690	62	*37	410	N/A[H]
Overnight Client Dormitory C	1185	925	1425	58	*41	380	N/A[H]
Overnight Client Bathroom	290	NMF[I]	280	10	36	N/A[H,J]	*1050[J]
Overnight Client Sink Room	290	0[I]	300	8	27	N/A[H,J]	N/A[H,J]
Overnight Client Shower Room	0[I]	NMF[I]	405	20	49	N/A[H,J]	*400 (N/A)[H,J,K]
Overnight “Cage” Storage Area	105	0[I]	70	2	29	10	N/A[H]
Overnight Client Locker Room	1500	850	810	80	99	N/A[H]	200
Security Room	295	NMF[I]	180	1	*6	20	N/A[H]
Veterans South Dormitory	770	580	825	16	19	130	N/A[H]
Veterans North Dormitory	1150	1315	1200	24	20	190	N/A[H]

Table 3 (continued). Total air delivered by ventilation systems, occupant densities, and recommended outdoor air and exhaust flow

Space[A]	Supply Air Flow (cfm)[B]	Exhaust Air Flow (cfm)[B]	Approximate Area (ft^2)[C]	Typical Occupants[D]	Occupant Density (#/1000 ft^2)[D,E,F]	Recommended Outside Air Flow (cfm)[B,G]	Recommended Exhaust Air Flow (cfm)[B,F,G]
Second Floor (continued)							
Eugene Ford Library	805	670	700	6	9	110	N/A[H]
Initial Program Dormitory	1115	185	480	20	*42	130	N/A[H]
Initial Program Bathroom	210	NMF[I]	110	3	27	N/A[H,J]	*210[J]
Initial Program Shower Room	0[I]	NMF[I]	160	6	38	N/A[H,J]	220 (N/A)[H,J,K]
Chaplain's Office #224	395	620	215	2	*9	20	N/A[H]
Mens Lounge	1300	NMF[I]	1240	10	8	120	N/A[H]
Chaplain's Office #217	220	220	180	2	*11	20	N/A[H]
Veterans Affairs Office #216	240	0[I]	155	2	*13	20	N/A[H]
Waiting Area Outside #216 and #217	365	1430	415	2	5	30	N/A[H]
Chaplain's Office #213	255	230	225	2	*9	20	N/A[H]
Chaplain's Office #212	290	0[I]	185	2	*11	20	N/A[H]
Full Program Library	725	0[I]	435	3	7	70	N/A[H]
Full Program Dormitory	6385	>5000	3500	46	13	440	N/A[H]
Full Program Bathroom/Shower Room	0[I]	1085	740	15	20	N/A[H,J]	960 (560)[J,K]
Director of Development's Office	150	NMF[I]	170	1	*6	20	N/A[H]
Chief Administrator's Office	185	35	170	1	*6	20	N/A[H]
Executive Director's Waiting Area	195	NMF[I]	230	3	13	30	N/A[H]
Executive Director's Boardroom	285	NMF[I]	375	8	21	60	N/A[H]
Executive Director's Office	165	NMF[I]	235	1	4	20	N/A[H]

[A] May not represent all locations served by the AHU.
[B] cfm = cubic feet per minute (also commonly shown as ft^3/min).
[C] ft^2 = square feet.
[D] Occupant numbers estimated by visual observation during NIOSH visit.
[E] #/1000 ft^2 = number of occupants per 1000 ft^2 of occupied floor space. Calculated by dividing the number of typical occupants in the space by the approximate area of the space and multiplying by 1000.
[F] Entries preceded by an asterisk (*) represent spaces where the actual occupant density likely exceeds the default occupant density or where the measured exhaust flow rate is lower than the required exhaust flow rate for typical occupancy levels, as shown in Table 2.

Footnotes for Table 3 Continued:

[G] Calculated based on recommendations published in: *Dallas Building Code*: Mechanical (CHAPTER 55: 2012 International Mechanical Code with Dallas Amendments), effective November 1, 2013, and American National Standards Institute (ANSI)/ASHRAE Standard 62.1-2013: *Ventilation for Acceptable Indoor Air Quality*. In most cases, the *Dallas Building Code* has adopted ventilation recommendations directly from ASHRAE Standard 62.1. Values have been rounded to the nearest 10 cfm.

[H] N/A = not applicable.

[I] NMF = no measureable flow. The air capture hoods used to determine air flow measurements were unable to accurately read volumetric air flow rates less than 30 cfm. When the actual flow is below 30 cfm, the air capture hoods typically read 0 cfm, although the true value could be anywhere between 0 and 30 cfm. If there were no supply vents and/or return grilles in the space, the flow is reported as 0 cfm.

[J] Neither the *Dallas Building Code* nor ASHRAE Standard 62.1-2013 include outdoor air recommendations for restrooms, bathrooms, and shower facilities, but they both include exhaust recommendations for public bathrooms. The *Dallas Building Code* applies the recommendations based on exhaust fan type. If exhaust fans are operated continuously, 50 cfm per water closet should be exhausted. If exhaust fans are operated intermittently (e.g., fans activated by a light switch), 70 cfm per water closet should be exhausted. The ASHRAE Standard 62.1-2013 recommendation is based on expected usage. 70 cfm per water closet should be provided when periods of heavy use are expected to occur (e.g. prior to guests leaving in the morning). If periods of heavy use are not anticipated, 50 cfm per water closet is prescribed. For private bathrooms (i.e., bathrooms meant to be occupied by only one person at a time), the *Dallas Building Code* and ASHRAE Standard 62.1-2013 both specify 50 cfm per water closet if the exhaust fan is operated intermittently and 25 cfm per water closet for continuously operated exhaust fans. For shower facilities, the *Dallas Building Code* prescribes 20 cfm per shower head if exhaust fans are operated continuously or 50 cfm per shower head if exhaust fans are operated intermittently. ASHRAE Standard 62.1-2013 does not provide exhaust air flows for shower rooms.

[K] The required exhaust flow according to the *Dallas Building Code* is shown first and the ASHRAE Standard 62.1-2013 requirement is shown in parentheses (assuming no exhaust requirement for the shower heads).

Figures

Figure 1. Filters installed inside AHU 12 at the shelter showing a significant gap between individual filters that will allow air to pass between the filters instead of through them.

Figure 2. Incorrect filters installed and subsequently distorted and rendered ineffective inside AHU 19 at the shelter.

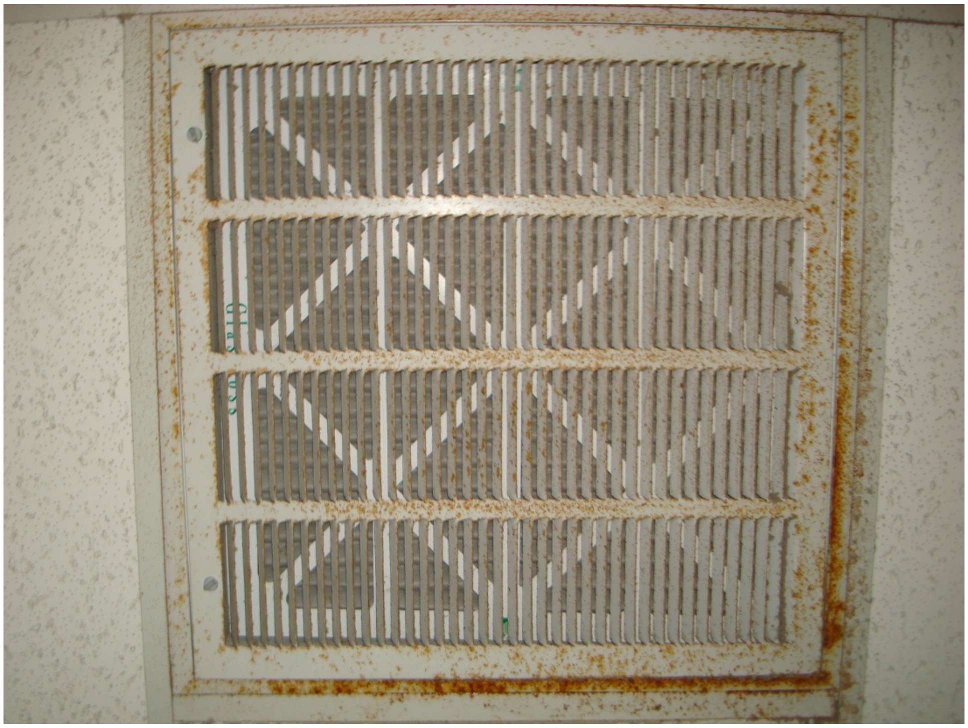

Figure 3. Ventilation filter installed directly behind a return air grille in the Initial Program Dormitory Area of the shelter.

Figure 4. Supply vent and return grille directly next to one another in the second floor lounge area at the shelter. This configuration will lead to short-circuiting of air in the occupied space.

Figure 5. Typical upper-air UVGI installations: Left–Wall-mounted fixture with louvers installed in a health clinic; Right–Ceiling-mounted fixture with an internal fan installed in a homeless shelter.

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Keywords: NAICS 624221 (Temporary Shelters), tuberculosis, environmental controls, ventilation, homeless shelter, airborne infection, airborne transmission, respiratory.

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Availability of Report

Copies of this report have been sent to representatives from the shelter, DCHHS, the Texas Department of State Health Services, CDC/NCHHSTP/DTBE, and the OSHA Regional Office. This report is not copyrighted and may be freely reproduced. The report may be viewed and printed at www.cdc.gov/niosh/hhe/. Copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161.

This report is available at http://www.cdc.gov/niosh/hhe/reports/pdfs/2013-0110-3218.pdf.

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